Letter to the Editor

Laura Schild

Dear Kirsten Elger,

Thank you for the opportunity to revise our manuscript. We have carefully considered the reviewers' comments and revised the manuscript accordingly. We are including detailed responses and changes to each comment in this document. Below we list the general changes we have made.

We are removing the optimization of RPP values and the reconstruction of the southern hemisphere vegetation from the manuscript because of the large uncertainties associated with these estimates. We also exclude all datasets that are not suitable for reconstruction with REVEALS, and we rename our calculated 80% pollen source area and expand on its applicability and calculation. We also add several more recent RPP studies to the synthesis of RPP values. To adequately acknowledge Neotoma and its constituent databases, we add citations and edit our Acknowledgments section. To clarify the use of the dataset, we expand the section on applications and limitations of the dataset and even provide a script with adjustable rasterization (https://zenodo.org/records/12800291). Records that are uncertain for site-specific analyses are highlighted in the dataset. We believe that these revisions have significantly improved our manuscript and have submitted the revised version.

We have updated our dataset accordingly and uploaded the new version to Zenodo (https://zenodo.org/records/12800159). Once the reviewers are satisfied with the changes made, we will update the dataset on PANGAEA and update the links provided in the Code and Data Availability section.

Best regards,

Laura Schild

Reply to Gaillard

Laura Schild & Ulrike Herzschuh

General reply

Dear Marie-José Gaillard,

We thank you for your extensive review of our manuscript and the constructive comments. While you welcome our work towards global pollen-based vegetation reconstructions and do not criticize the general method you stated helpful comments regarding some concerns. We are confident we have been able to implement all of them .

Large basins provide great value to large-scale reconstructions and site-wise reconstructions will only be kept if the original basin is of sufficient size (>= 50ha). We do agree with and recognize the limited suitability of small basins for site-wise reconstructions. Our previous intention was to create a dataset that could be gridded at different resolutions desired by the user, which we did not emphasize enough in our manuscript. We believe this flexibility would improve the usefulness of the reconstructions. To still acknowledge and highlight potential downfalls here, it is pertinent to both flag unreliable, small basins in the data set and provide a detailed description of potential uses and an adjustable script for rasterization. We implemented this in our revisions. Additionally, any non-lake or peat basins will be removed from the data set as they are unfitting for reconstruction by REVEALS.
The naming of our calculated source area is indeed unfortunate and will be changed. We will also expand on its calculation and usability in the manuscript text. Additionally, new RPP studies were added to our synthesis.

We have been able to implement all of these adjustments and believe it improved the clarity of the manuscript greatly. Below we respond in detail to each major issue raised and the detailed comments.

An updated version of the dataset can now be found here: https://doi.org/10.5281/zenodo.12800159. The dataset on PANGAEA will be updated as soon as possible.

Best regards
Laura Schild and Ulrike Herzschuh

Specific replies

Major Issues

Pollen records appropriate for the application of the REVEALS model to reconstruct REGIONAL plant cover

Original comment

1. The REVEALS model was developed to reconstruct REGIONAL plant cover using pollen records from LARGE LAKES, alternatively multiple SMALL LAKES (Sugita 2007a, REVEALS model). Trondman et al. (2016) (VHA) tested the REVEALS model using MULTIPLE SMALL SITES (lakes and bogs) and concluded that pollen records from MULTIPLE SMALL BOGS could be used, ideally in mixture with pollen records from LARGE and/or SMALL lakes. Thus:
2. The REVEALS model is NOT appropriate to reconstruct regional plant cover using pollen records from SINGLE SMALL sites (lakes or bogs) and from LARGE BOGS (single or multiple). See Sugita (2007a, REVEALS model) for the definition of large lake, and Trondman et al. (2015) for the choice of 50 ha as a “practical” delimitation between small (< 50 ha) and large (>50 ha) sites.
3. The REVEALS model IS appropriate to reconstruct plant cover using pollen records from SINGLE LARGE LAKES (however always better with records from SEVERAL LARGE LAKES in the same vegetation region); and it is also appropriate using pollen records from MULTIPLE SMALL LAKES (Sugita 2007a REVEALS model) and from a mixture of SMALL SITES (bogs and lakes) (Trondman et al., 2016).
4. In the LandCover6k protocol, LARGE BOGS are used, but the reconstructions are considered as not or less reliable (information provided in the publications) if they include: (1) only one large bog record, (2) several large bog records and no lake record or too few lake records relative to the number of large bog records.
5. The REVEALS model is NOT appropriate using pollen records from marine sediments or other types of sites receiving large amounts of pollen from rivers or surface run-off. The LandCover6k reconstructions have excluded marine and large deltas pollen records. Pollen records from lagunes that are sufficiently sheltered from the sea can be used.
6. **All the points made above, and the first point made below, imply that** (1) the dataset of single site REVEALS estimates of plant cover CANNOT BE USED AS SUCH as each REVEALS reconstruction from a single small site (bog or lake) and a single large bog is incorrect; (2) Only REVEALS estimates using pollen records from single LARGE LAKES or REVEALS **MEAN** ESTIMATES based on the REVEALS estimates from **MULTIPLE SITES** are correct and can therefore be used. This also implies that IF THIS DATASET IS MADE OPEN ACCESS FOR USE, **it MUST BE CLARIFIED for the user what can be done AND NOT DONE with these single sites REVEALS estimates**, i.e. (1) one CANNOT use the original single site REVEALS plant cover if the pollen record is from a SMALL SITE (lake or bog) or a LARGE BOG. (2) one **CAN** calculate **MEAN REVEALS estimates** within regions from ca. 50 km x 50 km (se Hellman et al., 2008b in VHA and Trondman et al., 2015 in GCB) up to whole regions or continents (the latter continental scale is provided in Schmid et al.’s dataset, but nothing else).

Reply

Our site-wise reconstructions using large lakes are still valid and their information can be used in gridded versions of this data set. We agree and recognize that reconstructions from small lakes and peatland sites should not be used alone as site-wise reconstructions. Our validation was adjusted to also use these sites aggregated in grid cells and not individually. Revised Figures 9 and 11 below show this validation.

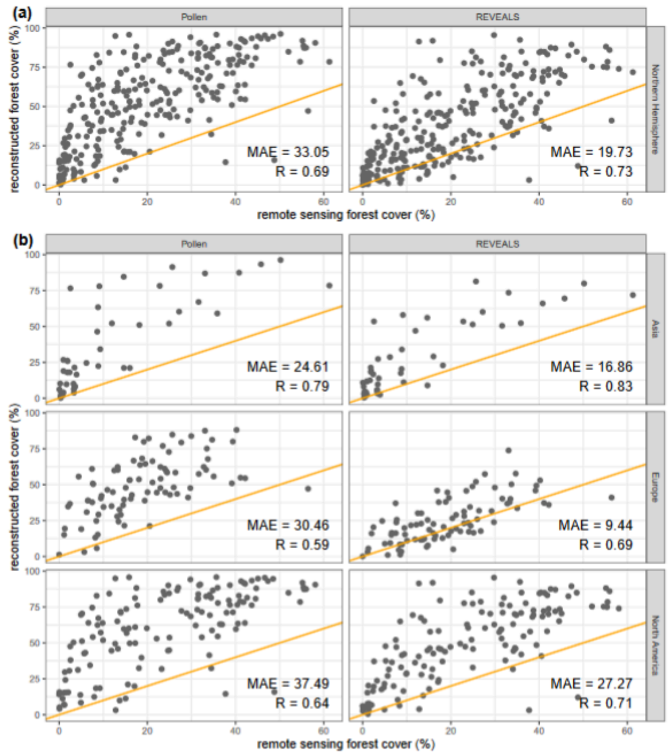


Figure 9. Remote sensing forest cover (LANDSAT) and modern reconstructed forest cover from Pollen and REVEALS (< 100 years BP) in 2x2° grid cells with mean absolute errors (MAE) and correlation coefficient (R) per group. Reconstructed forest cover from the original pollen data tends to overestimate observed (remote sensing) forest cover. Improvements with the REVEALS reconstruction are especially high in Europe. Validations with different grid cell sizes are available in the supplement (S3: Validation results for different spatial resolutions).

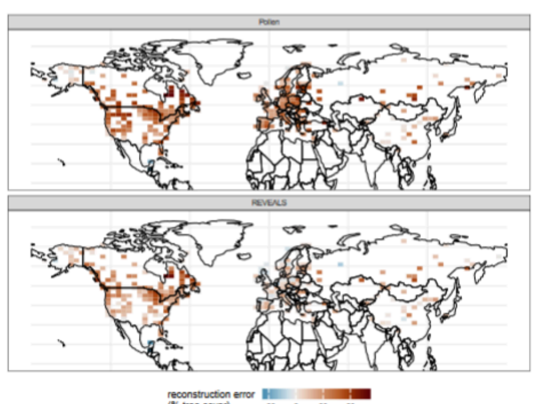


Figure 11. Map of the reconstruction error (in % forest cover) for forest cover reconstructed from Pollen and REVEALS data. Remaining errors with the overall better REVEALS reconstructions are especially high in North America (Northern West Coast, Labrador Peninsula).

Our aim is for the data set to be used flexibly, meaning that users can set their own temporal and spatial resolution for rasterization.This is why we did not prepare a set rasterization. To highlight this use case we **provided a script to rasterize the dataset dynamically and classify grid cell reliability by record availability (https://zenodo.org/records/12800291)**. Additionally, we expanded on this in our data usability section and clarify how we intend the data set to be used reliably. Small sites and peatland will also receive an additional flag in the data set.

Tracked changes (data usability):

To ensure the correct utilization of the dataset and to obtain reliable analysis results, several key considerations should be followed. Firstly, rasterization mitigates individual errors by temporal and spatial averaging. This process is particularly useful in reducing the variance that might arise from individual measurements, providing a more reliable representation of the underlying signal.The reliability of reconstructions varies among different taxa due to the quality of RPP values, and this is explicitly documented in a supplementary file that outlines the sources of RPP values (see Section Code and Data availability). Reconstructions of taxa with continental RPP values are the most reliable, followed by those based on hemispheric data, with standardized RPP values being the least reliable. This hierarchy should be taken into account when interpreting the results. Higher certainty is associated with forest cover reconstruction, as it is based on aggregation among taxa. Reconstructions of temporal forest cover trends are reliable, as evidenced by high correlation coefficients, despite a tendency for absolute values to be overestimated, particularly in North America. For individual time series, the reliability of data varies with the size of the lakes from which samples were taken. Only data derived from large lakes (≥ 50 ha) are reliable for site-wise analyses. This distinction is clearly indicated with validity flags in the dataset. Reconstructions from smaller basins should not be used alone.

Implementation of the REVEALS model and pollen source areas

Original comment

7. This first point is also relevant for the issue discussed above: The authors (Schild et al.) use Theuerkauf et al. (2016) "REVEALSinR" to implement the REVEALS model as an alternative to Sugita's REVEALS programme (last revised in 2022) or the R REVEALS program by Petr Kunes. The use of "REVEALSinR" implies that the REVEALS model assumptions (Sugita 2007a; further discussed and explained in e.g., Githumbi et al. (2022), Li et al. (2020; 2023) must be considered while implementing the model. For example, the selection of appropriate sites and the number of pollen records used for the reconstruction are essential. If using pollen records from SMALL sites, the larger the number of sites/pollen records the better. The use of a single small site or a single LARGE BOG will provide biased reconstructions that won't be useful for the analysis of past plant cover, neither at the regional scale nor at the local scale. For instance, Theuerkauf et al. 2016 write: "*Like the original REVEALS programme, 'REVEALSinR' includes a function to address deposition in lakes (for details see ESM). Both the original REVEALS programme and 'REVEALSinR' only consider atmospheric pollen deposition (and lake mixing); neither model is applicable to sites that receive significant amounts of pollen from rivers, streams or surface run-off*". Theuerkauf et al. (2016) do not say explicitly that REVEALS can be used with pollen records from SINGLE small sites. But, very unfortunately, they confuse the reader by introducing severe misunderstandings in their description of the REVEALS model and its application (selection of pollen records). For instance (under "Principles of 'REVEALSinR'": "*The REVEALS model (Sugita 2007a) is based on the assumption that pollen deposition of a plant taxon in a large lake or* ***peatland*** *is equal to the mean abundance of that taxon in the region, multiplied by its pollen productivity and its 'pollen dispersal-deposition coefficient' K….*etc".

Sugita 2007a calls his model REVEALS, i.e. Regional Estimates of Vegetation Abundance from Large **Sites" BUT** it is developed for pollen deposited in **LAKES** and tested theoretically with simulated pollen records from **LAKES**. Further, one of the assumptions of the REVEALS model is that **the deposition basin is NOT COVERED BY VEGETATION**. It follows, therefore, that REVEALS is not appropriate for pollen records from large bogs. Another unfortunate issue in Theuerkauf et al. (2016) is the use of small sites in one of the tests of the effect of different pollen dispersal models on the REVEALS reconstruction, **although the second experiment uses a pollen record from a LARGE LAKE, which is correct!**, i.e., (under Materials and Methods, in relation to the first experiment): "*We associate the record with lakes and peatlands of different size (100–10,000 m in diameter), using different cut-off distances for the tail of the GPM (50 km to infinity). This cut-off sets an arbitrary limit to the maximum distance pollen may travel (the region considered as pollen source area). The cut-off for the LSM is set to 100 km, which is the calculated average distance at which 95 % of the pollen has settled (cf. Fig. 1)*." The latter implies that the authors use REVEALS for single sites from 1 to 100 ha. Moreover, they use the fact that the "Radius of the 80 % source area of pollen" for sites of 1 ha or 100 ha are not significantly different to argue that what makes the largest difference between sites of different size is the pollen dispersal model. This is true for the "pollen source area" defined as the characteristic radius for 80% or 90% etc…. of the pollen reaching the site, but it is NOT true for the size of the area a quantitative pollen reconstruction of plant cover represents when pollen records are from **SMALL SITES. See the LOVE model (Sugita 2007b) and definition of RSAP (Sugita, 1994). This is a typical example of what a published paper having got weak reviews may lead to in studies by scientists that do not go back to the sources, in this case the description of the REVEALS model by its author!..... <u>A good scientist should know that all what's published is not necessarily correct, especially today as the review system is close to collapse due to a too large article production in comparison to the number of reviewers that have the appropriate expertise to evaluate a new study.</u> GO BACK TO THE ORIGINAL SOURCES!**

Reply

As outlined above, we agree that peatland sites as well as small lakes are unsuitable for a site-wise reconstruction, which is why we will **aggregate them in grid cells and highlight in the manuscript that this is the intended use case (https://zenodo.org/records/12800291)**. This will be supplemented by a script to create flexibel rasterized data sets. See the tracked changes for the reconstruction methods below.

Forest cover was reconstructed by summing up percentages of arboreal taxa (see ~~S1~~S2: List of arboreal taxa) with Betulaceae, *Betula*, and *Alnus* being classified as arboreal at sites below 70° N. The mean reconstructed compositional coverages from the REVEALS results were used for the forest cover reconstructions. REVEALS results were then rasterized to aggregate and include records from smaller basins as well. Reconstructed time series were averaged in 500 year bins and then rasterized in grids of differing spatial resolution. A grid cell was classified as having a valid reconstruction when it contained records from at least one large lake (>= 50 ha) or at least two small basins following Serge et al. (2023). Standard deviations of the REVEALS estimates were aggregated by applying the delta method by Stuart and Ord (1994), using the same equation as Wieczorek and Herzschuh (2020). We provide a script for rasterization with adjustable temporal and spatial resolution for users of the dataset on Zenodo (https://zenodo.org/doi/10.5281/zenodo.12800290). For validation, the reconstructed forest cover of

Additionally, the 80% pollen source area is indeed less informative if calculated from small sites. We **removed calculated values from the small lake and peatland sites** in our data set.
Of course we do not intend to recreate the RSAP as defined by Sugita in our data set creation, but the area where 80% of pollen originates from. The overlap in naming is indeed unfortunate,

which is why we see no problem **changing the name of our calculated parameter** to "80% pollen source area". See tracked changes for this terminology change below.

2.2.2 Modifications in REVEALSinR

We calculate the radius of ~~relevant~~ the 80% pollen source area by finding the radius in which the median influx of all taxa is 80% of the total influx (as defined by the total influx in the maximum extent of regional vegetation chosen). This is calculated

Original Comment

8. The authors of the discussed paper (Schmid et al.) claim that they are calculating the "RELEVANT SOURCE AREA" of each site, small and large (although it says RELATIVE pollen source area in the abstract". It is unclear how this is calculated. Under 2.2.2 it says, *"We calculate the radius of relevant pollen source area by FINDING THE RADIUS IN WHICH THE MEDIAN INFLUX OF ALL TAXA IS 80% OF THE TOTAL INFLUX (as defined by the total influx in the MAXIMUM extent of REGIONAL VEGETATION CHOSEN)"*. This seems to be the source area of pollen as defined by Theuerkauf et al (2016). **This in any case NOT the RELEVANT SOURCE AREA OF POLLEN (RSAP)**. RSAP was defined originally by Sugita (1994, Ecology) and can only be estimated for SMALL SITES using the LOVE model (backwards modelling approach; Sugita 2007b The LOVE model) or the ERV model and a forward modelling approach (Hellman et al., 2009, R. Pal. Pal). **The RSAP is the minimum size of the area for which the LOVE estimates of plant cover using pollen records from SMALL SITES is valid.** The maximum size of the area cannot be calculated. The definition of the pollen source area by Schmid et al. mentioned above seems to correspond to the "characteristic radius" approach first described by Prentice (1988). This method is generally used to estimate the parameter *Zmax* needed to apply the REVEALS model (see examples in Hellman et al. 2008b in VHA; and in Gaillard et al. 2022, see Figure below). Zmax is defined as the maximum extent of the regional vegetation and is not estimated in the REVEALS programme by Sugita. Z*max* is not the same as RSAP and it is not either necessarily the size of the area for which a REVEALS plant cover reconstruction (using appropriate pollen records!) is valid (or most valid). See point 9 below.

From Supplementary Material for Gaillard, M.-J. Githumbi, E., Achoundong, G., Lézine, A.-M., Hély, C., Lebamba, J., Marquer, L., Mazier, F., Li, F., and Sugita, S. (2021). "The challenge of pollen-based quantitative reconstruction of Holocene plant cover in tropical regions: A pilot study in Cameroon." In: Runge, J., Gosling, W., Lézine, A.-M., and Scott, L. (eds) Quaternary Vegetation Dynamics. The African Pollen Database, pp. 183- 1518 205. CRC Press. eBook ISBN9781003162766, Taylor and Francis Group. https://doi.org/10.1201/9781003162766-12

"Z_{max} (distance within which most pollen comes from) is a parameter needed to apply the ERV model (see equation above). A way to estimate this distance is to calculate the "characteristic radius" (CR) sensu Prentice (1988) for each taxon involved in the ERV analysis and for the "basin size" (or radius) of the sample site (0.5 m for soil samples, lake size for sediment samples) using the taxa FSP (e.g. Hellman et al., 2008b). We calculated CR using Prentice's bog model (GPM) and the Sutton's parameters cz (vertical diffusion coefficient, 0.12); cy (horizontal diffusion coefficient, 0.21), n (empirical coefficient, 0.25), and u (wind speed, 3 m/s).The CR of the 12 taxa used in this study (Table 2, above) for a basin size of 0.5 m (soil sample) (Figure 1) implies that 90% of three pollen taxa are coming from > 200 km (e.g. Moraceae, ca. 250 km) and 90% of nine pollen taxa are coming from < 200 km (e.g. Syzygium, ca. 290 km (max CR); Macaranga, ca. 150 km; Podocarpus, ca. 100 km; Poaceae, ca. 20 km (min CR)). ≤ 85% of all 26 taxa used in the first ERV model run come from ≤ 200 km (all results not shown here). Therefore, Z_{max} was set to 200 km."

9. Theuerkauf et al. (2016) also discuss the size of the area represented by REVEALS estimated plant cover (under Discussion): "*REVEALS output is commonly interpreted as representing the regional vegetation composition— but how large is this region? Or, where does the pollen come from? There is no simple answer because pollen arrives from nearby as well as far away, with* *nearby sources contributing (much) more (Janssen 1966). Prentice and Webb (1986) suggested approximating the source area as the area outside the basin from which e.g. 80 % of total pollen deposition arrives. For large lakes and peatlands with 1,000 m diameter (***MJG: e.g. large sites***!), the LSM predicts that the size of the 80 % source area is *55 km for all taxa, whether with high or low fall speed. In contrast, the conventional GPM for neutral conditions predicts a large difference in the 80 % source area of taxa with low (*120 km) and taxa with high fall speed (12 km; Table 1). Whereas the unrealistic GPM defies definition of a distinct source area, the realistic LSM offers a clear delineation." (……).* The latter result is perfectly logical but does not mean that it is not possible to define a pollen source area with the definition "*the area outside the basin from which e.g. 80 % of total pollen deposition arrives".* In the results presented by Theuerkauf et al. (2016) **the pollen source area is ca 55 km in diameter with the LSM and for the GPM it is maximum 120 km (i.e. distance for the low fall speed pollen, the distance for the high fall speed pollen being smaller, but for ALL the pollen types together, the max distance becomes 120 km.**

10. On the subject of "the size of the area represented by REVEALS estimated plant cover", Shinya Sugita writes in Li et al. (2022; pages 4-5): "*When REVEALS is applied using pollen records from multiple sites, one of the important assumptions is that there is no spatial gradients in vegetation composition within the multiple sites region (Sugita, 2007a). In addition, it is assumed (and computer simulations support it) that, **when the basin size is >100 ha, the site-to-site variation of pollen assemblages becomes negligible even if the spatial structure of vegetation is <u>highly patchy</u> (Sugita, 2007a).** Accordingly, **<u>the averaged values</u>** of the REVEALS estimates using pollen records from **<u>multiple large sites</u>*** (**MJG: and multiple small sites, see Hellman et al., 2016**) ***approximate the species composition of the regional vegetation reasonably well*** *as simulations and empirical studies have demonstrated (e.g. Hellman et al., 2008a, b). 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 (Zmax).** Simulations and previous empirical studies (e.g. Sugita, 2007a, b; Hellman et al., 2008b; 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. Unfortunately, no other evaluation studies following the strategy of Hellman et al., 2008a have been published so far for other regions of the world*."

11. Theuerkauf et al. also write: "*Therefore, in situations where **regional vegetation is expected to be p<u>atchy</u>**, approaches that do not rely on **<u>homogeneity</u>** are preferable to REVEALS. For **<u>a single site</u>**, multiple scenario approaches allow the detection of vegetation mosaics (Fyfe 2006; Bunting et al. 2008)."* . "Patchy" is not the same as "non homogenous" (see e.g., Hellman et al., 2009a in Rev. Pal. Pal.) and above. The regional vegetation can be patchy for a REVEALS application as long as the patchiness is homogenous, see also point 10 above.

12. **All the points above imply that the authors of the discussed paper (Schmid et al.) MUST clarify how their calculate the "pollen source area" of each site (lake or bog, large or small), what the definition of that source area is, and what it can be used for when it is calculated for a small site, given that it is not the same as the RSAP and does not necessarily define the size of the area for which the REVEALS reconstruction of plant**

cover is valid.

Reply

As outlined above, we **adapted our terminology** and call the parameter calculated by us "80% pollen source area". We define it as the area from which the median relative influx of all taxa is 80%. This is calculated by employing the lake deposition model in Theuerkauf et al.'s REVEALSinR. Starting from zmax the deposited pollen is calculated per taxon. This is assumed to be the total pollen each taxon deposits. This is of course not the reality as pollen can originate from even much further and fluvial inputs into lakes are inevitable as well. But this is an assumption that REVEALS makes as well. In a step-wise process the radius around the basin is increased and the deposited pollen relative to the total influx at zmax calculated for each taxon. We define our 80% pollen source radius as the radius where the median of the relative influx of all taxa reaches 80%. The aim of this calculation is mainly to give an idea of the scale of source area to users not familiar with pollen data. It emphasizes the regional character of lacustrine pollen data and showcases how lake size influences this source area. Please see the tracked changes below with an expanded explanation.

2.2.2 Modifications in REVEALSinR

We calculate the radius of ~~relevant~~ the 80% pollen source area by finding the radius in which the median influx of all taxa is 80% of the total influx (as defined by the total influx in the maximum extent of regional vegetation chosen). This is calculated by employing the lake deposition model in REVEALSinR (Theuerkauf et al., 2016). Starting from z_{max} the deposited pollen is calculated per taxon. This is assumed to be the total pollen each taxon deposits. In a step-wise process the radius around the basin is increased and the deposited pollen relative to the total influx at z_{max} is calculated for each taxon. We define our 80% pollen source radius as the radius where the median of the relative influx of all taxa reaches 80%. The primary objective of this calculation is to provide a clear understanding of the scale of the source area for users unfamiliar with pollen data. It highlights the regional nature of lacustrine pollen data and demonstrates the influence of lake size on this source area.

We also reduced computational effort in REVEALSinR by implementing a maximum number of steps in the lake model used to model mixing in the basin. The number of steps was set to 500 unless n falls below that maximum value for $n = basin\,radius/10$ for basins with a radius of at least 1000 m and $n = basin\,radius/2$ for basins with a radius smaller than 1000 m.

Selection of RPP dataset and RPP values

Original comment

1. The RPP dataset used is the one published by Wieczorek and Herzschuh (2020). The RPP used in Schmid et al (this paper) are mean RPPs based on 1 to n original RPP values, **they are NOT original values**.
2. The Wieczorek and Herzschuh (2020) (WH) dataset does not include original RPP values from the southern hemisphere and doesn't use RPPs published since 2020 in China, Europe, and subtropical/tropical regions as well as Australia. As far as I can see the WH dataset uses only the original values in Commerford et al. (2013) for N America, but not the values from Calcote and others (?).
3. Both points MUST be clarified. As it stands now it looks like a) there are no original RPP values from the southern hemisphere/sub-tropical and tropical regions and b) northern hemisphere RPP values are used for the southern hemisphere and when the SH taxa do not exist in NH the RPP

is put to 1. Moreover, Tables A1 and A2 may give the impression to the reader that all these taxa have original RPP values in all continents. **It is VERY CONFUSING! CLARIFY. Do not call the values in Table A1 "Original RPP", these are means of original RPPs AS SELECTED AND CALCULATED BY WH! And provide the Tables A1 and A2 in a different format, with the list of taxa only ONCE in the first column and ascribe the following columns to the different continents/regions you have defined. Indicate for each continent whether the RPP value you use is a mean of original values (1-n) from a single continent or several (for instance with an asterisk for the mean value used and indicate with e.g. a cross the continents in which those values are used although there are no original values in those continents. Also indicate what RPP value used is based on a single original RPP value! It would also be useful if the taxa within a family for which a RPP value exists are named, for instance Thymelaceae (only one value and it is for *Stellara* (China), and Orobanchaceae, only one value for *Rhinanthus* type (Europe), etc. This will make the RPP dataset much more transparent, the reader will have the direct information of whether the RPP value is robust for the continent in question or not, without having to go back to WH (2020) and the ESM in there. You could also indicate for the taxa you have put RPP=1 in case there is an original value published since WH (2020) that can be used as an alternative to 1 or your "optimized values", for instance for Alchornea, Melastomataceae, Podocarpus etc (e.g., Gaillard et al., 2021). NOTE: correct the spelling errors of the plant taxa names!**

Finally, the points mentioned on the first page of this comment related to other existing continental REVEALS reconstructions and their use could be included the introduction of the paper (or the Discussion). I.e. better describe the difference between this "Global" REVEALS reconstruction and the existing continental REVEALS reconstructions.

Reply

We thank you for making us aware of this confusion. We used "original" here to describe the synthesis values and distinguish them from values that we tried to optimize. **As we omitted the Optimization from the manuscript, the reconstruction is now only titled REVEALS** and makes use of synthesized RPP values. The synthesis by Wieczorek and Herzschuh does indeed take the 1996 publication by Calcote into account.

Concerning syntheses from reconstructions following Wieczorek and Herzschuh (2020), the synthesis used in Githumbi et al. (2021) was finalized in 2019, before the publication of Wieczorek and Herzschuh, and the RPP studies used overlap with the ones used in Wieczorek and Herzschuh. A set of RPP values in southern France by Mazier was not used by WH, but is cited as "unpublished" in Githumbi et al. (2021) so we were unable to acquire these values or a description of the study. The preprint of Dawson et al.'s reconstruction unfortunately only became available after submission of this manuscript. The authors detail the use of the synthesis by Wieczorek and Herzschuh and the addition of RPP values for *Ambrosia* and *Tsuga* from a previous synthesis. **We examined the original publications for these values and and found that they did not meet the requirements for inclusion** as stated in Wieczorek and Herzschuh 2020 as they do not use ERV models. We did however include several RPP studies for Asia in our synthesis, which were published after 2020. Please see the tracked changes for the method description below and also the new Appendices with original RPP values and the RPP synthesis in the uploaded revised manuscript.

2.2.1 Parameters and Model Settings

For each taxon, values for RPP (with uncertainties provided as standard deviation) and fall speeds are used. ~~When available, we use continent-specific values in our reconstruction following~~ We made use of the synthesis of Northern Hemisphere RPP and fall speed values by Wieczorek and Herzschuh (2020). Several RPP studies published since this synthesis were added to the compilation (Geng et al., 2022; Li et al., 2022b; Wang et al., 2021; Huang et al., 2021; Zhang et al., 2021a, b; Wan et al., 2020, 2023; Jian . The methods by Wieczorek and Herzschuh (2020) were followed fore study selection and calculation of synthesis values. An overview of original values and synthesized values can be found in Appendix A and B respectively.
When available, we use continent-specific values in our reconstruction. For taxa with no continental values present, we use ~~northern hemispheric~~ Northern Hemispheric values. If no values exist for a taxon, RPP is set to a constant (RPP = 1, σ=0.25) and fall speeds are filled with mean continental fall speeds~~(see Appendix A: Original RPP and fall speed values per continent~~. Continental RPP values are available for the majority of pollen counts in all three continents (see Fig. 3). The fraction of pollen counts for which ~~RPP estimates are available are much higher in the Northern Hemisphere than in the Southern Hemipshere (see Fig. 3).~~ standard RPP values were assumed is highest in North America but still < 10%. For each site, the REVEALS model also requires information on basin type, basin size and original pollen counts, all of which were collected in the LegacyPollen 2.0 dataset (Li et al., 2024b). Apart from taxon- and basin-specific parameters the REVEALS model requires several constant parameters to be set, which can be found in Table 2.

As we perceive a high uncertainty for reconstructions in the southern hemisphere, due to a lack of RPP values, **we decide to exclude reconstructions from these records from the data set.**

Detailed Comments

Abstract

adjust after having considered all major comments above. Clarify how the REVEALS dataset of plant-cover reconstructions for single sites of any type and size should be used! Clarify the definition of your "relative pollen source area" that I would rather call "characteristic pollen source area" or simply "pollen source area". See above.

- We added a short explanation of the use of the dataset.

The improvements in forest cover reconstructions with the REVEALS reconstruction using ~~original/optimized parameters range from 1/0% (Australia and Oceania/Australia and Oceania) to 58/65~~continental RPP values range from 24% (North America) to 72% (Europe~~/North America~~) relative to the mean absolute error (MAE) ~~in~~ of the pollen-based reconstruction. ~~Optimizations were considerably more successful in reducing MAE when more records and RPP estimates were available. The optimizations were purely statistical and only partly ecologically informed and should, therefore, be used with caution depending on the study matter~~The dataset can be used as a grid with binned and aggregated samples (adjustable script provided on Zenodo; https://zenodo.org/doi/10.5281/zenodo.12800290) or as individual timeseries if the record's basin size exceeds 50 ha.

Lines Comment

Introduction

26 akin ??

- We will change this wording to “comparable”.

and even trigger feedback effects with other earth system elements (IPCC, 2023; Armstrong McKay et al., 2022). Predicting these changes through modeling is challenging. A sufficient mechanistic understanding of vegetation dynamics and interactions with climate is needed, which requires validation and testing of model data with extensive vegetation data across climatic transitions ~~akin~~ comparable to those anticipated in the future (Dearing et al., 2012). Given the relatively brief duration of available instrumental climate and vegetation data, there is a clear need for long-term ~~environmental~~ vegetation records derived from paleoecological archives that cover broader climatic gradients than modern datasets (Dearing et al., 2010; Dallmeyer et al., 2023).

41 “real”, perhaps “actual vegetation” is better4

- Implemented

compositions do not accurately reflect vegetation (Davis, 1963; Prentice, 1985; Prentice and Webb III, 1986). This limitation arises from variations in taxon-specific parameters ~~like~~ such as relative pollen productivity (RPP) and pollen dispersal characteristics, leading to discrepancies between the pollen record and ~~real~~ actual past vegetation. This hinders quantitative

47-49 “By accounting for ….. REVEALS models quantitative vegetation cover in relevant pollen source areas ….” WRONG! Correct

- Implemented

gional Estimates of Vegetation Abundance from Large Sites” (REVEALS) . By accounting for taxon-specific RPP and fall speed values, as well as basin-specific parameters such as basin size and type, REVEALS models quantitative vegetation cover in ~~relevant pollen source areas~~ the region surrounding a basin from pollen compositions. The model has been applied

63 “Yet, only Serge et al. …use the opportunity for extensive validation…” WRONG! See Pirzamanbein et al. (2014) for Europe: Pirzamanbein, B., Lindström, J., Poska, A., Sugita, S., Trondman, A. K., Fyfe, R., Mazier, F., Nielsen, A.B., Kaplan, J.O., Bjune, A.E., Birks, H.J.B., Giesecke, T., Kangur, M., Latałowa, M., Marquer, L., Smith, B., and Gaillard, M.J. (2014). “Creating spatially continuous maps of past land cover from point 1780 estimates: A new statistical approach applied to pollen data.” Ecological Complexity 20: 127–141. https://doi.org/10.1016/j.ecocom.2014.09.005

- We added this reference here as well.

constructions (Hjelle et al., 2015; Roberts et al., 2018). Yet, only Serge et al. (2023) and Pirzamanbein et al. (2014) use this opportunity for extensive validation and even improvement of reconstructions from European pollen records. No ~~site-wise~~

64 “No site-wise validations …. exist….” What do you mean? What about the the validations by Hellman et al., 2008a and b, and Sugita et al., 2010, and others?

- We changed this to grid-cell based.

dation of reconstructions (Hjelle et al., 2015; Roberts et al., 2018). Yet, only Serge et al. (2023) and Pirzamanbein et al. (2014) use this opportunity for extensive validation and even improvement of reconstructions from European pollen records. No

Mention somewhere in the Introduction the available syntheses of RPP without forgetting the latest RPP synthesis for Europe published in Githumbi et al. (2022a) and the new REVEALS reconstruction for northern America: Dawson, A., Williams, J. W., Gaillard, M.-J., Goring, S. J., Pirzamanbein, B., Lindstrom, J., Anderson, R. S., Brunelle, A., Foster, D., Gajewski, K., Gavin, D. G., Lacourse, T., Minckley, T. A., Oswald, W., Shuman, B., and Whitlock, C. (2024). “Holocene land cover change in North America: continental 1410 trends, regional drivers, and implications for vegetation-atmosphere feedbacks.” Climate of the Past 1411 Discussion [preprint].

https://doi.org/10.5194/cp-2024-6 , in review, 2024.

Reply

Even though the reconstruction by Githumbi et al. was published in 2022, the RPP synthesis was completed in 2019 prior to Wieczorek and Herzschuh (2020). The same studies were considered in Githumbi et al. and Wieczorek and Herzschuh with the exception of one unpublished study concerning RPP values in southern France by Mazier. We were not able to acquire the values from this study. Githumbi et al. provide more RPP values because a combination of taxa was not done as in Wieczorek and Herzschuh.

The preprint by Dawson et al. (2024) was unfortunately only available after our submission. We found that the authors used RPP values as synthesized by Wieczorek and Herzschuh for Northern America. RPP values for two additional taxa were added but did not meet the requirements for synthesis as stated in Wieczorek and Herzschuh 2020. We added a mention of Githumbi et al. for their earlier synthesis.

> though the model's performance heavily relies on accurate taxon-specific parameters. While Wieczorek and Herzschuh (2020) and Githumbi et al. (2022)provide a comprehensive compilation of RPP and fall speed values for taxa of the Northern Hemisphere, the overall availability of RPP studies is still limited and regional variations in RPP values exist (Harris et al., 2020; Broström et al., 2008; Li et al., 2017; Mazier et al., 2012). This makes the application of REVEALS on larger scales particularly

Methods

Figure 1 Explain in the Figure caption what the different colours of dots mean, I guess lakes versus bogs

- We have revised the figure to indicate different basin types.

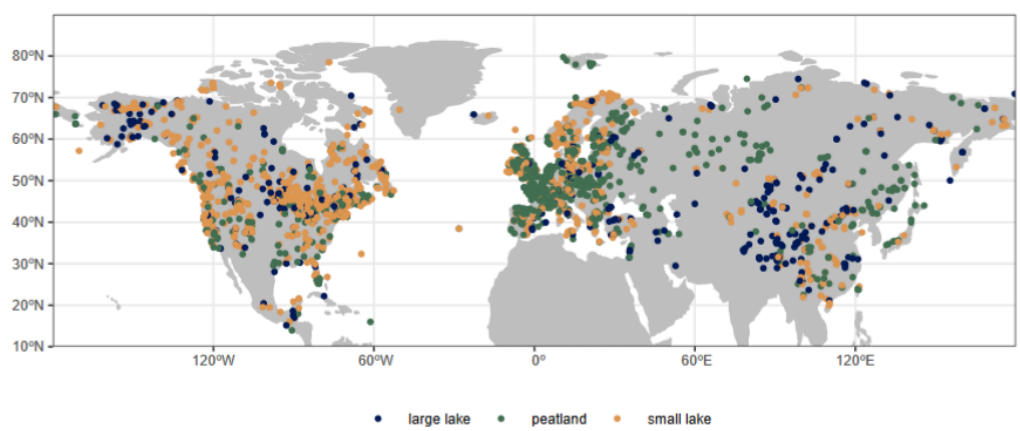


Figure 1. Pollen record locations in the LegacyVegetation dataset. Colors indicate record type (large lake ≥ 50 ha). Record density is highest in Europe and Eastern North America, and lowest in Northern and Central Asia.

86-87 page 4 last lines until ca line 95 page 5

Explain the REVEALS model better and correctly OR simply refer to Sugita (2007a).

- We feel that a concise description of the model is adequate and cite Sugita in line 85. We will add an additional reference to Githumbi et al. 2022 for further details the REVEALS model.

~~For each site,~~ For further details on the REVEALS model ~~also requires information on basin type, basin size and original pollen counts, all of which were collected in the LegacyPollen 2.0 dataset (Li et al., 2024b).~~ see the original publication Sugita (2007) or Githumbi et al. (2022).

97 “using peatland records for reconstructions is, therefore, appropriate.” NOT CORRECT. You MUST clarify that only pollen records from small bogs can be used if the mean REVEALS estimates from SEVERAL single small bogs is used, and even better, if the mean REVEALS estimates are from a mix of SEVERAL small bogs and small LAKES. Etc.… see major issues above

- Revised

instead of Sugita’s deposition model (Sugita, 1993) in the dispersal and deposition function (see Eq. 1; Sugita, 2007). Previous studies show that results from small bogs are still reliable when aggregated, while results from large bogs tend to deviate from

5

those of large lakes ~~(Trondman et al., 2015; Mazier et al., 2012)~~(Trondman et al., 2015; Mazier et al., 2012; Trondman et al., 2016 . Using peatland records for reconstructions is, therefore, appropriate ~~. All sitesthat were not classified as lakes were run with peatland settings~~when spatially averaging multiple sites. We use the implementation of REVEALS from the R package REVEALSinR (Theuerkauf et al., 2016).

8 (12)

Table 2 Several of these are not parameters but models, methods or function …..

- We changed the table title.

Table 2. Static model parameters and model settings for REVEALS runs using REVEALSinR (Theuerkauf et al., 2016).

Figure 3 Specify that the “available” RPP values are not necessarily original values obtained in these continents, but can be values obtained in other continents, right?

- We revised the figure to indicate RPP source.

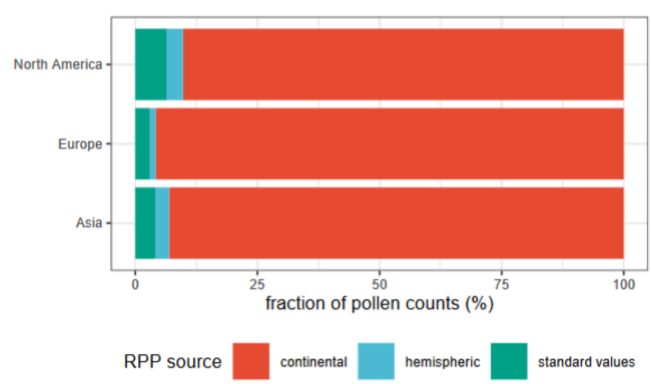


Figure 3. Regional source of RPP values for percentage of pollen counts per continent. A majority of pollen counts is covered by continental RPP values with the highest fraction in Europe. Only a small percentage of pollen counts has only hemispheric RPP values available. No available RPP values lead to the use of a standardized RPP value of 1±0.25.

110 Modifications in REVEALSinR:

a. What are these modifications? Are they modifications compared to REVEALSinR published in Theuerkauf et al (2016) or modifications compared to the REVEALS program by Sugita? Or anything else?

- These are modifications compared to Theuerkauf et al.'s REVEALSinR. We clarified this in the text.

We also reduced computational effort in REVEALSinR by implementing a maximum number of steps in the lake model used to model mixing in the basin. The number of steps was set to 500 unless n falls below that maximum value for $n = basin\,radius/10$ for basins with a radius of at least 1000 m and $n = basin\,radius/2$ for basins with a radius smaller than 1000 m.

b. You did not calculate the "relevant source area of pollen" (RSAP) but something else that you define as "the radius in which etc.....total nflux (.....)." RSAP is something else, see my major comments above. Moreover the definition you provide is badly written, use instead the wording for the definition given in Theuerkauf et al. (2016)

- We adjusted the naming as described above and edited the description of the definition to contain more detail.

We calculate the radius of ~~relevant~~ the 80% pollen source area by finding the radius in which the median influx of all taxa is 80% of the total influx (as defined by the total influx in the maximum extent of regional vegetation chosen). This is calculated by employing the lake deposition model in REVEALSinR (Theuerkauf et al., 2016). Starting from z_{max} the deposited pollen is calculated per taxon. This is assumed to be the total pollen each taxon deposits. In a step-wise process the radius around the basin is increased and the deposited pollen relative to the total influx at z_{max} is calculated for each taxon. We define our 80%

pollen source radius as the radius where the median of the relative influx of all taxa reaches 80%. The primary objective of this calculation is to provide a clear understanding of the scale of the source area for users unfamiliar with pollen data. It highlights the regional nature of lacustrine pollen data and demonstrates the influence of lake size on this source area.

We also reduced computational effort in REVEALSinR by implementing a maximum number of steps in the lake model used to model mixing in the basin. The number of steps was set to 500 unless n falls below that maximum value for $n = basin\,radius/10$ for basins with a radius of at least 1000 m and $n = basin\,radius/2$ for basins with a radius smaller than 1000 m.

117-127 This validation is problematic as it uses the REVEALS estimates for individual sites which implies that the reconstructions using pollen records from small sites (lakes or bogs" will be biased compared to the REVEALS estimates obtained with pollen records from large sites. If you keep this "validation", you MUST clarify that the REVEALS estimates for the small sites can be strongly biased and therefore the correlation with the modern vegetation might be less good than if you would use the mean REVEALS estimates from several sites within a given area size (e.g., grid cells of 1 degree, or vegetation regions, biomes, or continents).

- We revised the validation to use gridded values.

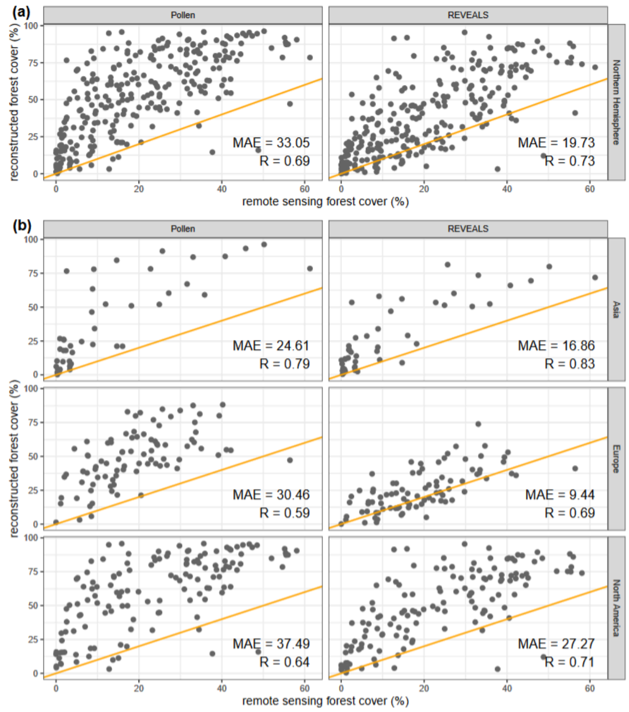


Figure 9. Remote sensing forest cover (LANDSAT) and modern reconstructed forest cover from Pollen and REVEALS (< 100 years BP) in 2x2° grid cells with mean absolute errors (MAE) and correlation coefficient (*R*) per group. Reconstructed forest cover from the original pollen data tends to overestimate observed (remote sensing) forest cover. Improvements with the REVEALS reconstruction are especially high in Europe. Validations with different grid cell sizes are available in the supplement (S3: Validation results for different spatial resolutions).

134 I do not understand this equation, it doesn't make sense to me. This perhaps because it is not clear what you mean with "reconstructed tree cover", and "corrected tree cover". It is clear what "unvegetated" cover is, and it is clear that you have to adjust the modern vegetation cover by using the sum of open vegetated cover as 100% or (1) (i.e. total open cover – unvegetated cover = 1). Is your "reconstructed cover" the total open cover including the unvegetated cover? The use of "reconstructed" here is confusing

- Reconstructed tree cover pertains to the tree cover reconstructed from a pollen product. In our manuscript this includes the original pollen counts, REVEALS reconstructions and optimized REVEALS reconstructions. It is created by summing the percentage of arboreal taxa. Because of the closed compositional nature of pollen records, there is no way to reconstruct unvegetated areas with pollen counts. The value we get can be defined as the percentage of forested area in the vegetated source area around the basin. The forest cover available in remote sensing products is differently defined as the percentage of forested area in the total source area around the basin, which includes unvegetated areas. In order to correct for this within the validation we make use of land cover maps and extract the percentage of unvegetated area in the source area around the basin (Equation 2). This way we are able to convert the reconstructed forest cover to a value which also represents the percentage of forested area in the total source area around the basin and enables a comparison between remote sensing forest cover and corrected, reconstructed forest cover.

General comment for Methods: I do not understand from this description what is the time resolution of the reconstructions, from the Figure 8 it looks to be 1000 years. In this case, this should also be mentioned as a difference in comparison with the continental PAGES LandCover6k that use 500 years resolution up to recent times, and 3 shorter time windows, 350, 250 and ca 100 years between 0.7 k BP up to "present" (see e.g. Trondman et al., 2015).

- For the gridded dataset highlighted in the results a 500 yr temporal resolution was chosen. Validation makes use of the past 100 years.

Forest cover was reconstructed by summing up percentages of arboreal taxa (see ~~S1~~S2: List of arboreal taxa) with Betulaceae, *Betula*, and *Alnus* being classified as arboreal at sites below 70° N. The mean reconstructed compositional coverages from the REVEALS results were used for the forest cover reconstructions. REVEALS results were then rasterized to aggregate and include records from smaller basins as well. Reconstructed time series were averaged in 500 year bins and then rasterized in grids of differing spatial resolution. A grid cell was classified as having a valid reconstruction when it contained records from at least one large lake (>= 50 ha) or at least two small basins following Serge et al. (2023). Standard deviations of the REVEALS estimates were aggregated by applying the delta method by Stuart and Ord (1994), using the same equation as Wieczorek and Herzschuh (2020). We provide a script for rasterization with adjustable temporal and spatial resolution for users of the dataset on Zenodo (https://zenodo.org/doi/10.5281/zenodo.12800290). For validation, the reconstructed forest cover of the past ~~500 years was~~ 100 years was rasterized and compared to modern remote sensing forest cover. Only valid grid cells as

Data Summary

3.1 Pollen source area Adjust according to my major comments above

- We changed the name to "80% pollen source area" as described above.

3.1 80% Pollen Source Areas

3.2 Comparison of original and optimized values Do not use the term "original" for the RPP values you are using but rather "WH mean RPP values" or something similar. The values you are using are not "original values from specific studies unless there is only ONE value that you are using. See my major comment re Tables A1 and A2

- We have omitted the optimization from the manuscript.

Figure 4 Map indicating the size of relevant pollen source areas: CORRECT! It is not RSAP!

- We changed the name to "80% pollen source area" as described above.

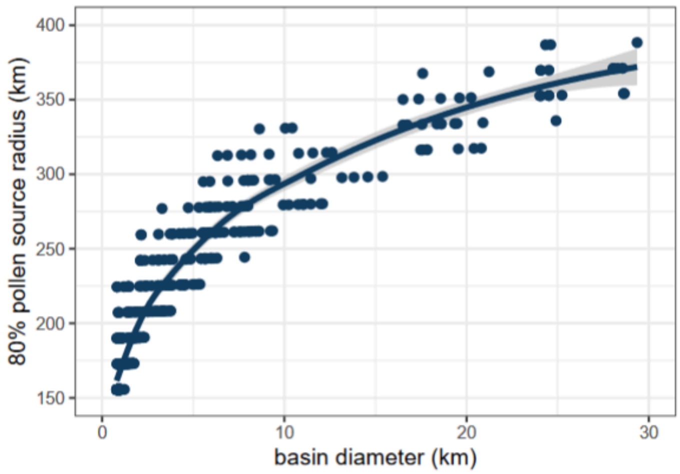


Figure 5. Scatterplot of basin diameter and 80% pollen source area of large lakes in the REVEALS data set. In general, larger basins have larger pollen source areas with the relationship between diameter and 80% pollen source radius being roughly logarithmic.

165-169 "The highest and lowest absolute change respectively occurred for Quercus (4.08) and Fabaceae (0.09) in Africa, etc…." What do you mean? Is it a +/- change or only + change, specify! I see that it is often a + change. I would write: "The highest respectively lowest absolute change (highest/lower) occurred for Quercus (+4.08)/Fabaceae (-0.09) in Africa. If this is not what you meant, CLARIFY!

- We omitted the Optimization and therefore also this paragraph from this manuscript.

175-197 The comparison presented in Figure 7 is fine as you have calculated average REVEALS-estimated cover for whole continents, which is OK even if you used pollen records from small sites. See my major comments above. My question is: did you calculate errors for the average REVEALS estimates using the errors produced by REVEALSinR from each individual pollen record?

- We did not calculate errors for this figure and only show mean values. Standard deviations were calculated using the delta method.

from at least one large lake (>= 50 ha) or at least two small basins following Serge et al. (2023). Standard deviations of the REVEALS estimates were aggregated by applying the delta method by Stuart and Ord (1994), using the same equation as Wieczorek and Herzschuh (2020). We provide a script for rasterization with adjustable temporal and spatial resolution for users of the dataset on Zenodo (https://zenodo.org/doi/10.5281/zenodo.12800290). For validation, the reconstructed forest cover of

199-209 Similarly, Figures 8 and 9 present average forest cover using REVEALS estimates from pollen records available within 10 degrees grid cells, which means that most grid cells are represented by REVEALS estimates using several pollen records. As these data are also made accessible, it would be useful for the user if you added a file that provides the identity code of the grid cells for which the "average" REVEALS estimate is based on the reconstruction from a single pollen record from one-several large bog(2), or 1-2 small bog(2), or 1-2 small lakes, or 1 small bog + 1 small lake. See example in Githumbi et al. (2022a).

- We added this classification in this figure and included it in the script for rasterization to be used by the user. Temporal averages always include only valid grid cells.

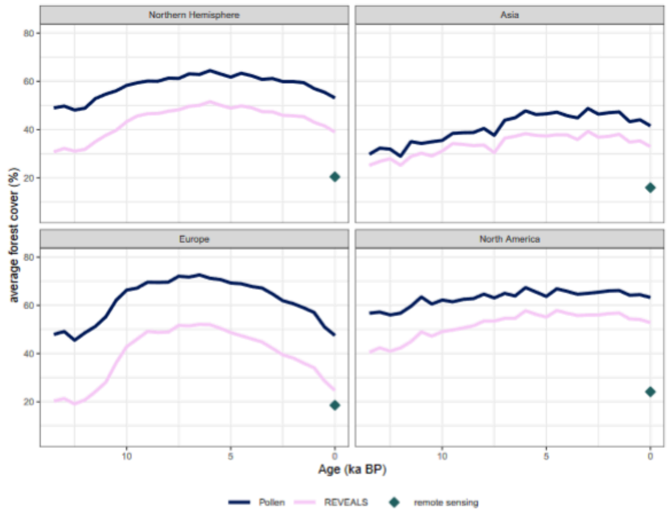


Figure 7. Northern Hemisphere and continental average forest cover from 2x2° grid cell means for raw pollen data and the REVEALS reconstruction (Northern Hemisphere averages from different grid cell resolutions are available in S2: Reconstruction results for different spatial resolutions). Remotely sensed global average forest clover for the grid cells with valid pollen coverage is indicated with the diamond. Temporal trends are the same, but absolute forest cover is reduced in the REVEALS reconstructions compared to the original pollen data. Both reconstructions still overestimate forest cover.

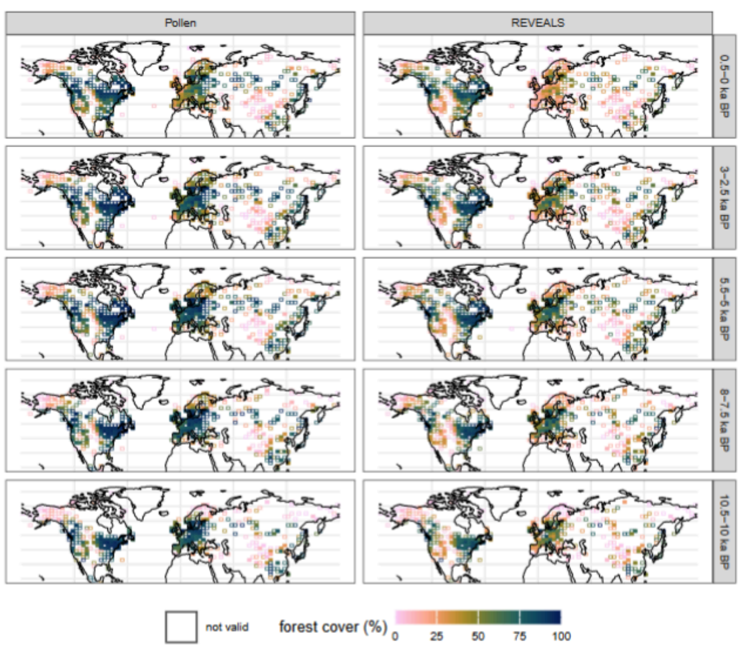


Figure 8. Reconstructed forest cover in 2x2° grid cells from raw pollen data and the REVEALS reconstruction for 5 example time slices (reconstructions with different grid cell sizes are available in the in S2: Reconstruction results for different spatial resolutions). Valid cells are filled and include reconstructions from at least one large lake ($\geq$ 50 ha) or several smaller basins. Forest cover in Eastern North America is higher than in Europe and Asia. REVEALS reconstructed forest cover is generally lower than raw pollen reconstructions.

3.5 validation It is not correct to validate the REVEALS model with modern vegetation data SITE BY

SITE, given that a REVEALS reconstruction using a pollen record from ONE large bog or ONE small site (bog or lake) will in most cases be biased. **A proper revision of this paper should/MUST use the 10 degree grid cell reconstructions to validate these new REVEALS reconstructions (using WH RPP dataset or optimized RPP), and use the cover of modern vegetation within those same grid cells for comparison. Even the SLOO validation should be redone using 10 degree grid cells as the basis for the validation.**

- We revised the validation to use gridded data.

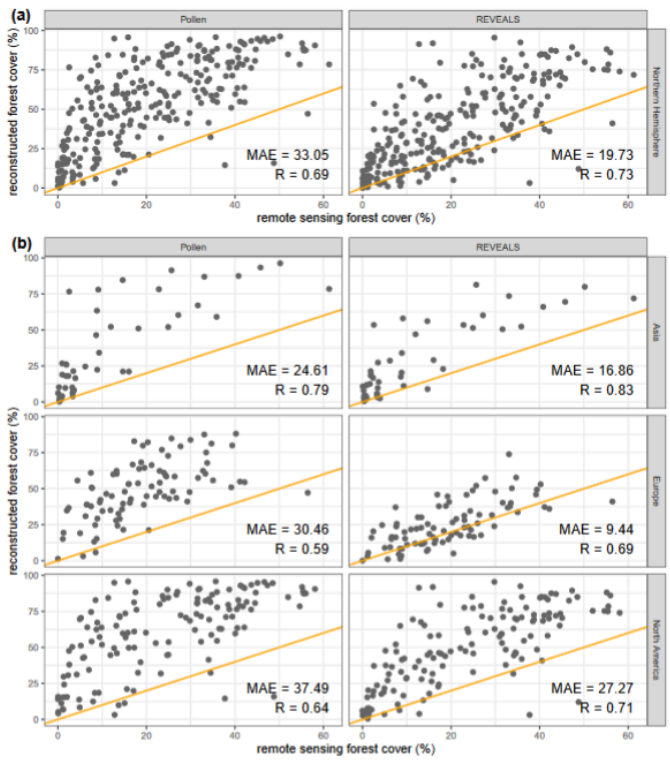


Figure 9. Remote sensing forest cover (LANDSAT) and modern reconstructed forest cover from Pollen and REVEALS (< 100 years BP) in 2x2° grid cells with mean absolute errors (MAE) and correlation coefficient (R) per group. Reconstructed forest cover from the original pollen data tends to overestimate observed (remote sensing) forest cover. Improvements with the REVEALS reconstruction are especially high in Europe. Validations with different grid cell sizes are available in the supplement (S3: Validation results for different spatial resolutions).

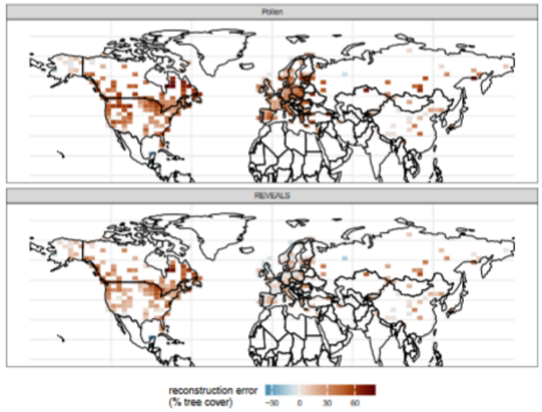


Figure 11. Map of the reconstruction error (in % forest cover) for forest cover reconstructed from Pollen and REVEALS data. Remaining errors with the overall better REVEALS reconstructions are especially high in North America (Northern West Coast, Labrador Peninsula).

251-258 The major difference between N hemispheric vegetation and sub tropical-tropical vegetation is that: in northern and temperate (mediterranean) regions a majority of the tree species are wind pollinated and produce large quantities of pollen per unit area, while pollen of herbaceous plants use to be insect pollinated or both wind and insect pollinated and produce less quantities of pollen per unit area, which implies that trees often are overrepresented by pollen compared with herbs; in (sub) tropical regions it is the inverse, many trees are insect pollinated and often produce small quantities of pollen which implies that herbs may be overrepresented by pollen compared to trees. The latter is well illustrated by Figure 10 pollen % versus remote sensed plant cover.

In this section you MUST clarify that you have not used the RPP values that have been obtained from modern pollen-vegetation datasets in (sub) tropical regions and are available today in published articles (China, Africa, southern America) and provide
example references (you do not need to do a literature search given that you do not use them). It's however important that you inform the reader that such values exist. For instance, in Gaillard et al. (2021) the obtained RPP in Cameroon for 13 taxa are compared with values obtained for these taxa in Africa and China, which already provide a significant number of existing values. Another useful paper is that by Wan et al. (2020): Wan, Q., Zhang, Y., Huang, K., Sun, Q., Zhang, X., Gaillard, M.-J., Xu, Q., Li, F. and Zheng, Z., 2020, Evaluating quantitative pollen representation of vegetation in the tropics: A case study on the Hainan Island, tropical China. Ecological Indicators, 114, article: 106297, 10.1016/j.ecolind.2020.106297.

- We decided to exclude the Southern Hemisphere from this reconstruction as missing RPP and high fraction of insect pollination make our reconstruction too unreliable here.

Dataset applications and limitations and Conclusions

Adjust these two sections according to the major comments explained in the first part of this review in addressing all the issues implied by your dataset, in particular the REVEALS estimates for single sites.

285-286 "…with previous REVEALS applications and show an increase ….until roughly 4 ka BP (references). **This is not correct, the REVEALS reconstructions mentioned show an increase of forest cover/respectively a decrease in openland cover until around 6 ka BP.** The best reference for this is Strandberg et al. (2023) in Clim of the Past and Figure 1 therein that is based on the REVEALS reconstruction from Githumbi et al.

(2022a, in ESSD).

- We revised this.

previous reconstructions as well (Li et al., 2023, 2022b, 2024a). Results for European forest cover also roughly correspond with previous REVEALS applications and show an increase of forest cover after the last glacial maximum until roughly ~~4 ka BP (Githumbi et al., 2021; Fyfe et al., 2015; Serge et al., 2023)~~6 ka BP (Githumbi et al., 2022; Fyfe et al., 2015; Serge et al., 2023; Strandber

. The gridded reconstruction by Serge et al. (2023) was even validated with modern remote sensing forest cover and showed a good fit.

293-294 The deglacial forest conundrium (or Holocene temperature conundrium (HTC)) is also discussed in Strandberg et al. (2022, in QSR).

- We added this reference.

reconstructions as shown by Binney et al. (2011). Additionally, this dataset can address unanswered questions about Holocene vegetation dynamics, including the deglacial forest conundrum ~~(Dallmeyer et al., 2022)~~(Dallmeyer et al., 2022; Strandberg et al., 2022)

. It also serves as a valuable tool for validating models with coupled climate and vegetation, ~~relying~~ which rely on extensive

References

387-389 replace this reference by/ or add : Dallmeyer et al. (2024) in Clim Past Discussion: Dawson, A., Williams, J. W., Gaillard, M.-J., Goring, S. J., Pirzamanbein, B., Lindstrom, J., Anderson, R. S., Brunelle, A., Foster, D., Gajewski, K., Gavin, D. G., Lacourse, T., Minckley, T. A., Oswald, W., Shuman, B., and Whitlock, C. (2024). “Holocene land cover change in North America: continental trends, regional drivers, and implications for vegetation-atmosphere feedbacks.” Climate of the Past Discussion [preprint]. https://doi.org/10.5194/cp-2024-6 , in review, 2024

- We reference Dawson et al.’s (2024) manuscript now as it was not available at the time of submission.

. It also serves as a valuable tool for validating models with coupled climate and vegetation, ~~relying~~ which rely on extensive time series and vegetation data for accurate predictions ~~(Dallmeyer et al., 2023).~~ (Dallmeyer et al., 2023; Dawson et al., 2024).

409-413 replace the Githumbi et al. 2021 in Clim Past Discussion by Githumbi et al. (2022): Githumbi, E., Fyfe, R., Gaillard, M.-J., Trondman, A.-K., Mazier, F., Nielsen, A.-B., Poska, A., Sugita, S., Woodbridge, J., Azuara, J., Feurdean, A., Grindean, R., Lebreton, V., Marquer, L., Nebout - Combourieu, N., Stančikaitė, M., Tanţău, I., Tonkov, S., Shumilovskikh, L., and LandClimII data contributors (2022a). “European pollen-based REVEALS land-cover reconstructions for the Holocene: methodology, mapping and potentials.” Earth System Science Data 14: 1581–1619. https://doi.org/10.5194/essd-14-1581- 2022

- We corrected this citation.

Githumbi, E., Fyfe, R., Gaillard, M.-J., Trondman, A.-K., Mazier, F., Nielsen, A.-B., Poska, A., Sugita, S., Woodbridge, J., Azuara, J., Feurdean, A., Grindean, R., Lebreton, V., Marquer, L., Nebout-Combourieu, N., Stančikaitė, M., Tanţău, I., Tonkov, S., Shumilovskikh, L., and data contributors, L.: European pollen-based REVEALS land-cover reconstructions for the Holocene: methodology, mapping and potentials, Earth System Science Data, 14, 1581–1619, https://doi.org/10.5194/essd-14-1581-2022, publisher: Copernicus GmbH, 2022.

Do remember to also refer to Trondman et al. (2016) (see my major comment on the application of REVEALS using pollen records from small sites): Trondman, A.-K., Gaillard, M.-J., Sugita, S., Björkman, L., Greisman,
A., Hultberg, T., Lagerås, P., and Lindbladh, M. (2016). “Are pollen records from small sites appropriate for REVEALS model-based quantitative reconstructions of past regional vegetation? An empirical test in southern Sweden.” Vegetation History and

Archaeobotany 25: 131–151. https://doi.org/10.1007/s00334-015-0536-9

- We added this reference

instead of Sugita's deposition model (Sugita, 1993) in the dispersal and deposition function (see Eq. 1; Sugita, 2007). Previous studies show that results from small bogs are still reliable when aggregated, while results from large bogs tend to deviate from those of large lakes ~~(Trondman et al., 2015; Mazier et al., 2012)~~(Trondman et al., 2015; Mazier et al., 2012; Trondman et al., 2016) . Using peatland records for reconstructions is, therefore, appropriate ~~. All sitesthat were not classified as lakes were run with peatland settings~~when spatially averaging multiple sites. We use the implementation of REVEALS from the R package REVEALSinR (Theuerkauf et al., 2016).

Reply to Mariani

Laura Schild & Ulrike Herzschuh

General reply

Dear Michela Mariani,

We thank you for your careful review or our manuscript. We appreciate the valid points you have made and found them to be easily remediable. Regarding other matters you have mentioned, we see a good opportunity to provide clarification on how we follow common procedures and highlight the usability and validity of our dataset.

Firstly, the use of continental syntheses of RPP values is widely accepted in continental-scale reconstructions and has been applied in several previously published reconstructions in Europe, North America and Asia. The use of even hemispheric values, when continental ones are missing, maximizes the utility of available data while still producing improved reconstructions as our validations show. As we cannot achieve small-scale perfect reconstructions yet, we advocate for these broader and necessarily coarser insights into vegetation dynamics by generalizing reconstructions.

Furthermore, our REVEALS application using previously published synthesized RPP values is completely independent of remote sensing data. This means using remote sensing data allows for reliable validation. This shows us a clear improvement of forest cover reconstructions compared to raw pollen-data.

We do concur that uncertainties with Southern Hemispheric reconstructions are high and will exclude those from our evaluation along with samples prior to the 14 ka BP. Moreover, the few non-lake and non-peat records will be removed from the data set as they are unfit for reconstruction with REVEALS. Their removal has no effect on our spatial coverage and general reconstruction results. These adjustments were all completed.

We have added replies to your specific comments below.

An updated version of the dataset can now be found here: https://doi.org/10.5281/zenodo.12800159 . The dataset on PANGAEA will be updated as soon as possible.

Best
Laura Schild and Ulrike Herzschuh

Specific replies

Major issues:

Original Comment

Inadequate regional calibrations: The generalization of RPPEs across broad geographical scales (hemispheres) ignores crucial ecological and bioclimatic regional variations. This approach most likely leads to significant inaccuracies in the vegetation reconstructions, in spite of what the presumed 'validation' approach suggests (see below).

Reply

While we agree that a reconstruction using synthesized values will not reflect reality exactly, we still argue for the usability and informativeness of the result of this generalized approach. Continental syntheses of RPP values are standard practice in large-scale reconstructions as they allow an approximation of past vegetation dynamics on a large scale. Notable examples of previously used continental-scale syntheses in Europe include Serge et al. (2023), Trondman et al. (2015) and Pirzamanbein et al. (2014). Githumbi et al. (2022) also synthesize values for Northern and Central Europe and treat only mediterranean records differently. Reconstructions in North America (Dawson et al. 2024) and Northern Asia (Cao et al. 2019) synthesize values on large or continental scales as well.

While we recognize the variability of relative pollen productivity (RPP), we advocate for the use of even hemispheric averages when continental values are lacking. The direction of taxon-specific correction (over- or underproduction of pollen) will generally be correct and provide a vast improvement of REVEALS estimates to using pollen percentages alone while being able to make the most of the data currently available. We highlight that compositional reconstructions using this method come with uncertainties, but are confident that aggregates, such as reconstructed forest cover, are much closer to reality than previous pollen-based estimates. By employing this methodology, our overarching goal is to generate reconstructions that facilitate comparisons across the Northern Hemisphere while shedding light on general vegetation dynamics. This approach mirrors the methodology utilized in large-scale climate models, where local nuances are necessarily sacrificed for broader insights. We highlight the uncertainty connected with hemispheric and standardized RPP values in the revised section "Data applications and limitations" (see tracked changes below).

Importantly, this is underlined by our validation which uses independent remote sensing data and demonstrates notable improvements in reconstruction accuracy compared to reconstructions based on raw pollen data. We will expand on this in our reply to an issue below.

Githumbi, Esther, Ralph Fyfe, Marie-Jose Gaillard, Anna-Kari Trondman, Florence Mazier, Anne-Birgitte Nielsen, Anneli Poska, u. a. „European Pollen-Based REVEALS Land-Cover Reconstructions for the Holocene: Methodology, Mapping and Potentials".

Earth System Science Data 14, Nr. 4 (8. April 2022): 1581–1619. https://doi.org/10.5194/essd-14-1581-2022.

Serge, M. A., F. Mazier, R. Fyfe, M.-J. Gaillard, T. Klein, A. Lagnoux, D. Galop, u. a. „Testing the Effect of Relative Pollen Productivity on the REVEALS Model: A Validated Reconstruction of Europe-Wide Holocene Vegetation“. *Land* 12, Nr. 5 (Mai 2023): 986. https://doi.org/10.3390/land12050986.

Dawson, Andria, John W. Williams, Marie-José Gaillard, Simon J. Goring, Behnaz Pirzamanbein, Johan Lindstrom, R. Scott Anderson, u. a. „Holocene Land Cover Change in North America: Continental Trends, Regional Drivers, and Implications for Vegetation-Atmosphere Feedbacks“. *Climate of the Past Discussions*, 20. Februar 2024, 1–52. https://doi.org/10.5194/cp-2024-6.

Trondman, A.-K., M.-J. Gaillard, F. Mazier, S. Sugita, R. Fyfe, A. B. Nielsen, C. Twiddle, u. a. „Pollen-Based Quantitative Reconstructions of Holocene Regional Vegetation Cover (Plant-Functional Types and Land-Cover Types) in Europe Suitable for Climate Modelling“. *Global Change Biology* 21, Nr. 2 (2015): 676–97. https://doi.org/10.1111/gcb.12737.

Pirzamanbein, Behnaz, Johan Lindström, Anneli Poska, Shinya Sugita, Anna-Kari Trondman, Ralph Fyfe, Florence Mazier, u. a. „Creating Spatially Continuous Maps of Past Land Cover from Point Estimates: A New Statistical Approach Applied to Pollen Data“. *Ecological Complexity* 20 (1. Dezember 2014): 127–41. https://doi.org/10.1016/j.ecocom.2014.09.005.

Cao, Xianyong, Fang Tian, Furong Li, Marie-José Gaillard, Natalia Rudaya, Qinghai Xu, und Ulrike Herzschuh. „Pollen-Based Quantitative Land-Cover Reconstruction for Northern Asia Covering the Last 40 Ka Cal BP“. *Climate of the Past* 15, Nr. 4 (8. August 2019): 1503–36. https://doi.org/10.5194/cp-15-1503-2019.

Tracked changes:

signal.The reliability of reconstructions varies among different taxa due to the quality of RPP values, and this is explicitly documented in a supplementary file that outlines the sources of RPP values (see Section Code and Data availability). Reconstructions of taxa with continental RPP values are the most reliable, followed by those based on hemispheric data, with standardized RPP values being the least reliable. This hierarchy should be taken into account when interpreting the results. Higher certainty is associated with forest cover reconstruction, as it is based on aggregation among taxa. Reconstructions of temporal forest cover

Original comment

Questionable data assumptions and methodological gaps: The use of northern hemisphere RPPE values for taxa not natively present in the southern hemisphere, such as *Alnus* in Australia, introduces substantial and confusing biases. Presumably, the authors have not consulted the relevant scholars who worked within this field and the geographical areas mentioned. Similarly, defaulting RPP to 1 for taxa without specific data oversimplifies pollen-vegetation relationships. The paper does not adequately address the absence of data for the Southern Hemisphere, leading to a misleading portrayal of global vegetation.

It is suggested >50% of RPPEs are missing for Australia and Oceanic pollen records. So, in this work a decision was made to run these records using the Northern Hemispheric RPPEs, despite very different bioclimatic and ecological contexts. This extrapolation of Northern Hemisphere RPPEs to southern locations missing PPEs without considering ecological or bioclimatic differences is particularly problematic. RPPEs empirically produced using ground truthing work (field surveys and surface pollen collection) were ignored, especially across the Southern Hemisphere (see some references below).

Duffin, K. I., & Bunting, M. J. (2008). Relative pollen productivity and fall speed estimates for southern African savanna taxa. Vegetation History and Archaeobotany, 17, 507-525.

Mariani, M., Connor, S. E., Theuerkauf, M., Kuneš, P., & Fletcher, M. S. (2016). Testing quantitative pollen dispersal models in animal-pollinated vegetation mosaics: An example from temperate Tasmania, Australia. Quaternary Science Reviews, 154, 214-225.

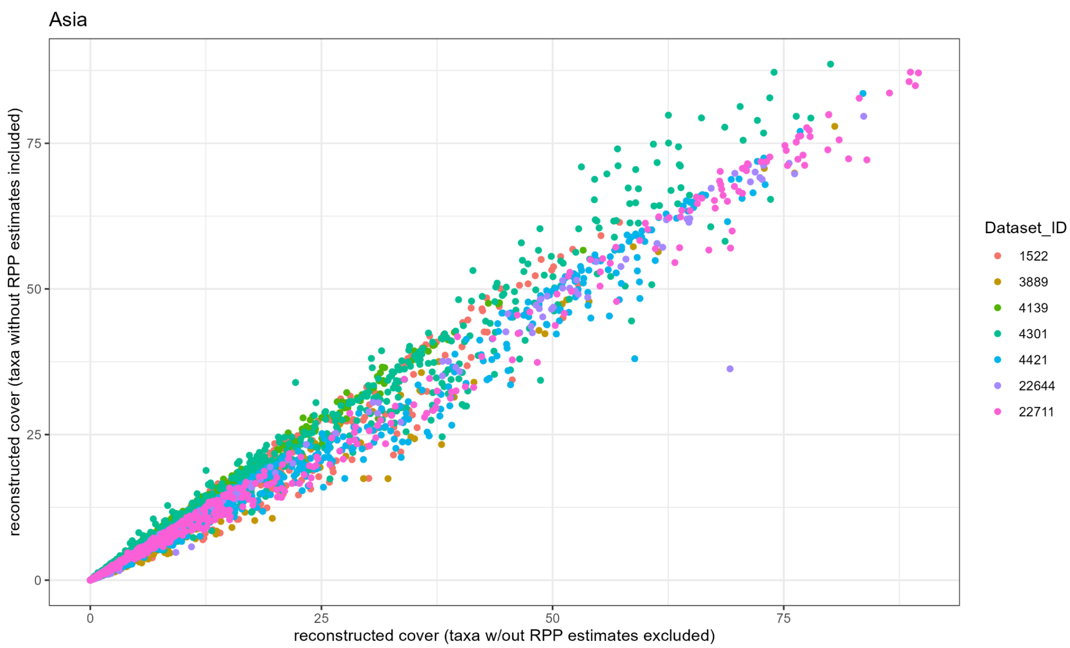
Mariani, M., Connor, S. E., Fletcher, M. S., Theuerkauf, M., Kuneš, P., Jacobsen, G., ... & Zawadzki, A. (2017). How old is the Tasmanian cultural landscape? A test of landscape openness using quantitative land-cover reconstructions. Journal of Biogeography, 44(10), 2410-2420.

Mariani, M., Connor, S. E., Theuerkauf, M., Herbert, A., Kuneš, P., Bowman, D., ... & Briles, C. (2022). Disruption of cultural burning promotes shrub encroachment and unprecedented wildfires. Frontiers in Ecology and the Environment, 20(5), 292-300.

Reply

We do concur that uncertainties with Southern Hemispheric reconstructions are high due to a lack of regional RPP values and will exclude those from our data set.
We believe that including other observed taxa in the model and setting their RPP to 1, will still result in better estimates of aggregate values such as forest cover than the raw pollen data and therefore apply this standard value to include as much data as possible. Including missing RPP values by setting them to 1 or excluding taxa without RPP estimates leads to relatively similar coverage estimates as indicated by the figures below. Excluding any taxa tends to result in an overestimation of the remaining taxa as the total pollen count is reduced. By including all taxa we aim to account for this.

We have added several RPP studies published since the synthesis by Wieczorek and Herzschuh (2020) to our synthesis or RPP values and we highlight the percentage of pollen counts without RPP values (see tracked changes and revised Figure 3 below).



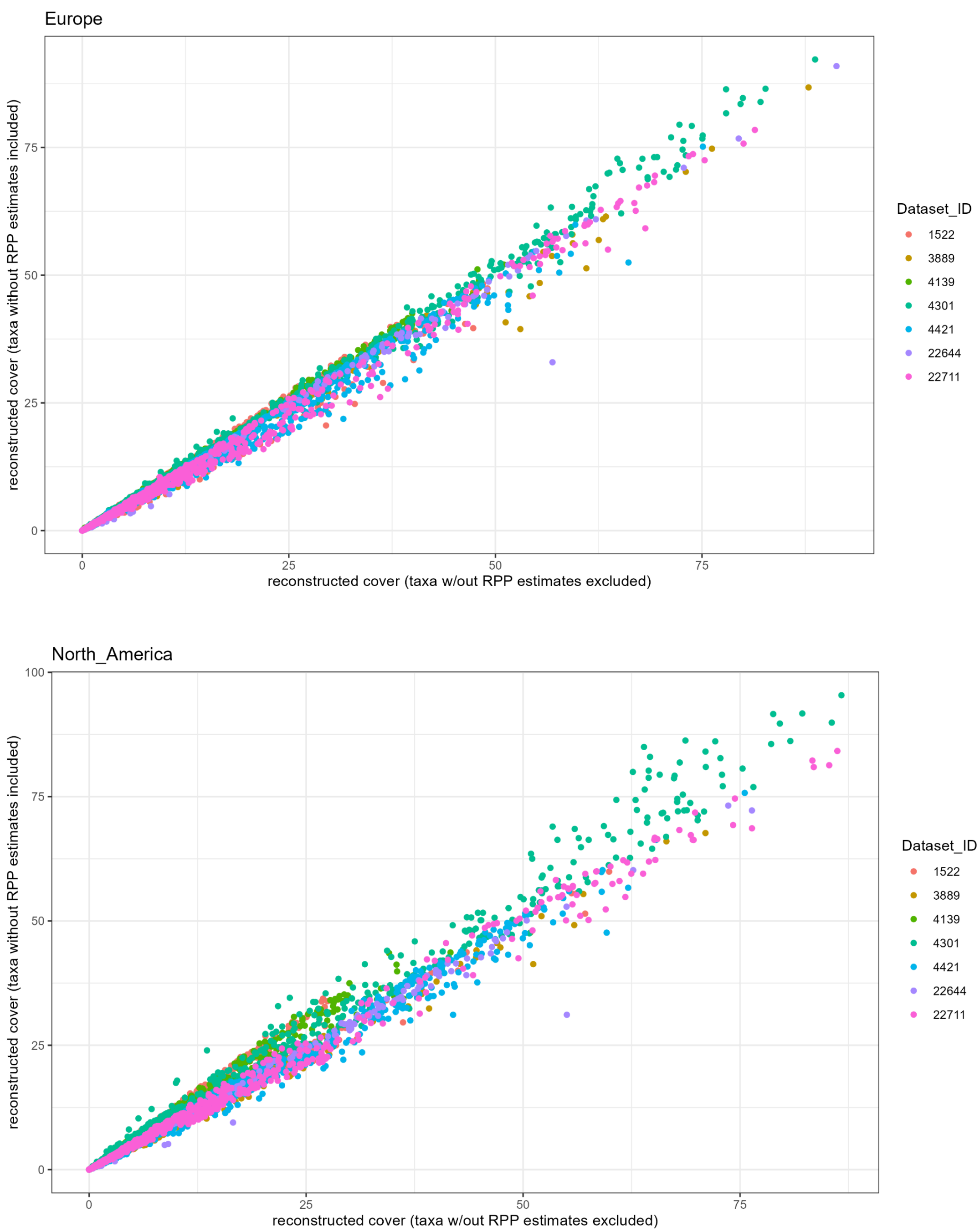


Fig 1: *(newly created)* Comparison of reconstructed cover values for taxa in a reconstruction excluding taxa, for which no RPP estimates are available, and in a reconstruction where all taxa are included and unknown RPP set to 1. **The results are highly correlated, showing that including taxa with unknown RPP does not impact the reconstruction of the taxa for which RPP were already known.**

Tracked changes (new RPP values):

For each taxon, values for RPP (with uncertainties provided as standard deviation) and fall speeds are used. ~~When available, we use continent-specific values in our reconstruction following~~ We made use of the synthesis of Northern Hemisphere RPP and fall speed values by Wieczorek and Herzschuh (2020). Several RPP studies published since this synthesis were added to the compilation (Geng et al., 2022; Li et al., 2022b; Wang et al., 2021; Huang et al., 2021; Zhang et al., 2021a, b; Wan et al., 2020, 2023; Jian . The methods by Wieczorek and Herzschuh (2020) were followed fore study selection and calculation of synthesis values. An overview of original values and synthesized values can be found in Appendix A and B respectively.
When available, we use continent-specific values in our reconstruction. For taxa with no continental values present, we use ~~northern hemispheric~~ Northern Hemispheric values. If no values exist for a taxon, RPP is set to a constant (RPP = 1, σ=0.25) and fall speeds are filled with mean continental fall speeds~~(see Appendix A: Original RPP and fall speed values per continent~~. Continental RPP values are available for the majority of pollen counts in all three continents (see Fig. 3). The fraction of pollen counts for which ~~RPP estimates are available are much higher in the Northern Hemisphere than in the Southern Hemipshere (see Fig. 3).~~ standard RPP values were assumed is highest in North America but still < 10%. For each site, the REVEALS model also requires information on basin type, basin size and original pollen counts, all of which were collected in the LegacyPollen 2.0 dataset (Li et al., 2024b). Apart from taxon- and basin-specific parameters the REVEALS model requires several constant parameters to be set, which can be found in Table 2.

Revised Fig 3:

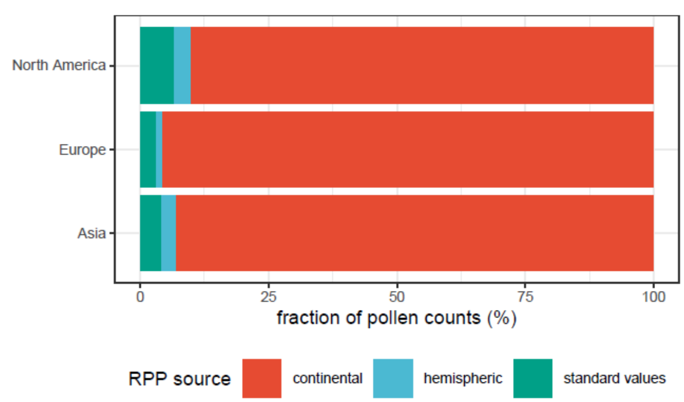


Figure 3. Regional source of RPP values for percentage of pollen counts per continent. A majority of pollen counts is covered by continental RPP values with the highest fraction in Europe. Only a small percentage of pollen counts has only hemispheric RPP values available. No available RPP values lead to the use of a standardized RPP value of 1±0.25.

Original Comment

Oversimplified and incorrect spatial and temporal settings: The inclusion of incorrect basin types in the model without appropriate adjustments is very concerning. Why are marine records included for a model explicitly designed to work for large lakes of closed basins with wind dispersal as the only mechanism for pollen deposition?

The manuscripts states that ‘all sites that were not classified as lakes were run with peatland settings’ = can we consider the ocean a peatland? REVEALS cannot work with marine records and it definitely does not make sense to apply the ‘peatland’ settings for marine records with some random arbitrary basin radius (100m?). Further, using a deep temporal scope (50ka) without any consideration for massive climatic shifts (likely larger than the effect of regional RPPEs values vs regional bioclimate variations) are concerning oversights, making any pre-Holocene glacial REVEALS reconstructions unrealistic with current interglacial PPEs.

Reply

We agree with the unsuitability of non-lake and non-peat records and apologize for their inclusion. **We will remove them from our data set** (see tracked changes below). We realize that many of the peat sites used do not have basin sizes assigned to them. However, peatlands tend to be relatively small and therefore similar in size, with the mean size of peatlands used in Trondman et al. (2016) being lower than 100m and the average peatland size in the data used by Githumbi et al. (2022) being 716 m (with a rather large standard deviation of 1901 m due to few unrealistically large peatlands). These differences of several hundred meters at most do not influence the reconstruction of REVEALS estimates considerably, which is why a standardization of peatland sizes is appropriate here. Please see Figure 2 below for an example peatland reconstruction using different basin diameters.

Trondman, Anna-Kari, Marie-José Gaillard, Shinya Sugita, Leif Björkman, Annica Greisman, Tove Hultberg, Per Lagerås, Matts Lindbladh, und Florence Mazier. „Are Pollen Records from Small Sites Appropriate for REVEALS Model-Based Quantitative Reconstructions of Past Regional Vegetation? An Empirical Test in Southern Sweden". *Vegetation History and Archaeobotany* 25, Nr. 2 (1. März 2016): 131–51. https://doi.org/10.1007/s00334-015-0536-9.

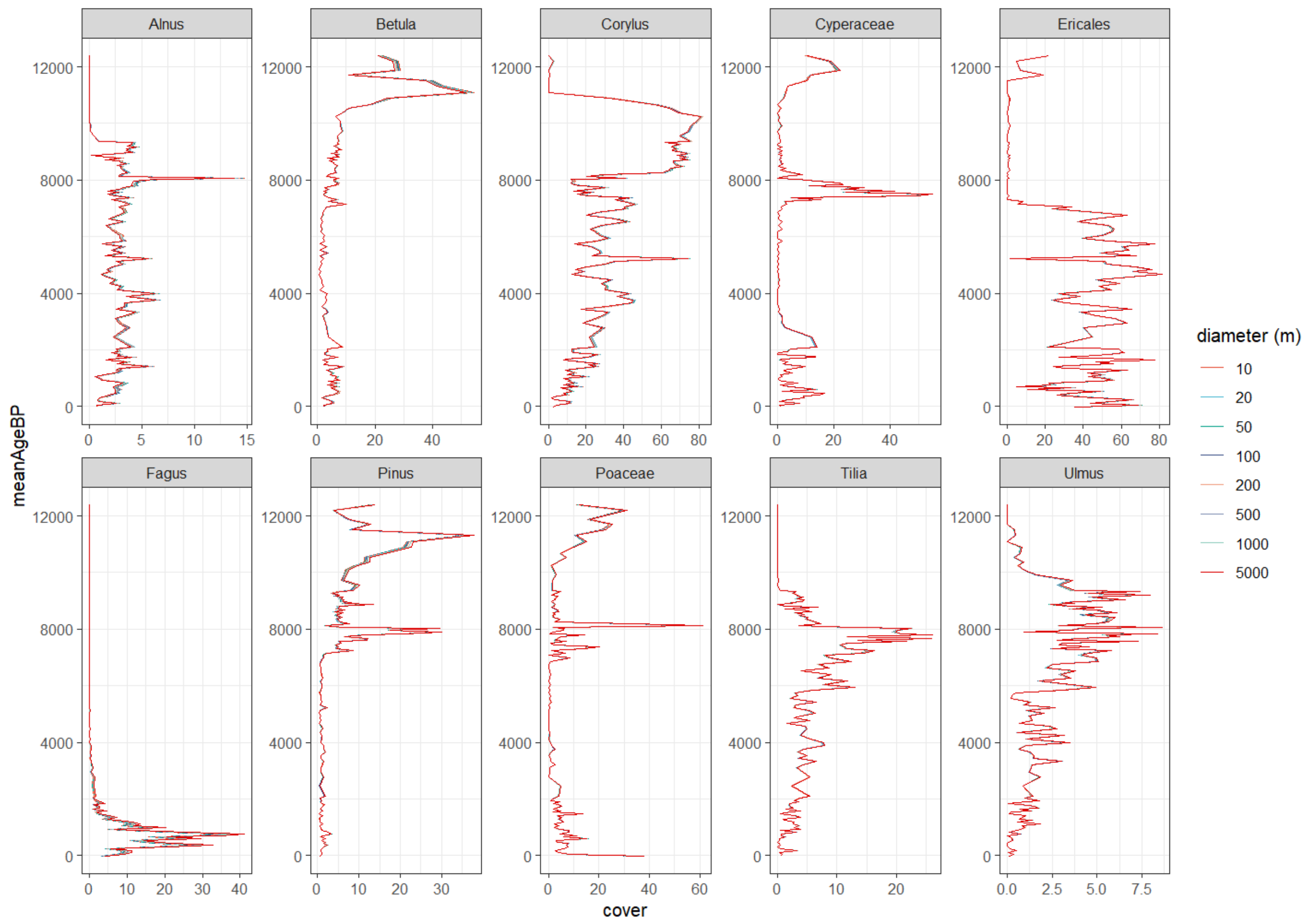


Fig 2: Example peatland site (Agerösd mosse, 13.42774W 55.93448N) with reconstructed vegetation at different set basin sizes (diameter in m). **The basin size has minimal impact on the reconstructed result when using peatlands and can therefore be standardized.**

Tracked changes (exclusion of non-lake and non-peat records):

Sediment and peat cores used for the creation of pollen data are of lacustrine, peat and marine origin. For the REVEALS reconstruction only lake and peat records in the Northern Hemisphere were used ($n = 2732$) Analogous to the preceding LegacyPollen 1.0 dataset (Herzschuh et al., 2022), the data synthesis involved revising age modeling and taxonomic harmonization for consistency of records. Spatial data coverage of records in the reconstruction is ~~densest in North America (1132~~ dense in Europe (1275 records) and ~~Europe (1451) , sparser~~ North America (1016 records) and sparsest in Asia (~~706) and very scattered in South America (191), Africa (164) and Australia and Oceania (84,~~ 441) (see Fig. 1). The records~~primarily span the last 50 ka with temporal coverage being a lot sparser before 20 ka BP~~' sample density decreases with age (see Fig. 2).

Original Comment

Dubious optimization and validation: Optimizing PPEs to match remote sensing data risks validating the model based on its own assumptions rather than providing an unbiased estimation of past vegetation, which REVEALS is designed to do. This circular reasoning undermines the scientific integrity of the model's outputs. While an interesting concept this needs to be validated separately on a much smaller spatially and higher resolution scale before such a widespread application. This cannot really be called a 'validation'.

Reply

We apologize for any confusion that may have arisen here, but **there is no circularity associated with the validation of the REVEALS reconstruction** making use of published syntheses (titled "REVEALS (original RPP)" in our original manuscript). The remotely sensed forest cover is independent of the REVEALS reconstruction and has previously been used to validate large-scale reconstruction by Serge et al. (2023) and Pirzamanbein et al. (2014). We make use of the openness correction to account for predominantly urban structures influencing modern forest cover from remote sensing with large consolidated areas. However, we do this to both the original pollen data and the REVEALS reconstruction. **Our validations show a clear improvement in forest cover reconstruction compared to pure pollen data.**

et al., 2013; Townshend, 2016). An openness correction was applied to sites containing urban areas and paved surfaces within the 80% pollen source areas (PSA) to correct for areas without any pollen sources and thus ~~improve~~ ensure comparability to modern remote sensing forest cover (see Equations 2-4). For this, the percentage of unvegetated land cover classes for the year 2015 in the ESA CCI land cover data set was used (ESA, 2017, see Table 3). Areas covered by water or ice are already considered as missing values in the remote sensing forest cover data set and do not need to be corrected for. Forest cover was validated ~~site-wise~~ for each grid cell and mean absolute error (MAE) and correlation coefficients calculated for each continent. No openness correction was applied to the reconstruction values in the final dataset. Validation for a 2x2° grid is included in the results section. Further validations using 1°,5°, and 10° resolution are included in the supplementary material (S3: Validation results for different spatial resolutions).

We have decided to **omit the optimization** from this manuscript.

Original comment

The reconstructed forest cover for the past 500 years was compared to modern remote sensed cover. Why not a smaller and more recent age bin was considered? In the past 500 years many areas of the world have been colonised by Europeans and have experienced major shifts in vegetation structure, as management transferred from Indigenous to colonial regimes (e.g. the Americas and Australia). This means that forest cover over the whole 500 years bin is not comparable to modern remote sensing data. This highlights a Eurocentric view of the global vegetation patterns.

An example of validation of RPPEs using modern vegetation data (with surveys) has been done in the following papers:

Mariani, M., Connor, S. E., Fletcher, M. S., Theuerkauf, M., Kuneš, P., Jacobsen, G., ... & Zawadzki, A. (2017). How old is the Tasmanian cultural landscape? A test of landscape openness using quantitative land‐cover reconstructions. Journal of Biogeography, 44(10), 2410-2420.

Mariani, M., Connor, S. E., Theuerkauf, M., Herbert, A., Kuneš, P., Bowman, D., ... & Briles, C. (2022). Disruption of cultural burning promotes shrub encroachment and unprecedented wildfires. Frontiers in Ecology and the Environment, 20(5), 292-300.

Reply

Our choice of 500 year age bins was founded in the aim to include as many records as possible, since not all have samples as young as 100 years BP. We have, however, **tested a smaller age bin for the REVEALS reconstruction** using published synthesis values and found similar validation results. In our revised manuscript we include a 100 year age bin with gridded data.

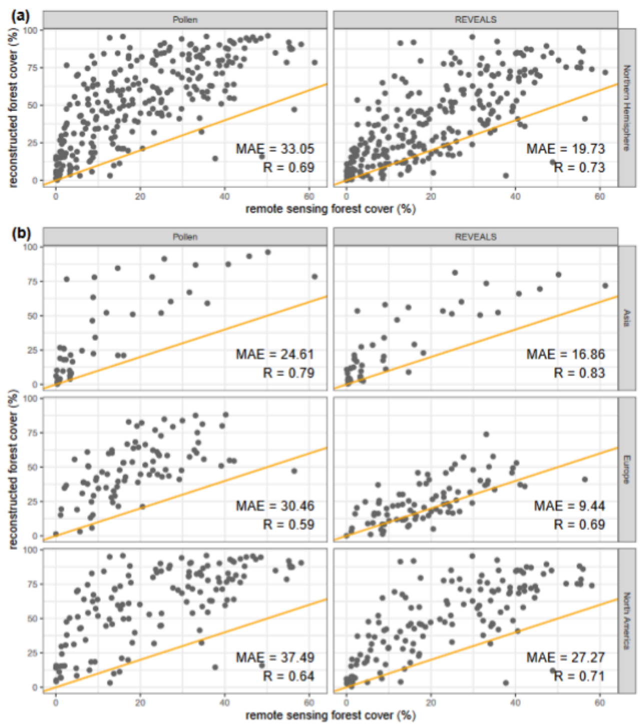


Figure 9. Remote sensing forest cover (LANDSAT) and modern reconstructed forest cover from Pollen and REVEALS (< 100 years BP) in 2x2° grid cells with mean absolute errors (MAE) and correlation coefficient (R) per group. Reconstructed forest cover from the original pollen data tends to overestimate observed (remote sensing) forest cover. Improvements with the REVEALS reconstruction are especially high in Europe. Validations with different grid cell sizes are available in the supplement (S3: Validation results for different spatial resolutions).

Tracked changes (smaller age bin):

of the dataset on Zenodo (https://zenodo.org/doi/10.5281/zenodo.12800290). For validation, the reconstructed forest cover of the past ~~500 years was~~ 100 years was rasterized and compared to modern remote sensing forest cover. Only valid grid cells as defined above were used for validation. Average tree canopy cover ~~within pollen source areas of all sites~~ for all grid cells was

Reply to Williams et al.

Laura Schild and Ulrike Herzschuh

Dear John Williams and colleagues,

We thank you for your comments on our manuscript and appreciate your special attention towards open science and open data issues.
We apologize for the omission of a reference to Neotoma connected to the LegacyPollen dataset and will of course rectify this oversight. We add citations in the description of LegacyPollen2.0 and expand our acknowledgements. A table listing all included Neotoma records and their DOIs is appended as well. We especially thank you for the helpful inclusion of the *doi()* function in the neotoma2 R package and the example code on github.
Please see our revised passages below.

An updated version of the dataset can now be found here: https://doi.org/10.5281/zenodo.12800159. The dataset on PANGAEA will be updated as soon as possible.

Best regards
Laura Schild and Ulrike Herzschuh

Revised text at line 76:

The pollen data synthesis LegacyPollen2.0 (Li et al., 2024b) includes 3728 temporally resolved records (time-series) distributed globally. Data were collected from individual publications and the Neotoma Paleoecology Database which includes data from the European Pollen Database, the QUAVIDA data base for Australasia, the Latin American Pollen Database, the African Pollen Database and the North American Pollen database (Flantua et al., 2015; Fyfe et al., 2009; Giesecke et al., 2014; Lézine et al., 2021; Rowe et al., 2007; Whitmore et al., 2005; Williams et al., 2018). An overview of Neotoma records included in LegacyPollen 2.0 can be found in Table S2.

Flantua, S.G.A., Hooghiemstra, H., Grimm, E.C., Behling, H., Bush, M.B., González-Arango, C., Gosling, W.D., Ledru, M.-P., Lozano-García, S., Maldonado, A., Prieto, A.R., Rull, V., Van Boxel, J.H., 2015. Updated site compilation of the Latin American Pollen Database. Rev. Palaeobot. Palynol. 223, 104–115. https://doi.org/10.1016/j.revpalbo.2015.09.008

Fyfe, R.M., de Beaulieu, J.-L., Binney, H., Bradshaw, R.H.W., Brewer, S., Le Flao, A., Finsinger, W., Gaillard, M.-J., Giesecke, T., Gil-Romera, G., Grimm, E.C., Huntley, B., Kunes, P., Kühl, N., Leydet, M., Lotter, A.F., Tarasov, P.E., Tonkov, S., 2009. The European Pollen Database: past efforts and current activities. Veg. Hist. Archaeobotany 18, 417–424. https://doi.org/10.1007/s00334-009-0215-9

Giesecke, T., Davis, B., Brewer, S., Finsinger, W., Wolters, S., Blaauw, M., de Beaulieu, J.-L., Binney, H., Fyfe, R.M., Gaillard, M.-J., Gil-Romera, G., van der Knaap, W.O., Kuneš, P., Kühl, N., van Leeuwen, J.F.N., Leydet, M., Lotter, A.F., Ortu, E., Semmler, M., Bradshaw, R.H.W., 2014. Towards mapping the late Quaternary vegetation change of Europe. Veg. Hist. Archaeobotany 23, 75–86. https://doi.org/10.1007/s00334-012-0390-y

Lézine, A.-M., Ivory, S.J., Gosling, W.D., Scott, L., 2021. The African Pollen Database (APD) and tracing environmental change: State of the Art, in: Quaternary Vegetation Dynamics. CRC Press.

Rowe, C., Fraser, R., Harrison, S., Dodson, J., 2007. The QUAVIDA synergy: quaternary fire, vegetation and climate change in Australasia. Quat. Int. 167–168, 355–355. https://doi.org/10.1016/j.quaint.2007.04.001

Whitmore, J., Gajewski, K., Sawada, M., Williams, J.W., Shuman, B., Bartlein, P.J., Minckley, T., Viau, A.E., Webb, T., Shafer, S., Anderson, P., Brubaker, L., 2005. Modern pollen data from North America and Greenland for multi-scale paleoenvironmental applications. Quat. Sci. Rev. 24, 1828–1848. https://doi.org/10.1016/j.quascirev.2005.03.005

Williams, J.W., Grimm, E.C., Blois, J.L., Charles, D.F., Davis, E.B., Goring, S.J., Graham, R.W., Smith, A.J., Anderson, M., Arroyo-Cabrales, J., Ashworth, A.C., Betancourt, J.L., Bills, B.W., Booth, R.K., Buckland, P.I., Curry, B.B., Giesecke, T., Jackson, S.T., Latorre, C., Nichols, J., Purdum, T., Roth, R.E., Stryker, M., Takahara, H., 2018. The Neotoma Paleoecology Database, a multiproxy, international, community-curated data resource. Quat. Res. 89, 156–177. https://doi.org/10.1017/qua.2017.105

Tracked changes:

85 The pollen data synthesis LegacyPollen2.0 (Li et al., 2024b) includes ~~3728~~ 3680 temporally resolved records (time-series) distributed globally. Data were collected from individual publications and the Neotoma Paleoecology Database which includes data from the European Pollen Database, the QUAVIDA data base for Australasia, the Latin American Pollen Database, the

3

African Pollen Database and the North American Pollen database (Flantua et al., 2015; Fyfe et al., 2009b; Giesecke et al., 2014; Lézine et a
. An overview of Neotoma records included in LegacyPollen 2.0 and this reconstruction can be found in S1.

Revised acknowledgements:

We thank Thomas Böhmer for support with dataset curation and harmonization. The project was supported by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie through the German Climate Modeling Initiative PALMOD (grant no. 01LP1510C to UH), the European Union (ERC, GlacialLegacy grant no. 772852 to UH), and the China Scholarship Council (grant no. 201908130165 to CL). Data were partly obtained from the Neotoma Paleoecology Database (http://www.neotomadb.org) and its constituent databases (European Pollen Database, QUAVIDA data base for Australasia, Latin American Pollen Database, African Pollen Database and the North American Pollen database). The work of data contributors, data stewards, and the Neotoma community is gratefully acknowledged.

Tracked changes:

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Reply to Giesecke

Laura Schild and Ulrike Herzschuh

General reply

Dear Thomas Giesecke,

Thank you for your careful review of our manuscript. While you welcome our effort to conduct a global pollen-based vegetation reconstruction you raise some concerns. We are confident that these were resolved and will ultimately underline the validity and usability of our reconstruction.

We addressed connectivity of published data to original Neotoma records by adding citations and DOIs and we are keen to add revised chronologies and taxonomic harmonizations to existing Neotoma records. We acknowledge that manuscripts such as ours would not be possible without the considerable effort toward the Neotoma Paleoecological Database and include this in our acknowledgments. Added clarification of how we envision the data set to be used is indeed needed and we will expand on this in the manuscript and provide an additional R script for dynamic rasterization. We agree with the high uncertainty connected to the reconstructions in the Southern Hemisphere and have decided to omit these reconstructions from our data set. Additionally, we changed the name of our calculated source area and omitted the optimization from our manuscript.

We have been able to make all of these adjustments and address your comments. An updated version of the dataset can now be found here: https://doi.org/10.5281/zenodo.12800159. The dataset on PANGAEA will be updated as soon as possible.

Best regards
Laura Schild and Ulrike Herzschuh

Detailed replies

General comments

Original comment

Before looking more closely at the manuscript I like to extend on the comment by Williams et al. of developing the underlying Legacy Pollen Dataset. Branching of a large dataset from Neotoma into the Legacy Pollen Dataset with vetting and adding metadata, results in the additional work not being linked back to Neotoma. In the spirit of open science it would be better practice to contribute to Neotoma by uploading additional datasets and correcting or adding metadata. Look up tables for taxonomic harmonization or new chronologies could then be linked to the data in Neotoma. Republishing Neotoma derived data makes scientists using that data ignore the original data source. This also means that Neotoma loses recognition for the work of the data stewards and support for acquiring funding to maintain and develop the database.

Reply

We have added citations to Neotoma and constituent data bases and revised our acknowledgements. Additionally we provide a list of Neotoma records included in the LegacyPollen2.0 data set and their DOIs (see S1 in the revised Supplementary Material). We are also open to expanding Neotoma's records by adding revised chronologies and taxonomic harmonizations, but would require assistance from the Neotoma team to train one of our team members.

See tracked changes for revisions below:

The pollen data synthesis LegacyPollen2.0 (Li et al., 2024b) includes ~~3728~~ 3680 temporally resolved records (time-series) distributed globally. Data were collected from individual publications and the Neotoma Paleoecology Database which includes data from the European Pollen Database, the QUAVIDA data base for Australasia, the Latin American Pollen Database, the

3

African Pollen Database and the North American Pollen database (Flantua et al., 2015; Fyfe et al., 2009b; Giesecke et al., 2014; Lézine et
. An overview of Neotoma records included in LegacyPollen 2.0 and this reconstruction can be found in S1.

Acknowledgements. We thank Thomas Böhmer for support with dataset curation and harmonization. The project was supported by the Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie through the German Climate Modeling Initiative PALMOD (grant no. 01LP1510C to UH), the European Union (ERC, GlacialLegacy grant no. 772852 to UH), and the China Scholarship Council (grant no. 201908130165 to CL). Data were partly obtained from the Neotoma Paleoecology Database (http://www.neotomadb.org) and its constituent databases (European Pollen Database, QUAVIDA data base for Australasia, Latin American Pollen Database, African Pollen Database and the North American Pollen database). The work of data contributors, data stewards, and the Neotoma community is gratefully acknowledged.

Original comment

Regarding the here presented manuscript by Shild et al. I see several problems and directions of how to address them. I generally agree with the comments by Marie-Jose Gaillard and Michela Mariani regarding technical shortcomings, definition of the source area of pollen (NOT "relevant source area") and the recommendation to restrict a REVEALS application to the northern hemisphere. If attempting to include the southern hemisphere the authors should reduce the unrealistic assumptions as some more information could be gained. Fall speeds could be estimated using the size of pollen grains and initial guesses of RPPEs could have been made by inviting experts working on the different continents and including recent publications on RPPEs.

Reply

We will adjust our terminology to refer to the parameter calculated by us as the "80% pollen source area." This term describes the area from which the median relative influx of all taxa reaches 80%. This calculation uses the lake deposition model described in Theuerkauf et al.'s REVEALSinR. Initially, pollen deposition is calculated per taxon from zmax, representing the maximum depth. While this assumes that each taxon deposits all its pollen, it simplifies the reality where pollen can originate from farther distances, and fluvial inputs into lakes are inevitable. Nonetheless, this assumption aligns with REVEALS. Through a stepwise process, the radius around the basin is incrementally expanded, and the relative influx of deposited pollen for each taxon is calculated relative to the total influx at zmax. We define our 80% pollen source radius as the radius at which the median relative influx of all taxa reaches 80%. This calculation primarily serves to provide a sense of the source area's scale to users unfamiliar with pollen data. It underscores the regional nature of lacustrine pollen data and illustrates how lake size influences this source area. We included this detailed explanation in the manuscript.

Tracked changes:

We calculate the radius of ~~relevant~~ the 80% pollen source area by finding the radius in which the median influx of all taxa is 80% of the total influx (as defined by the total influx in the maximum extent of regional vegetation chosen). This is calculated by employing the lake deposition model in REVEALSinR (Theuerkauf et al., 2016). Starting from z_{max} the deposited pollen is calculated per taxon. This is assumed to be the total pollen each taxon deposits. In a step-wise process the radius around the basin is increased and the deposited pollen relative to the total influx at z_{max} is calculated for each taxon. We define our 80%

pollen source radius as the radius where the median of the relative influx of all taxa reaches 80%. The primary objective of this calculation is to provide a clear understanding of the scale of the source area for users unfamiliar with pollen data. It highlights the regional nature of lacustrine pollen data and demonstrates the influence of lake size on this source area.

We also reduced computational effort in REVEALSinR by implementing a maximum number of steps in the lake model used to model mixing in the basin. The number of steps was set to 500 unless n falls below that maximum value for $n = basin\,radius/10$ for basins with a radius of at least 1000 m and $n = basin\,radius/2$ for basins with a radius smaller than 1000 m.

We agree that uncertainties in Southern Hemispheric reconstructions are considerable due to limited regional RPP values and have decided to exclude them from our dataset.

example tracked changes:

LegacyVegetation 1.0: ~~Global~~ Northern Hemisphere reconstruction of vegetation composition and forest cover from pollen archives of the last ~~50~~ 14 ka

We thank you for the suggestion to calculate missing fall speed values. While we agree that this would be an apt way to deal with missing fallspeeds, we decided against this due to the large number of taxa with missing fall speed values. As we were unable to find a way of programmatically accessing pollen morphological properties, this would have entailed considerable additional time spent. The proportion of pollen counts of taxa without RPP or fall speed information is very low and close to negligible especially when reconstructing forest cover (see revised Figure 3 below).

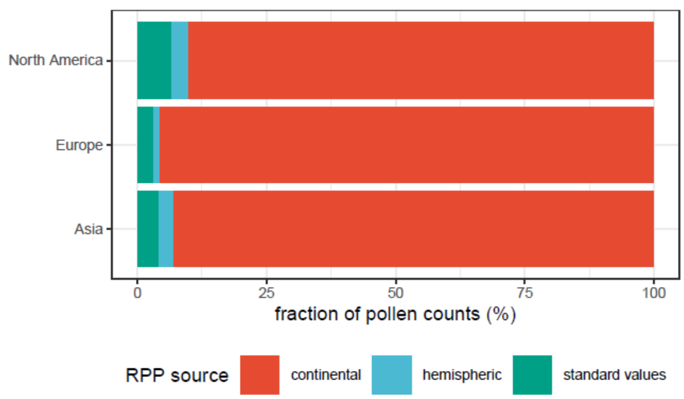

Figure 3. Regional source of RPP values for percentage of pollen counts per continent. A majority of pollen counts is covered by continental RPP values with the highest fraction in Europe. Only a small percentage of pollen counts has only hemispheric RPP values available. No available RPP values lead to the use of a standardized RPP value of 1 ± 0.25.

Original comment

My concerns are particularly related to the aim of the authors to publish the data resulting from the analysis. REVEALS results not only provide information on past woodland cover, but also on bias reduced abundance of the major plant genera or families. Given the way the authors used RPPEs and fall speeds for the southern hemisphere such estimates are unlikely to improve the bias in pollen percentage data. However, they may invite researchers not understanding the limitations to misuse such data. This is particularly the case where the authors adjusted RPPEs to obtain an overall better fit with modern tree cover globally. Here the authors admit that the adjusted RPPEs are ecologically meaningless, and I therefore urge the authors not to publish the resulting vegetation reconstructions as they will also be meaningless. If the authors are convinced that the resulting tree cover is meaningful, they could restrict the data publication to that.

Reply

We consider the optimized RPP and the related reconstruction not as the most relevant outcome from this manuscript but rather an addition to the reconstruction using a synthesis of published RPP. However, due to the uncertainties associated with optimization results, we have decided to omit the reconstruction using optimized values entirely. In the reconstruction using synthesized RPP values, we highlight which taxa had continental or hemispheric RPP available and which used standardized RPP values in a separate file outlining RPP sources.

As stated above, we removed the Southern Hemisphere from the data set as we agree with the notable uncertainties.

See the updated dataset here: https://doi.org/10.5281/zenodo.12793806

Original comment

If a data publication is pursued, the authors should explain in which way they envision the data to be used. Is the attempt to estimate the source area of 80% of pollen to then relate the information on tree cover to that area, and if so how shall that be implemented? Also, how will overlapping areas be treated? Even on the northern hemisphere the gained information is not continues and I therefore wonder how the results will be used in climate modelling. Moreover, I did not find anything in the manuscript of how the obtained data informs on the position of northern or southern forest or tree limits, that are difficult to estimate from percentage pollen data.

Reply

We mainly include the calculation of the 80% source area to give an idea of the scale of source area to users not familiar with pollen data. This emphasizes the regional scale of pollen data from large basins, when reconstructions are used at site-level.
Site-wise reconstructions using large lakes are valid alone and their information can be used in gridded versions of this data set as well. We recognize that reconstructions from small lakes and peatland sites should not be used alone as site-wise reconstructions. Our aim is for the data set to be used flexibly, meaning that users can set their own temporal and spatial resolution for rasterization.This is why we did not prepare a set rasterization. To highlight this use case we provide a script to rasterize the dataset dynamically and classify grid cell reliability by record availability (https://zenodo.org/records/12800291). Additionally, expand on this in our data usability section and clarify how we intend the data set to be used reliably. Small sites and peatland also received an additional flag in the data set as “unfit to be used on site-level” .
Tracked changes (how to use the dataset):

To ensure the correct utilization of the dataset and to obtain reliable analysis results, several key considerations should be followed. Firstly, rasterization mitigates individual errors by temporal and spatial averaging. This process is particularly useful in reducing the variance that might arise from individual measurements, providing a more reliable representation of the underlying signal.The reliability of reconstructions varies among different taxa due to the quality of RPP values, and this is explicitly documented in a supplementary file that outlines the sources of RPP values (see Section Code and Data availability). Reconstructions of taxa with continental RPP values are the most reliable, followed by those based on hemispheric data, with standardized RPP values being the least reliable. This hierarchy should be taken into account when interpreting the results. Higher certainty is associated with forest cover reconstruction, as it is based on aggregation among taxa. Reconstructions of temporal forest cover trends are reliable, as evidenced by high correlation coefficients, despite a tendency for absolute values to be overestimated, particularly in North America. For individual time series, the reliability of data varies with the size of the lakes from which samples were taken. Only data derived from large lakes ($\geq$ 50 ha) are reliable for site-wise analyses. This distinction is clearly indicated with validity flags in the dataset. Reconstructions from smaller basins should not be used alone.

Even though using REVEALS improves the reconstruction of vegetation compared to pollen data, we highlight the difficulty of detecting tree lines with compositional data in our manuscript.

Tracked changes (usefulness of dataset):

The REVEALS forest cover reconstructions presented here offer valuable insight into past vegetation changes. The global dataset provides an opportunity to explore past vegetation dynamics, gaining a deeper understanding of responses, trajectories, and potential feedback mechanisms. Given the increasing discussions surrounding the possibility of tipping events in vegetation cover (Armstrong McKay et al., 2022; Lenton and Williams, 2013), this could be of considerable use. While a reconstruction of exact tree lines is not trivial with pollen data, the application of REVEALS and subsequent biomization improve treeline reconstructions as shown by Binney et al. (2011). Additionally, this dataset can address unanswered questions about Holocene vegetation dynamics, including the deglacial forest conundrum ~~(Dallmeyer et al., 2022)~~(Dallmeyer et al., 2022; Strandberg et al., 2022) . It also serves as a valuable tool for validating models with coupled climate and vegetation, ~~relying~~ which rely on extensive time series and vegetation data for accurate predictions ~~(Dallmeyer et al., 2023).~~ (Dallmeyer et al., 2023; Dawson et al., 2024). Comparing modeled vegetation to reconstructed vegetation could help uncover missing dynamics in coupled climate-vegetation models. New insights gained from these applications could enhance our ability to predict future changes.

Original comment

Retaining all the current aspects of the manuscript I would recommend to revise the manuscript and publish it in a disciplinary journal to discuss aspects of this analysis which yield new insights. If continuing with the modern comparison I would suggest to use available surface sample data or core tops marked as modern. Using top samples as old as 500 years in the comparison with modern woodland cover introduces a huge bias.

Reply

Thank you for your suggestion. We do believe that it is more useful to validate with the data set instead of using independent surface samples. We agree that 500 years constitute a large age bin, we decided to use this in order to include as many records as possible. We revised this to include a validation using a smaller age bin in the manuscript. Below you find revised validations using gridded data from the past 100 years.

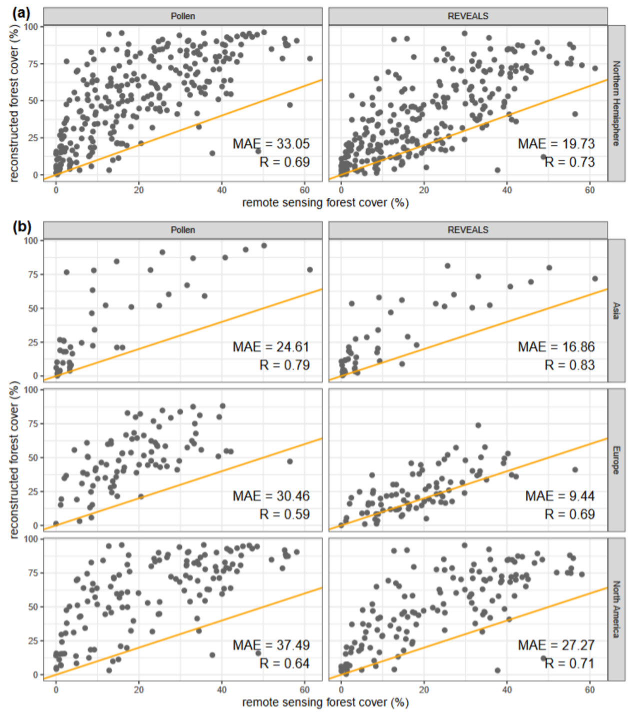

Figure 9. Remote sensing forest cover (LANDSAT) and modern reconstructed forest cover from Pollen and REVEALS (< 100 years BP) in 2x2° grid cells with mean absolute errors (MAE) and correlation coefficient (R) per group. Reconstructed forest cover from the original pollen data tends to overestimate observed (remote sensing) forest cover. Improvements with the REVEALS reconstruction are especially high in Europe. Validations with different grid cell sizes are available in the supplement (S3: Validation results for different spatial resolutions).

Original comment

In summary, I don't recommend the publication of the data from the current analysis and suggest restricting the analysis to the northern hemisphere with a publication of the findings in a topical journal.

Reply

The reviewers and commenters unanimously express interest in our dataset and acknowledge its potential usefulness. They also recognize the inherent challenges and uncertainties. A data publication allows for the thorough exploration and discussion of these limitations. This accurate documentation is especially necessary in the context of a PhD thesis. Publishing in a topical journal would be counterproductive as it might not allow the space or focus needed for comprehensive discussion of the data. The data have also significantly been altered compared to the original pollen data which justifies the new dataset.

Detailed comments

17: The uncertainties introduced here will not make the results invaluable for the investigation of past vegetation dynamics.

We rephrase this statement. But we do believe that usefulness is a given as we exclude the Southern Hemisphere and show a clear improvement of forest cover reconstructions compared to Pollen data in our validations.

This improved quantitative reconstruction of vegetation cover is ~~invaluable~~ beneficial for the investigation of past vegetation dynamics and modern model validation. By collecting more RPP estimates ~~for taxa in the Southern Hemisphere~~ especially in

28: The study is on vegetation cover not climate.

We clarified that we are not providing past climate data.

sitions ~~akin~~ comparable to those anticipated in the future (Dearing et al., 2012). Given the relatively brief duration of available instrumental climate and vegetation data, there is a clear need for long-term ~~environmental~~ vegetation records derived from palaeoecological archives that cover broader climatic gradients than modern datasets (Dearing et al., 2010; Dallmeyer et al., 2023).

34: Fyfe et al. 2009 is not in the reference list.

We added Fyfe et al. 2009 to the reference list and cite it at line 76 (revised).

The pollen data synthesis LegacyPollen2.0 (Li et al., 2024b) includes ~~3728~~ 3680 temporally resolved records (time-series) distributed globally. Data were collected from individual publications and the Neotoma Paleoecology Database which includes data from the European Pollen Database, the QUAVIDA data base for Australasia, the Latin American Pollen Database, the

3

African Pollen Database and the North American Pollen database (Flantua et al., 2015; Fyfe et al., 2009b; Giesecke et al., 2014; Lézine et a
. An overview of Neotoma records included in LegacyPollen 2.0 and this reconstruction can be found in S1.

36-38: This is not allowing for a broader but a more restricted application of pollen data as some aspects may not be possible to investigate with a reduced taxonomic depth. Please reword.

We reworded this section to highlight the improved comparability as a trade-off with taxonomic depth.

into the global database Neotoma (Williams et al., 2018). To allow for a broader application of pollen data, LegacyPollen 2.0 (Li et al., 2024b) offers a global, harmonized pollen dataset that underwent taxonomic standardization, metadata verification and consistent age modeling (Li et al., 2022a, 2021; Herzschuh et al., 2022). This taxonomic harmonization trades off higher taxonomic resolution of some datasets for equivalence, resulting in overall comparability useful for analyses at large spatial scales. Despite advances in harmonization, the use of pollen data remains limited due to the fact that pollen

49: "relevant" pollen source area is well defined, but this is not meant here.

Sugita (2007) tends to refer to the "region" or the area where "most of the pollen originates" for this model area. We have decided to use "region" here.

gional Estimates of Vegetation Abundance from Large Sites" (REVEALS) . By accounting for taxon-specific RPP and fall speed values, as well as basin-specific parameters such as basin size and type, REVEALS models quantitative vegetation cover in ~~relevant pollen source areas~~ the region surrounding a basin from pollen compositions. The model has been applied

50: Nielsen and Odgaard 2010 are a good example of applying the full Landscape Reconstruction Algorithm with a focus on LOVE not so much REVEALS.

We removed Nielsen and Odgaard from the citations here.

cover in ~~relevant pollen source areas~~ the region surrounding a basin from pollen compositions. The model has been applied

2

in several regional-scale studies ~~(Nielsen et al., 2012; Mazier et al., 2015; Hellman et al., 2008; Nielsen and Odgaard, 2010)~~ (Nielsen et al., 2012; Mazier et al., 2015; Hellman et al., 2008) and multiple validations have demonstrated its ~~accuracy~~ ability in approximating actual vegetation (Sugita et al., 2010; Hellman et al., 2008; Soepboer et al., 2010; Mazier et al., 2012), even

51: "ability" rather than "accuracy"

We changed "ability" to "accuracy" (see tracked changes for comment above).

105: No information is given where the RPPEs are coming from for the southern hemisphere if they are not set to 1 and not used from the northern Hemisphere. Please provide references.

We have decided to omit reconstructions for the Southern Hemisphere from the data set.

106: Fall speeds can be easily estimated based on the size of pollen grains.

Thank you for this suggestion. As outlined above we have decided against this.

111: Not "relevant source area"

We changed the name of this value to “80% pollen source area”.

2.2.2 Modifications in REVEALSinR

We calculate the radius of ~~relevant~~ the 80% pollen source area by finding the radius in which the median influx of all taxa is 80% of the total influx (as defined by the total influx in the maximum extent of regional vegetation chosen). This is calculated

118: How was that latitudinal limit used or derived for the past?

It is constant in time.

120: In most situations the forest cover has changed dramatically over the last 500 years. Why did you not use surface sample datasets for this exercise or sites with the top sample marked as modern?

We reduced the size of the age bin for validation to the past 100 years. As outlined above, we prefer a validation with data from this dataset rather than a separate surface sample dataset.

of the dataset on Zenodo (https://zenodo.org/doi/10.5281/zenodo.12800290). For validation, the reconstructed forest cover of the past ~~500 years was~~ 100 years was rasterized and compared to modern remote sensing forest cover. Only valid grid cells as defined above were used for validation. Average tree canopy cover ~~within pollen source areas of all sites~~ for all grid cells was

168: Chenopodiaceae are an old classification and now included in Amaranthaceae. Why do they have such different RPPEs in Europe?

Chenopodiaceae are included in Amaranthaceae in our input data. They have the same RPP in Europe. The next RPP in this sentence refered to Australia and Oceania (now void as we omit the Southern Hemisphere).

189: Particularly in the southern hemisphere one would expect that the adjustments lead to improvements. It would be interesting to explore the reasons why that is not the case e.g. the low pollen productivity of many tropical trees. I cannot see that low data availability is a reason here.

We decided to exclude reconstructions from the Southern Hemisphere in our data set.

195: Starting with initial values different from 1 may also be a way to explore this further.

We have omitted the optimization of RPP values.

201: It would be interesting to look at these trends for different continents. If a first approximation of forest cover could be made by adjusting arboreal pollen percentages on a continental scale that could be used by modelers as a first order estimate. Again such comparisons should better be done using the modern analogue approach.

We now also supplied this trend on a continental scale. That this could provide a rough estimate of potential error and its direction is true and could indeed be useful for modelers. We agree that the modern analogue technique is also a valid reconstruction method for past vegetation. However, REVEALS has been used for several large-scale and continental scale reconstructions in the past, which is why we think it is valid as well (see for example Githumbi et al. 2021, Dawson et al. 2024, Serge et al. 2023).

Dawson, Andria, John W. Williams, Marie-José Gaillard, Simon J. Goring, Behnaz Pirzamanbein, Johan Lindstrom, R. Scott Anderson, u. a. „Holocene Land Cover Change in North America: Continental Trends, Regional Drivers, and Implications for Vegetation-Atmosphere Feedbacks". *Climate of the Past Discussions*, 20. Februar 2024, 1–52. https://doi.org/10.5194/cp-2024-6.

Githumbi, Esther, Ralph Fyfe, Marie-Jose Gaillard, Anna-Kari Trondman, Florence Mazier, Anne-Birgitte Nielsen, Anneli Poska, u. a. „European Pollen-Based REVEALS Land-Cover Reconstructions for the Holocene: Methodology, Mapping and Potentials". *Earth System Science Data* 14, Nr. 4 (8. April 2022): 1581–1619. https://doi.org/10.5194/essd-14-1581-2022.

Serge, M. A., F. Mazier, R. Fyfe, M.-J. Gaillard, T. Klein, A. Lagnoux, D. Galop, u. a. „Testing the Effect of Relative Pollen Productivity on the REVEALS Model: A Validated Reconstruction of Europe-Wide Holocene Vegetation". *Land* 12, Nr. 5 (Mai 2023): 986. https://doi.org/10.3390/land12050986.

Revised figure:

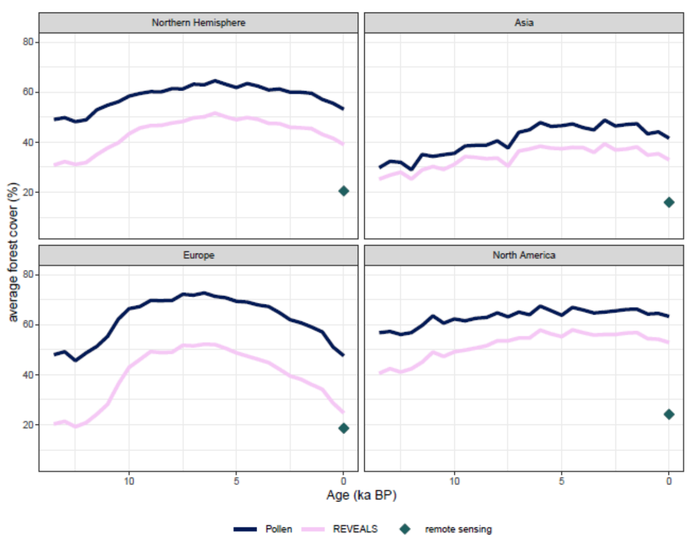

Figure 7. Northern Hemisphere and continental average forest cover from 2x2° grid cell means for raw pollen data and the REVEALS reconstruction (Northern Hemisphere and continental averages from different grid cell resolutions are available in S2: Reconstruction results for different spatial resolutions). Remotely sensed global average forest clover for the grid cells with valid pollen coverage is indicated with the diamond. Temporal trends are the same, but absolute forest cover is reduced in the REVEALS reconstructions compared to the original pollen data. Both reconstructions still overestimate forest cover.

289-296: I strongly disagree with these statements. Particularly regarding the northern and southern tree limits the manuscript is not demonstrating how their detection has improved.

We explain these statements. However, the validations show a clear improvement of forest cover reconstruction compared to pollen data which, at the very least, now constitutes a **better** reconstruction product. Due to the potentially high temporal and spatial variability of pollen data we cannot (and may not ever) be able to reconstruct true past vegetation (something that a modern analogue is also not able to do). Still we see that we reconstruct absolute modern vegetation better than before.

The REVEALS forest cover reconstructions presented here offer valuable insight into past vegetation changes. The global dataset provides an opportunity to explore past vegetation dynamics, gaining a deeper understanding of responses, trajectories, and potential feedback mechanisms. Given the increasing discussions surrounding the possibility of tipping events in vegetation cover (Armstrong McKay et al., 2022; Lenton and Williams, 2013), this could be of considerable use. While a reconstruction of exact tree lines is not trivial with pollen data, the application of REVEALS and subsequent biomization improve treeline reconstructions as shown by Binney et al. (2011). Additionally, this dataset can address unanswered questions about Holocene vegetation dynamics, including the deglacial forest conundrum ~~(Dallmeyer et al., 2022)~~(Dallmeyer et al., 2022; Strandberg et al., 2022) . It also serves as a valuable tool for validating models with coupled climate and vegetation, ~~relying~~ which rely on extensive time series and vegetation data for accurate predictions ~~(Dallmeyer et al., 2023).~~ (Dallmeyer et al., 2023; Dawson et al., 2024). Comparing modeled vegetation to reconstructed vegetation could help uncover missing dynamics in coupled climate-vegetation models. New insights gained from these applications could enhance our ability to predict future changes.

Data: I looked at the resulting data for a few sites in northern Patagonia where I am familiar with the vegetation. First of all I could not find where the RPPE for Nothofagus comes from. For a site in the steppe (Lago Mosquito) with Austrocedrus on its western shore, REVEALS estimated Holocene values around 60 % forest cover, which is too high. The adjusted run did indeed lower the forest cover to between 40 and 20 %. However, this reconstruction returned the lowest forest cover for the time that Austrocedrus woodlands were present on its western shore and tree cover was highest. This may be due to the fact that Cupressaceae was not part of the taxa used for optimization. Thus, while the amount of forest cover is more realistic in the adjusted run the reconstructed Holocene trend is the reverse of what was interpreted by the authors of the site based data. Moreover, the only tree growing abundantly near the site for the last 3000 years is not part of the reconstructed vegetation in the adjusted run. This is of cause just a single example, but it does illustrate my earlier points.

We have decided to omit reconstructions from the Southern Hemisphere from our data set.