Response to community comments

(The reviewer's comments are in regular text and our response in italics)

However I have a major concern regarding the reasoning used in S3 (Justification for the use of the fourth root of the palaeo burnt area fraction used in the fxTWA-PLS analyses)...

Burnt area data are highly skewed and it is therefore appropriate to transform the data in some way to reduce skewness. We explored various transformation methods and found that the 1/4 power transformation gave good results. However, we agree that the justifiation we gave for this transformation was over-simplified – and it is not necessary to our argument. In response to the reviewer's comment, we have now settled on a Box-Cox transformation with λ = 0.25. We have reanalyzed and updated all the reconstructions results in the latest version of manuscript and explained the process of Box-Cox transformation in the supplementary information:

We have modified L125-126 in the manuscript to:

We applied Box-Cox transformation (Box and Cox, 1964) with λ = 0.25 to the palaeo burnt area fraction in order to reduce skewness prior to the fxTWA-PLS analyses (see Supplementary Information).

We have modified L170-174 in the manuscript to:

The degree of local compression, which is assessed by whether the residuals are around zero across the burnt area range in locally estimated scatterplot smoothing, indicates that the low-compression zone where reconstructed values after Box-Cox transformation are most reliable is between –3.5 and –2.5, in other words, between 0.12% and 1.98% of the grid cell area (Fig. 3b).

In the supplementary information, we have added S4 Box-Cox transformation of palaeo burnt area fraction:

S4. Box-Cox transformation of palaeo burnt area fraction

The standard Box-Cox transformation is:

$$Y_i^{(\lambda)} = \begin{cases} \dfrac{Y_i^{(\lambda)} - 1}{\lambda} & (\lambda \neq 0) \\ \log(Y_i) & (\lambda = 0) \end{cases}$$

The inverse Box-Cox transformation is:

$$Y_i = \begin{cases} \exp\left(\dfrac{\log(1 + \lambda Y_i^{(\lambda)})}{\lambda}\right) & (\lambda \neq 0) \\ \exp\,(Y_i^{(\lambda)}) & (\lambda = 0) \end{cases}$$

After deriving paleo burnt area fraction from charcoal by applying conversion factors, we applied the Box-Cox transformation to the palaeo burnt area fraction in order to reduce the skewness of the data. The parameter λ was set as 0.25 after trials of a range of values (Figure S3, Table S7). It shows the highest predictive power (R^2 = 0.472) and a relatively less local compression (b_1 = 0.549) comparing with using other values of λ. Figure S3 shows the change in the distribution of palaeo burnt area fraction before and after Box-Cox transformation. The prediction values of palaeo burnt area fraction from fxTWAPLS were then obtained via the inverse Box-Cox transformation.

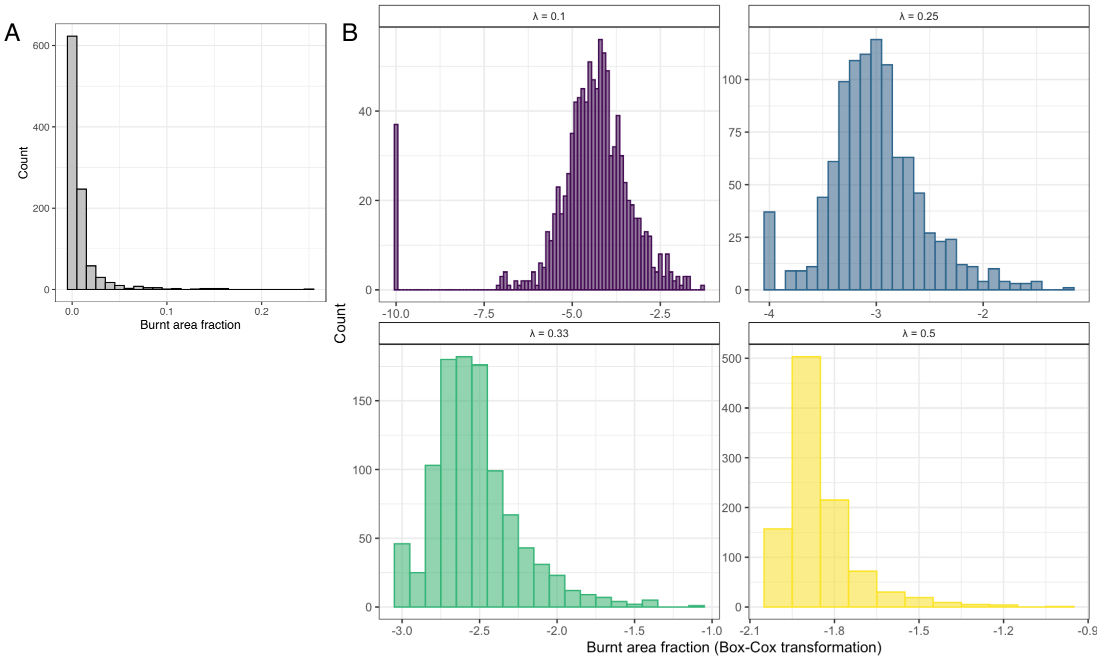

Figure S3. Distribution of palaeo burnt area fraction before (Panel A) and after (Panel B) Box-Cox transformation.

Table S7. Results of fxTWAPLS using different values of λ.

Method	ncomp	R^2	RMSEP	ΔRMSEP	p	b_0	b_1	b_0.se	b_1.se
	1	0.275	1.203	-12.529	0.001	-3.356	0.206	0.049	0.011
	2	0.338	1.144	-4.882	0.001	-3.143	0.264	0.055	0.012
	3	0.421	1.051	-8.128	0.001	-2.558	0.409	0.071	0.015
	4	**0.442**	**1.031**	**-1.897**	**0.010**	**-2.337**	**0.461**	**0.076**	**0.016**
λ = 0.1	5	0.465	1.009	-2.080	0.001	-2.320	0.464	0.073	0.016
	6	0.475	1.000	-0.953	0.019	-2.344	0.460	0.071	0.015
	7	0.477	1.009	0.904	0.700	-2.511	0.414	0.064	0.014
	8	0.476	1.009	0.006	0.511	-2.492	0.418	0.065	0.014
	1	0.277	0.372	-13.934	0.001	-2.035	0.305	0.047	0.016
	2	0.363	0.350	-6.013	0.001	-1.668	0.442	0.056	0.018
λ = 0.25	3	0.438	0.331	-5.459	0.001	-1.383	0.538	0.058	0.019
	4	**0.472**	**0.318**	**-3.815**	**0.002**	**-1.341**	**0.549**	**0.055**	**0.018**
	5	0.479	0.315	-1.059	0.220	-1.377	0.536	0.053	0.018

	6	0.490	0.311	-1.215	0.064	-1.361	0.544	0.053	0.017
	7	0.502	0.307	-1.153	0.025	-1.309	0.563	0.053	0.018
	8	0.510	0.306	-0.419	0.311	-1.252	0.580	0.054	0.018
λ = 0.33	1	0.260	0.246	-11.846	0.001	-1.648	0.334	0.045	0.018
	2	0.349	0.231	-6.031	0.001	-1.357	0.460	0.050	0.020
	3	0.429	0.216	-6.631	0.001	-1.168	0.534	0.049	0.019
	4	**0.459**	**0.210**	**-2.895**	**0.011**	**-1.105**	**0.557**	**0.048**	**0.019**
	5	0.452	0.212	0.948	0.766	-1.111	0.553	0.049	0.019
	6	0.470	0.207	-2.239	0.004	-1.092	0.564	0.048	0.019
	7	0.480	0.206	-0.523	0.197	-1.045	0.584	0.049	0.019
	8	0.475	0.207	0.642	0.754	-1.046	0.581	0.049	0.019
λ = 0.5	**1**	**0.215**	**0.121**	**-3.625**	**0.054**	**-1.252**	**0.302**	**0.034**	**0.018**
	2	0.304	0.110	-9.140	0.001	-1.114	0.384	0.034	0.018
	3	0.370	0.106	-3.367	0.043	-0.933	0.481	0.037	0.020
	4	0.398	0.103	-2.837	0.001	-0.908	0.495	0.035	0.019
	5	0.399	0.102	-0.558	0.338	-0.868	0.519	0.037	0.020
	6	0.417	0.100	-2.099	0.003	-0.832	0.541	0.037	0.020
	7	0.416	0.101	0.326	0.654	-0.809	0.555	0.038	0.021
	8	0.420	0.100	-0.582	0.261	-0.819	0.549	0.038	0.020

Figure 2 indicates the mean annual burned area to reach a maximum of 0.30% in northwestern Iberia. This is 2 orders of magnitude lower than the observed values. Judging from the map in Giglio et al. 2013 it's not produced by GFED4 underestimation, which by the way appears as GEFD4 in the text at least once.

We have corrected the spelling of GFED4.

There are three main differences between the results from Giglio et al. 2013 and the results presented in our manuscript: (1) the time period covered; (2) the spatial resolution; and (3) the definition of "mean area burnt". Here, we used burnt area data covering the period from 2001.01 to 2016.12, whereas Giglio et al. used data from 1996.07 to 2012.08 (their Figure 2). The data in Giglio et al. (2013) are at 0.25° × 0.25° resolution; since some of the environmental data sets we used in our study were only available at 0.5° × 0.5° resolution, we aggregated the burnt area data to this lower resolution using bilinear interpolation. The spatial aggregation has only a minor effect on the estimated burnt area but the choice of time period had a larger effect because our data set includes two years (2008 and 2014: 2014 is not included in Giglio et al. 2013) with a low incidence of fire.

However, the major difference between the two maps is caused by differences in the method of calculation of burnt area. We used the mean burnt area fraction of 16 years (192 layers) calculated from the raw monthly data. If this is multiplied by 12 to *calculate the annual mean for the interval from 1996-2012, then the overall pattern of burnt area fraction (see Figure below) is very similar, and we obtain a mean burnt area fraction of 0.39%. This value is similar to the estimate of 0.48% land area burnt obtained by Nunes et al. (2019) from forest inventory data. Since our use of averages based on the monthly burnt area is obviously confusing, we will present the results as an annual means calculated following the method of Giglio et al. (2013).*

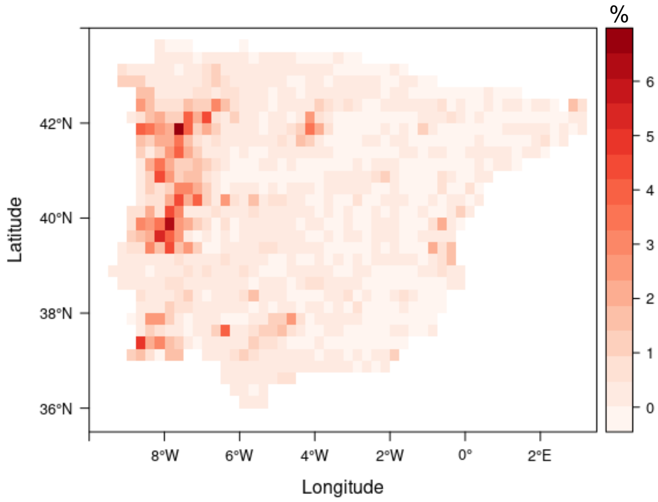

Figure extra. Mean annual area burned, expressed as the fraction of each grid cell that burns each year, derived from the July 1996 to August 2012 monthly GFED4 burned area time series.

We will replace Figure 2 in the manuscript by this new version:

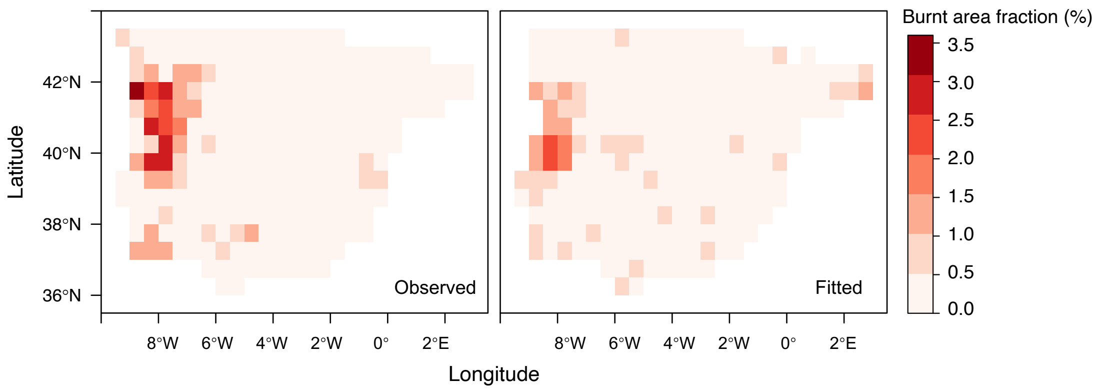

Figure 2. Mean (over 16 years) of observed (left) and fitted (right) values of burnt area fraction.

As modern burnt area fraction has changed, Figure 5 and Figure 6 showing reconstructed burnt area fraction have been updated too.

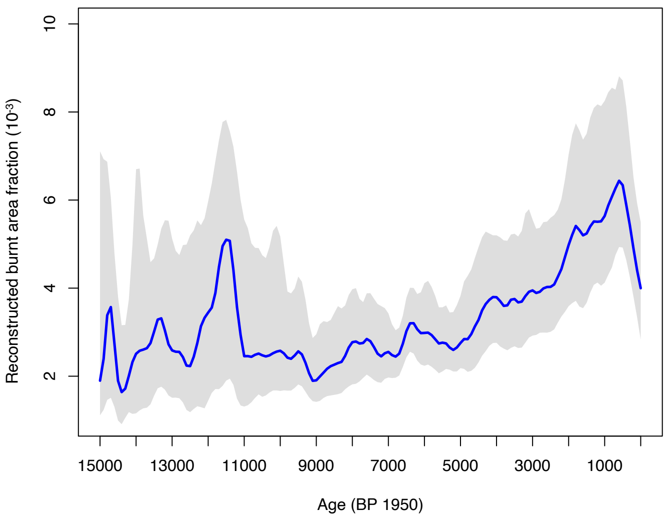

Figure 5. Composite curve of reconstructed burnt area using fxTWA-PLS, using the locfit() function with half-width = 300, number of bootstrap samples = 1000. The locally estimated scatterplot smoothing is shown in blue. The upper and lower 95th-percentile confidence intervals are shown in grey.

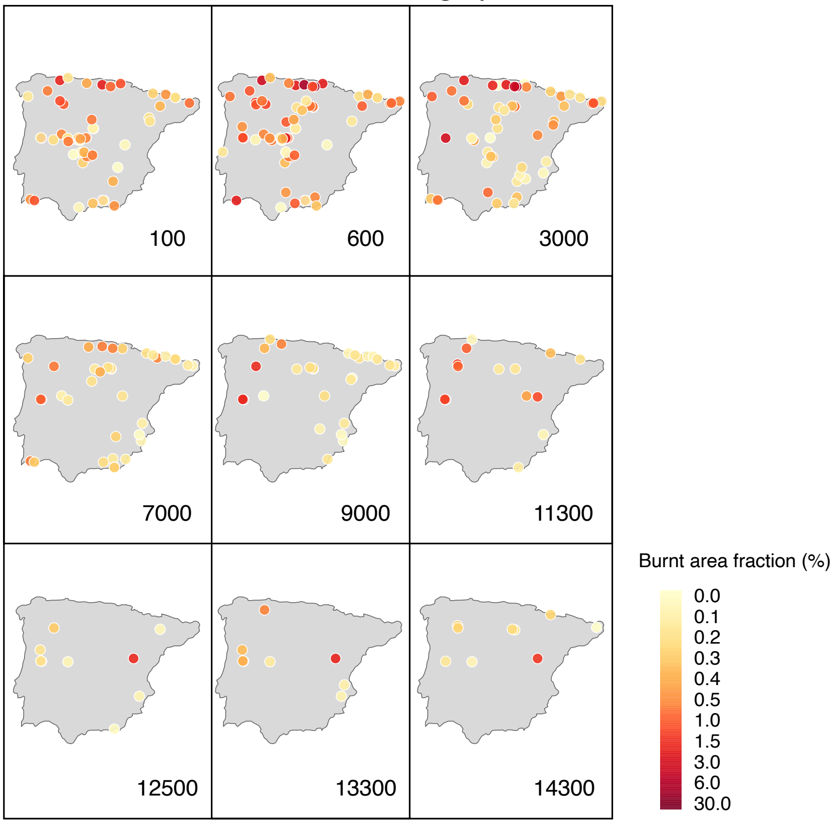

Figure 6. Spatial patterns of reconstructed burnt area fraction at key times in the Holocene.

Annual burned area of the Iberian Peninsula is currently about 200 kha, or 0.34% of the land mass. However, Fig. 5 points to about 0.04%, so about 10 times less. Again, this does not seem to be an artifact of using GFED4.

As explained in our response above, this is because we were using the monthly mean values rather than annual mean values. This has now been changed and the values are more consistent with the reviewer's expectations.