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REPLY TO PIPERNO ET AL.:

# It is too soon to argue for localized, short-term human impacts in interfluvial Amazonia

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We welcome the debate opened by Piperno et al. (1) in response to our recent article (2), and thank the editors of PNAS for the opportunity to reply.

Although acknowledging that we detected localized human impacts in our study area, Piperno et al. (1) downplay the increases in palms observed at the geoglyph sites, stating it's "unclear" whether humans actively managed the forest in these locations. Independent of one's opinion about intentionality, we argue that the rapid decline of palms after geoglyph abandonment suggests that their previously high levels were because of much more regular, longer-term human influences than Piperno et al. suggest.

We also reemphasize that the palm increases reflect the minimum scenario of human impact in the geoglyph landscape, and that one would still need to multiply anthropogenic forests of 0.5-km radius over the 450+ known geoglyph sites. Moreover, forest cover over ~80% of Acre state may be hiding many more geoglyphs.

Piperno et al. (1) state that we "curiously question" the significant role of charcoal data to their interpretations. Although we agree that testing the role of anthropogenic fires is important in the debate over forest clearance (3, 4), we question the correlation these authors make between less soil charcoal and smaller population sizes (5, 6). Indigenous Amazonian agroforestry practices rarely emphasize whole-scale burning, but instead convert the forest through more subtle means to increase its productivity (7, 8).

We also highlight that our methodology differed from that of McMichael et al. (5) in important aspects:

First, rather than sampling in random interfluvial locations, we closely combined archaeology and paleoecology in the vicinities of two geoglyphs (9). As no agreed "natural" baselines exist in Amazonia (6, 10), we started from the clearly anthropogenic (the geoglyphs) and worked backward to reconstruct a more detailed landscape history.

Second, we used sampling intervals of 5 cm rather than 20 cm, reducing false-negative results. For example, 40 y of a deforested modern landscape was reflected by 10–20% early successional herb (ESH) phytoliths (grasses+*Heliconia*) in the 0- to 5-cm profile samples. If we average these frequencies out over all samples between 0 and 20 cm, ESHs fall to 6–11%. McMichael et al. use >10% ESHs as the "cut-off" for human disturbance (5), but this approach may miss important decadal-scale transformations once temporal resolution is lowered.

Third, we analyzed the charcoal input of extralocal fires by incorporating a 0.125- to 0.25-mm size class. This proxy proved extremely useful for detecting regional fire increases in the late Holocene that would have been missed in their studies.

Finally, the "polarized" debate we refer to concerns the authors' claims that their research design can be used to meaningfully argue for "sparse" pre-Columbian populations, and "small" human footprints in interfluvial Amazonia (5, 6, 7, 10). In our opinion, many more years of discovery, methodological refinement, and debates like these are needed before this can be proven.

- 1 Piperno DR, McMichael C, Bush MB (2017) Further evidence for localized, short-term anthropogenic forest alterations across pre-Columbian Amazonia. *Proc Natl Acad Sci USA* 114:E4118–E4119.
- 2 Watling J, et al. (2017) Impact of pre-Columbian "geoglyph" builders on Amazonian forests. *Proc Natl Acad Sci USA* 114:1868–1873.

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