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Comment on Clement *et al.* 2015 'The domestication of Amazonia before European conquest'

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Clement *et al.* [1] paint a picture of cultural landscapes blanketing Amazonia prior to European arrival to the Americas in their recent publication entitled 'The domestication of Amazonia before European conquest'. A colourful narrative indeed, but here we would like to comment on their misinterpretation of previously published literature, use of data that may not be associated with pre-Columbian activities, and the extrapolative nature of their review both in time and across space.

Clement *et al.* [1] claim that a 'revisionist view of a domesticated Amazonia is contested by some natural and social scientists', that these views are 'based on small samples that are used to extrapolate across the region, often without engagement with the full breadth of scholarship on pre-Columbian Amazonia', and cited a series of our recent work [2–4]. They go on to say, 'Most commentators agree that Amazonia was occupied by societies with different levels of complexity and each had different impacts on their landscapes. There were dense populations along some resource-rich sections of major rivers, less dense populations along minor rivers and sparse populations between rivers.' These statements reference their previous work [5,6].

Our previous work, including those papers cited in the manuscript, has expressed the same views of heterogeneity in the distribution of pre-Columbian peoples in the forest, and the various intensities of those occupations. We have in fact consistently argued for: (i) heterogeneous landscape modifications, with dense and sedentary populations found in resource-rich areas, such as along the main Amazon river channel and elsewhere illustrated in our published figures; and (ii) less dense populations in the interfluvial areas far removed from river courses, *in those areas that we and others have researched and have thus far found little to no evidence of either human occupation or forest/landscape modification* [3,4,7–9]. Clement *et al.* claim that those results were based on 'small samples that are used to extrapolate across the region'. Yet we have provided empirical data from over 300 soil cores at 109 sites across a riverine-interfluvial gradient in western and central Amazonia that support our conclusions. We have also previously pointed out that the several thousand soil samples collected during the RADAM Brasil survey [10] and nearly a hundred sites from the RAINFOR project [11] also lacked mention of finding artefacts or dark earths. Even 1000 soil cores collected across the varzea-interfluvial gradient south of Santarem, near the oldest known occupation site in Amazonia, contained no evidence of modified soils [12]. The abstract of McMichael *et al.* [3, p. 1429], which addressed the idea of most of Amazonia as a transformed landscape, stated: 'Our data indicate that human impacts on Amazonian forests were heterogeneous across this vast landscape.'

Figs 1 and 2 presented by Clement *et al.* [1] also very closely resemble our predicted distributions of Amazonian dark earths [13] and earthwork formations in southwestern Amazonia [14]. So, essentially, Clement *et al.* [1] support what we have published vis-à-vis that pre-Columbian populations had heterogeneous densities and impacts on the forest (e.g. [3,4,7,9]). Both our and Clement *et al.*'s

figures showed two clear patterns in the distribution of where ancient human impacts are likely to be the highest. The first is that most ancient peoples were probably close to the major waterways of Amazonia. The second is that the majority of the Basin is not predicted to contain significant ancient human impacts. Thus, we feel the terminology of a 'domesticated Amazonia' is misleading.

We also find their argument for Basin-wide forest management quite problematic because large areas of Amazonia, particularly interfluvial forest, have not yet seen investigation. Despite the size of Amazonia and what are huge data lacunae, Clement *et al.* essentially argue that throughout Amazonia where techniques such as slash and burn agriculture were not practised and forests were not cleared for fields, people instead turned forests into orchard-like or other human-manipulated formations through the removal of some species not considered useful and replacement with preferred species. Their evidence is mostly from ethnobotanical data and anecdotes from modern indigenous people, or through their studies of modern 'useful' trees in various tracts of forest (e.g. [15]). Clement *et al.* stated that 'we fail to engage with' these lines of evidence. This is true, for the reason that such evidence does not suffice as documentation on the dynamics of the prehistoric past.

To directly attribute a characteristic of the modern forest to pre-Columbian activity is overlooking several hundred years of post-European human activity. As we have already discussed, much more consideration should be given to the historic period, because it is known that considerable vegetation and landscape reconfigurations took place during the past few hundred years, including the creation of stands of trees like the Brazil nut (below) and, probably, some dense stands of palms largely assumed by Clement and colleagues to be relicts from prehistoric time [4]. Modern vegetation distributions and patterns may be a result of *all* disturbances through time, not just pre-Columbian disturbances. Thus, until more recent disturbances resulting from the Amazonian rubber boom and early colonial influences are accounted for, linking modern vegetation to pre-Columbian disturbance dynamics does not constitute convincing evidence.

We also note that the primary work used to support claims of plant enrichment far away from rivers and occupation sites [15] contains no baseline for comparisons of enrichment versus natural distribution patterns. Thus, their hypothesis is essentially untestable. Clement *et al.* similarly suggest that Brazil nut distributions are primarily a function of ancient forest management across the Amazon. Modern Brazil nut *densities* are positively correlated with areas that most probably contained Amazonian dark earths [16], suggesting that people enriched Brazil nut in the more densely settled areas. But to map a native species of the Amazon and claim that humans have altered its distribution across the Basin is unsubstantiated.

Clement *et al.* also declare that the phytolith and charcoal evidence from Amazonian soils that we have presented [3,4,7,9] cannot detect the kind of forest management they posit over Amazonia. Although some of the major economic species (e.g. rubber, the Brazil nut) leave little in the way of palaeobotanical evidence, others such as the major economic palms (*Bactris gasipaes*—the peach palm, *Astrocaryum* and others), are easily detectable with phytolith analyses. We have found little to no evidence for the presence of these species or increase of palms generally in our extensive series of soil analyses. Furthermore, many trees and other species that are not of major (or in some cases even minor) human utility today are well represented in phytolith diagrams, and these taxa do not show decreases in our profiles as would be expected had they been removed or reduced in number to be replaced by other human-preferred species.

We have long recognized, along with other investigators, the variety of ways that pre-Columbian people altered the forests, such activities being documented largely in areas that could support denser human populations. What we question is the extent to which forests were altered where natural resources were considerably less abundant, such as the interfluves, where much palaeoecological and archaeological research is needed. Clement *et al.* agree that interfluvial areas were probably less densely settled, but argue that, even so, 'this minimal level of landscape domestication results in enduring and dramatic anthropogenic footprints in a variety of settings, particularly when considered at centennial and millennial scales' [15,17,18]. Without directly testing these assertions, how can one distinguish between a pattern that may have been driven by (i) human dispersal (either pre- or post-European), (ii) seed-dispersing forest animals, (iii) environmental parameters, (iv) inter- or intra-specific competition, or (v) stochastic processes? We have consistently stressed that more work is needed, especially in the vast, under-studied interfluvial areas, to begin to understand to what extent and degree the Amazon and its different ecological zones were inhabited and modified in prehistory.

We offer a final caution with regard to indigenous rights. Clement *et al.* find motivation for their study in linking past land use to establishing those rights. There is no problem with that usage. A problem surfaces, however, when others, who do not agree about the scientific evidence, are criticized for undermining a social goal. As a scientific community, we must be vigilant in defending the independence of science from social activism. Scientists rightly deplored senatorial committees harassing researchers who held different views on climate change from their own. The rights of indigenous peoples are manifest and it should be a scientist's goal to help reveal their history, not establish those rights.

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