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## How pristine are tropical forests? An ecological perspective on the pre-Columbian human footprint in Amazonia and implications for contemporary conservation

Jos Barlow<sup>a,\*</sup>, Toby A. Gardner<sup>b</sup>, Alexander C. Lees<sup>c</sup>, Luke Parry<sup>a</sup>, Carlos A. Peres<sup>d</sup>

<sup>a</sup> Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, UK

<sup>b</sup> Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, UK

<sup>c</sup> Coordenação de Zoologia, Museu Paraense Emílio Goeldi, Belém, Pará, Brazil

<sup>d</sup> School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK

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## ABSTRACT

Archeologists, paleoecologists and anthropologists argue that ecologists need to give greater consideration to the pre-historical influence of humans in shaping the current structure and composition of tropical forests. We examine these arguments within the context of Amazonia, and assess the extent to which (i) the concepts of “pristine forests” and “cultural parklands” are mutually exclusive, (ii) the aggregated distribution of some plants necessarily indicates enrichment planting, (iii) pre-Columbian human disturbance has increased forest biodiversity, (iv) pre-Columbian indigenous practices were always sustainable, and (v) if indeed, the ecological impacts of pre-Columbian peoples are relevant for modern biodiversity conservation. Overall, we reject the notion that “the pristine myth has been thoroughly debunked” by archeological evidence, and suggest that the environmental impacts of historical peoples occurred along gradients, with high-impacts in settlements and patches of Amazonian Dark Earth (ADE), lesser impacts where occasional enrichment planting took place in forests surrounding agricultural plots, and a very low influence (in terms of light hunting pressure and other types of resource extraction) across vast areas of Amazonia that may always have been far from permanent settlements and navigable rivers. We suggest that the spatial distribution of pre-Columbian finds is given more attention, and urge caution before case studies are extrapolated to the entire Basin. Above all, we feel that debates over “naturalness” and environmental impacts of pre-Columbian humans are of limited relevance to present and future biodiversity conservation, and can detract from the major challenges facing Amazonia and other tropical forest regions today.

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### 1. Introduction

Archeologists, paleoecologists and anthropologists have long suggested that ecologists should give greater consideration to the effects of pre-historical and modern human disturbance on the contemporary ecology of Amazonian forests (Denevan, 1992; Heckenberger et al., 2007; Willis et al., 2004). Clement and Junqueira (2010) suggest that although “the pristine myth has been thoroughly debunked, too many biodiversity researchers fail to incorporate historical ecology into their analyses”, and similarly Heckenberger et al. (2007) argues that “The majority opinion still holds that natural forces and processes, little impacted by human actions until recently, are responsible for the current composition of the region”.

These arguments could be important, as the disturbance history of tropical forests has repercussions for our understanding of contemporary global environmental change. For example, observed increases in aboveground biomass and turnover in Amazonian and African forests (Lewis et al., 2009; Phillips et al., 2008) could be explained by two alternative hypotheses: either global environmental change such as CO<sub>2</sub> fertilization or nutrient deposition may be accelerating the rate at which tropical trees are growing (Phillips et al., 2008), or tropical forests may simply be recovering from past (but unknown) disturbance events (Chave et al., 2008; Muller-Landau, 2009). Archeological evidence confirming widespread human disturbance would lend significant weight to the latter argument.

We take this opportunity, in memory of our colleague Navjot Sodhi, to discuss these arguments in more detail and provide an ecological perspective to the debate. We examine five arguments or claims that have been made about the influence and spatial distribution of pre-historical human disturbance in tropical forests, and show how greater scrutiny of biological detail and spatial scale

\* Corresponding author. Tel.: +44 1603 591426.

E-mail addresses: [jos.barlow@lancaster.ac.uk](mailto:jos.barlow@lancaster.ac.uk), [josbarlow@gmail.com](mailto:josbarlow@gmail.com) (J. Barlow).

could improve our understanding of the relative importance of such disturbances.

## 2. Are “Pristine Forests” and “Cultural Parklands” mutually exclusive?

Academic debates, especially those that span different disciplines, are readily polarized and often employ straw-men arguments to help establish particular positions. This problem can be exacerbated by high-impact publications that illicit a dose of controversy in their titles in order to attract the reader's attention. For example, Heckenberger et al. (2003) suggest two competing hypotheses about the make-up of Amazonia in 1492, suggesting it existed either as a “pristine forest” or a “cultural parkland”, reinforcing the idea that the two concepts are mutually exclusive.

In fact, Heckenberger et al. (2003) reaches a far more nuanced and reasonable conclusion that points towards the “complex interplay of ecological, historical, and political conditions in Amazonia”, which is supported by calls for a “middle path” that accepts that both extremes existed (Bush and Silman, 2007). However, some authors continue to deny the possibility that modern day tropical forests persist as mosaics, where the legacy of past human impacts is strongly evident in some places but virtually absent in others. For example, Clement and Junqueira (2010) argue that pre-Columbian peoples led to a “domestication of landscapes in Amazonia” and leave no space for the ‘pristine’ or ‘primary’ forests that ecologists refer to when representing the most natural conditions available.

We support calls to adopt a more considered assessment of the likely spatial distribution of the ecological impact of pre-Columbian peoples (Bush and Silman, 2007). Human decisions about where to settle, grow crops or hunt are far from random, and it is very unlikely that human impacts were dispersed homogeneously across the basin. For example, much of the archeological evidence that has been used to promote so-called “cultural parklands” indicates that indigenous peoples focussed their settlements and agricultural activities in relatively confined areas. We examine the implication of this on two different spatial scales.

At a macro-scale, these include wetland regions such as the highly productive seasonally flooded savannas in French Guiana (McKey et al., 2010) and Marajó Island (Meggers, 2003), and the settlements and managed lands along the upper Xingú (Heckenberger et al., 2007) and parts of western Amazonia (Mann, 2008). At present there is insufficient evidence to know whether we can extrapolate evidence from these finds to other regions (Meggers, 2003), especially as the distribution of archeological sampling effort itself is not random, with archeologists tending to work in regions where they are most likely to find evidence of human settlements.

The focussed spatial distribution of pre-Columbian activities can also be observed at smaller scales, including their propensity to settle and intensively farm zones around riverine bluffs (Denman, 1996). In particular, the extent of pre-Columbian agricultural activities has been largely informed by research on Amazonian Dark Earths (ADEs) (known as *terra preta* or *terra mulata*; Woods and McCann, 1999), which have been used as evidence for the widespread influence of pre-Columbian peoples on Amazonian forests (Willis et al., 2004). However, the majority of patches of ADE have been described along rivers and are either absent or undetected in much of Amazonia (see maps in (Fraser et al., 2011; Glaser, 2007)) and account for a very small proportion of total land cover in regions where they are present. For example, Woods and McCann (1999) studied 12 black earth locations ranging from 0.5 to 120 ha in the Santarém–Arapuins region that hosted one of the most prominent pre-Columbian cultures, and estimated that

“hundreds exist” across a study area that encompasses more than a million hectares of forest. However, a generous estimate of 1000 patches with an average size of 10 ha would still indicate that non-*terra preta* soils cover make up more than 99.9% of the land. Similar estimates could be made by extrapolating numbers from the middle Madeira, where 350 ha of ADEs have been found along 150 km stretch of river (Fraser et al., 2011). Our own observations (from a collective experience that includes over 60 years of work across the Amazon, including many regions notorious for their dark soils) suggest that while it is not uncommon to find evidence of ADE in the vicinity of riverine communities, these are invariably very localized and limited in extent, and ADEs are rarely encountered far from rivers. While any large-scale extrapolation from spatially focussed samples is likely to be highly inaccurate (c.f. Henige, 1998), the overall point remains: ADEs only account for a tiny fraction of Amazonia's total area.

The pre-Columbian land-use zones described by Heckenberger et al. (2007) could provide a useful framework for understanding impacts, as they include “areas of continual management”, “areas of active but occasional management”, and “areas that are utilized [for occasional hunting and NTFP extraction] but not actively managed”. When ecologists use the notion of relatively undisturbed primary forests to represent reference conditions for assessing modern-day human impacts, they are normally referring to the latter category. Where our views diverge from Heckenberger's and others is in the likely spatial extent of the different activities: crude estimates and our own personal experiences suggest that unmanaged forests covered many orders of magnitude more land than managed forests (c.f. Bush and Silman, 2007).

## 3. Does the aggregated distribution of some plants always indicate enrichment planting?

Enrichment planting of economically important species to create ‘forest gardens’ is a central tenet of the cultural parkland theory (Balee, 1989), and archeologists often base their arguments on the local monodominance of certain economically important plants such as Brazil nut trees (*Bertholletia excelsa*) or *Mauritia* palms (*Mauritia flexuosa*). While indigenous peoples undoubtedly planted some species – deliberately or otherwise – tree monodominance can have a variety of different explanations in Amazonia (Villela and Proctor, 2002) and ecological processes can often explain plant spatial distributions without invoking the need for human dispersal. For example, *Mauritia* palms are considered “the most important non-architectural industrial plant among Xinguanos” that are “closely associated with ancient settlement areas and flourishes in managed wetlands” (Heckenberger et al., 2008). However, *Mauritia* palms are also a clear indicator of wetlands across most of northern South America (Ribeiro et al., 1999), and their presence along rivers and in disturbed wetlands does not necessarily indicate enrichment planting or pre-Columbian human influence. In a similar way, it cannot be assumed that clusters of adult Brazil nut trees (*B. excelsa*) necessarily require an anthropogenic explanation. While humans may have contributed to the long-range dispersal of *B. excelsa* (Shepard and Ramirez, 2011), local distributions in aggregated stands are also explained by the scatterhoarding behavior of agoutis, the most important natural dispersal vector of this species (Peres and Baider, 1997). Finally, it is worth noting that understanding the distribution of Amazonian plants is an immensely challenging task, that remains complicated by taxonomic uncertainty and the patchy distribution of plant collections (see Barlow et al., 2011 and references therein). Our knowledge of pre-Columbian impacts on plant populations will doubtless improve as we further our knowledge of all plants, and not just a few large-seeded species with important anthropogenic uses.

#### 4. Has human disturbance increased biodiversity?

It has been suggested that “biodiversity is equal if not higher in anthropogenic than in non-anthropogenic areas” (Heckenberger et al., 2007) and “disturbances counter intuitively ... result in net increases of alpha and even beta diversity” (Balee, 2006). First, few ecologists would consider this counter-intuitive: it is exactly what you would predict from the intermediate disturbance hypothesis (Connell, 1978), and empirical studies show that species richness is higher in lightly disturbed tropical forests (Bongers et al., 2009; Molino and Sabatier, 2001). Second, even when past human impacts may have had a demonstrable effect on patterns of diversity, basing these arguments on simplistic univariate metrics such as species richness creates a misleading representation of total biodiversity, as these short-term increases in total species richness are typically followed by the loss of forest-dependent species (Gibson et al., 2011). As a result, most ecologists advocate measuring conservation value using information on species rarity and/or vulnerability (Waltert et al., 2011) or the richness of forest-dependent species (Gibson et al., 2011).

#### 5. Were pre-Columbian indigenous practices always sustainable?

While some ecologists are undoubtedly guilty of romanticizing and exaggerating the concept of wilderness and wild nature, anthropologists and archeologists have equally overestimated the degree to which paleo-Indian land-use practices were sustainable. For example, Heckenberger et al. (2007) states that “the discovery of large, settled communities and dense regional populations suggests a much longer and complex history of human use and, by definition, *sustainable resource use*” (emphasis added). Without knowing the extent and integrity of forest that presumably surrounded these settlements it is impossible to draw conclusions about sustainability, although empirical data indicates larger settlements are actually less sustainable than smaller ones in terms of hunting pressure (Jerzolimski and Peres 2003) and that even sparsely settled human populations well below 0.5 person/km<sup>2</sup> deplete game stocks in Amazonian indigenous territories and extractive reserves (Peres, 2011). The notion that native Amazonians before Gaspar de Carvajal’s descent of the River Amazon did not overexploit Amazonian forest resources also seems to be at odds with the links between overhunting and the Pleistocene extinctions of South America’s large-bodied vertebrates (Barnosky et al., 2004).

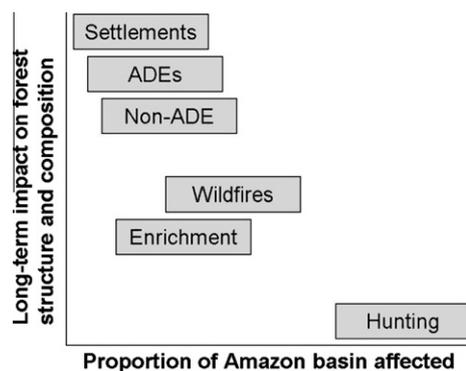
In another argument about sustainability, Clement and Junqueira (2010) argue that “the combination of fire management and plant cultures [used by indigenous peoples] nurtured the soil, rather than mined it”. Most land managers would support the notion that compared to large swathes of mechanised agriculture, small manually-cultivated plots are likely to regenerate faster, reduce soil erosion and nutrient loss, and increase seed rain from surrounding forest. But to imply that these practices somehow nurture soils is counter to our understanding of slash-and-burn farming, which results in a net loss of nutrients from the system (Uhl and Jordan, 1984) and slows subsequent regrowth (Zarin et al., 2005). Denevan (1992) sums up a realistic assessment of the sustainability of pre-Columbian peoples: “sometimes they did; sometimes they didn’t” have sustainable systems of resource management. Unfortunately, dispersed and incomplete archeological and fossil records mean we are unlikely to move far beyond this assessment.

#### 6. Is pre-Columbian land management relevant for contemporary biodiversity conservation?

Some authors have suggested that the prehistoric modification of rainforests has “critical implications for questions of biodiversity, ecological resilience, and sustainability” (Heckenberger et al., 2008) that “should not be overlooked by conservation biologists” (Willis et al., 2004). While we do not deny that prehistoric humans had demonstrable, albeit localized, effects on their environments, we fail to understand how such effects are critical for informing modern-day conservation strategies.

Willis et al. (2004) conclude that the scale of archeological finds suggest “that it is no longer acceptable to suggest that land loss caused by previous human activities was too small to have had a major impact”. They continue this argument by asserting that these impacts are in some way comparable to present-day losses, as the principal cause (slash-and-burn) remains the same today as it was in prehistoric times. However, the impact of forest enrichment, subsistence hunting, and ADE fertilization is dwarfed by contemporary deforestation and degradation in logged, burned, overhunted and edge-dominated fragmented stands (Beehler et al., 2004; Hambler, 2004) driven by the current wave of agricultural expansion and global consumer demand (Koh and Lee, *this issue*; Peres and Schneider, *this issue*). Furthermore, the argument that if “left for long enough, forests will almost certainly regenerate” (Willis et al., 2004) ignores the likely extinction of restricted-range species and seems to confuse the immediacy of present-day biodiversity crises with the centennial or millennial timescales that are necessary to achieve forest recovery after large-scale intensive disturbances that are characteristic of modern-day human impacts (Chai and Tanner, 2011).

There is a stark disparity between the spatial scale and intensity of pre-Columbian human impacts and contemporary anthropogenic forest disturbance. This means that studies of the former provide limited useful information about the resilience of forests to contemporary human disturbance. The issue is not whether some kind of forest will return, but rather to what extent will biodiversity persist in regions that are currently being affected by deforestation and degradation? We agree with the assertion that even if “Amazonian landscapes are richly historical and constructed makes them no less natural or interesting, or tainted in terms of biodiversity” (Heckenberger et al., 2007). From a



**Fig. 1.** A schematic representation of the spatial scale of pre-Columbian human impacts on present-day forest structure and composition across the Amazon basin. Plotting spatial extent against different patterns of environmental impact allows a more considered approach to the debate. Although there is considerable uncertainty about these estimates, we consider it likely that the highest-impact activities occurred on the smallest spatial scales. ADEs = Amazonian Dark Earths; Non-ADE = more transient slash-and-burn cultivation that did not result in ADEs; Wildfires = anthropogenic fires escaping into forests; Enrichment = enrichment planting within forests; Hunting = hunting and resource extraction for subsistence or trade.

conservation perspective it is simple: we can only attempt to conserve the plant and animal populations that have survived previous human activities, whether those activities occurred yesterday or many millennia ago.

## 7. Conclusion

Archeologists and paleo-ecologists have made an important contribution to our understanding of the structure and composition of modern-day tropical forests. Indeed, we are in awe of some of the amazing finds that have been unearthed in Marajó Island, Santarém, Manaus, the upper Xingú, Acre, and the Llanos de Moxos region of eastern Bolivia (Erickson, 2000; Heckenberger et al., 2007; Mann, 2008). However, these finds remain the exception and not the rule across the vastness of Amazonia, and by attempting to alert ecologists to the importance of pre-Columbian peoples, archeologists risk taking the debate too far the other way, stating that “today’s biodiversity exists within a historical ecology created by the human enterprise itself” (Clement and Junqueira, 2010), and that “all species [are] adapted to domesticated landscapes” (Balee, 2010). These statements reflect a highly anthropocentric worldview, and should be evaluated in the context of many millions of years of evolution without humans (Hoorn et al., 2010), and the hundreds of thousands of species persisting in Amazonia today.

We therefore urge caution before presuming that findings from a few well studied regions can be extrapolated to the entire Amazon, and reject the idea that the pristine myth has been thoroughly debunked by archeological evidence (Clement and Junqueira, 2010). Instead, we suggest that the influence of historical peoples occurred along gradients, with high impacts in settlements and small and scattered Amazonian Dark Earths, moderate impacts where enrichment planting occurred or where forests were affected by anthropogenic wildfires, and finally a largely imperceptible footprint from subsistence hunting and resource extraction across vast tracts of Amazonian forests that are far from permanent settlements and navigable rivers (Fig. 1).

The notions of pristine or primary are whatever we make of them. In the context of the immense challenges facing Amazonian biodiversity conservation in the 21st Century these terms are widely used to mean those places that are still largely free from logging, fragmentation, fire, and overhunting. These forests provide a vital baseline against which the sustainability of modern-day human activities can be assessed, and the performance of conservation efforts measured. Understanding pre-historic environmental impacts is a fascinating scientific endeavor but is of little practical value for the conservation of Amazonia today.

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