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Madagascar's environmental and human histories are dynamic, complex and deeply intertwined

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Traces of a flawed colonial-era narrative about early settlers destroying 90% of Madagascar's 'original' island-wide forests persist in recent scientific debates, despite evidence of great regional diversity – from humid, deciduous and spiny forests to woodlands, heaths and grassy biomes – and regionally distinct changes through time, deep into the past. Understanding these patterns and the historical interplay of natural and human drivers of environmental change is key to effective management strategies today, in addition to these aspects being of major scientific interest. Escape from narrative traps is difficult, but contemporary deforestation and the broader environmental crisis facing Madagascar make a complete liberation from the colonial-era story more urgent than ever. We highlight evidence of landscape dynamism and the spatiotemporal complexity of human settlement and impact; we identify knowledge gaps that must be filled to resolve contested interpretations of data; and we emphasize the need for more closely integrated interdisciplinary research and its central importance for present and future landscape policy and management.

Environmental dynamism

Palaeoenvironmental records do not yet fully capture patterns of change. The number of published site records remains small and localized, with about half from the central highlands and half from other regions spanning a range of biomes (Gillson et al. 2023, Razafimanantsoa & Razanantsoa 2024). All of these sites show some level of environmental dynamism: sediment cores from the central highlands point to landscapes oscillating between grassy biomes, heathlands and forest, and sediment cores and speleothems document extensive spatiotemporal variability in the south-east, north-west, west and south-west (Virah-Sawmy et al. 2009, Faina et al. 2021).

Inferences about the diets of now-extinct herbivores (giant tortoises and lemurs, elephant birds and hippopotamuses) potentially provide additional landscape insights. However, sample sizes are small and geographically restricted (Crowley et al. 2023), the interpretation of isotope ratios is complicated (Codron et al. 2018) and the idea of fixed diets is itself problematic: seasonal and longer-term climatic changes would have required dietary shifts between C3 and C4 foods. This is well documented for African hippos and Indian Ocean giant tortoises (Gerlach 2004, Cerling et al. 2008), and the evidence for Madagascar hippos indicates diets ranging from mostly pure browse (C3) to mostly pure grasses (C4) (Hixon et al. 2021, Silander et al. 2023)

Extant communities offer further clues to the past. Madagascar supports a diverse, endemic grass flora of considerable antiquity, with substantial functional and biogeographical differentiation (Vorontsova et al. 2016, Solofondranohatra et al. 2020). Endemic animal species that use or live exclusively in grasslands include invertebrates, birds, reptiles and mammals (Bond et al. 2023). Mouse lemur populations in small forest isolates in the central highlands and in humid forests in the north-east show no evidence of gene flow over timespans long predating human presence, suggesting that forest fragmentation and isolation by surrounding grasslands drove evolutionary diversification in these forest-living primates (Yoder et al. 2016, Polestra et al. 2021).

Evidence of ancient dynamism extends to the physical environment, upending the longstanding assumption that erosion gullies in the central highlands are uniquely due to human activities. Recent research shows that gully occurrence is closely associated with earthquake activity, and isotopic dating of 'old' gullies signals times of origin from long before people arrived (Cox et al. 2024).

Varying interpretations of current evidence are partly attributable to poor geographical sampling, data gaps and confusing classificatory language for vegetation. In addition, traces of colonial before-and-after stories still permeate debates, particularly regarding grassy biomes in

Figure 1. Ongoing research. (A) Sampling grasses in the central highlands. (B) Discussing fire management with villagers in the central highlands. (C) Excavating the north-western port city of Mahilaka. (D) Extracting a sediment core in the central highlands. Photographs by M. Vorontsova, V. Fernandez Garcia, Sealinks Project, A.P. Rasolonjatovo.

the central highlands. They show up as binary hypotheses – forested versus open – and in terms such as 'original habitat'. Continued adherence to simplistic models is deeply at odds with the dynamic history of change documented by recent evidence.

Human history and diversity of impact

The earliest traces of probable human presence in Madagascar are c. 10 000 years old, consisting of cut-marks probably made by stone tools on the bones of extinct species (Douglass et al. 2019). The first glimpse of a living site comes from a 4000-year-old rock shelter, with excavated remains suggesting that the shelter occupants were foragers.

Evidence of villages appears along the coastline from the eighth century CE, established by people arriving from Indonesia and Africa (Wright & Rakotoarisoa 2022). They lived mostly by fishing, farming, herding and/or trade. Based on palaeoenvironmental records, their impacts on the vegetation around them varied at very local as well as regional levels (Faina et al. 2021). People also hunted, although bones of now-extinct animals are almost completely absent from excavated settlements. Hunting is primarily inferred from changing ratios of extant-to-extinct bones in palaeontological accumulations, which signal an initial decline of megafaunal populations in the seventh century CE and a precipitous drop thereafter. Although local climate fluctuations probably contributed to the decline, the extinction of all large-bodied species by the sixteenth century cannot be explained by climate change alone, and human pressures, including hunting, must have played a major role in island-wide extinctions (Godfrey et al. 2019).

Archaeological traces of Madagascar's first major town, on the north-west coast, date to the twelfth century CE (Radimilahy 1998). In contrast, the earliest archaeological evidence of people in the central highlands is a scattering of small villages dating to the eleventh century CE, and the first city emerged only in the mid-eighteenth century (Wright & Rakotoarisoa 2022). This marked the rise of the Merina Kingdom and substantial landscape transformation in the central highlands, with extensive land clearance and terracing for irrigated rice production. Deforestation associated with agriculture and logging accelerated after France took possession of Madagascar in 1896, and the impact of colonial exploitation was evident in other regions too: broad swathes of humid forest were cleared for irrigated rice in the north-west and dry and spiny forest for commercial sisal production in the south; in the east, Malagasy subsistence farmers driven out of fertile valley bottoms moved to marginal lands on steep slopes, where cultivation accelerated deforestation, degradation and erosion.

People had no discernible impacts on Madagascar's vegetation or mega-faunal populations for almost 9000 years after their initial arrival (Ekblom et al. 2016). They arrived at different times from different places, with different cultures, knowledge, skills and interests, and with markedly varied impacts on the island's landscapes (Wright & Rakotoarisoa 2022). We find no place for conceptualizing this history as a single moment, 'at human settlement' (Joseph et al. 2021), which collapses time and space, elides history and ignores the interplay of factors driving regional environmental changes. The concepts of 'subsistence shift' and 'organizational shift' offer more compelling interpretive frameworks (Godfrey et al. 2019, Richard 2022). The first highlights an early change from foraging to agriculture and pastoralism, and the second captures more recent societal transformations when state-level organizations emerged. In short, what mattered was what people did and how many were doing it, not the fact of human presence.

Gaps, and the importance of filling them

Gaps in Madagascar's environmental and human histories are gradually being filled (Fig. 1). For example, recent analysis of

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modern pollen from soil surface samples across the island (Razafimanantsoa & Razanatsoa 2024) opens up important new avenues for interpreting ancient pollen records. But many gaps remain (Lehmann et al. 2022). A more complete record of climate and vegetation changes and their spatial dynamics over the past 10 000 years requires wider sampling of sedimentary deposits and speleothems, as well as systematic regional studies of soil geochemistry and biochemical markers. Further dietary isotope data on extinct megafauna are called for, as is continued research on plant and animal species that occur in open, grassy biomes.

There are few Malagasy archaeologists, and the island has attracted limited international archaeological interest, but extensive archaeological surveys and regional excavations must be done to elucidate Madagascar's human history. Major gaps include the lifeways and geographical range of early foragers, as well as detailed regional settlement histories. Intensive excavations coupled with new archaeobiological methods are needed to unpack the range of human impacts, and findings must be more closely integrated with ecological and palaeoecological data.

Historical fire regimes are not well described, and little is known about contemporary regimes in drier regions that are more likely to be fire-adapted. For example, did human activities in the southern-central highlands help shape the tapia tree-dominated grasslands that burn annually today (Kull & Birkenshaw 2022)? And why have landscape-scale fires in Madagascar's grassy biomes declined at a faster rate in the twenty-first century than in most other regions of the world (Phelps et al. 2022)? Links between contemporary human activities, erosion and gully formation demand further investigation, coupled with a deeper understanding of landscape management techniques in rural communities (Cox et al. 2024).

Filling these gaps will increase our knowledge of the past and – crucially – inform decision-making about environmental management and conservation priorities. The task is urgent, as anthropogenic climate changes continue to modify contemporary disturbance regimes. Landscape management strategies must incorporate not only historical evidence but also the present stewardship practices of people who make their living on the land. Today, conservation efforts focus primarily on eastern rainforests, western dry forests and spiny thickets in the south. Grassy biomes exhibiting high levels of biodiversity should also be recognized as priority areas.

Returning to our first point in this Comment, we agree with William Cronon (1992): '... narratives remain our chief moral compass in the world. Because we use them to motivate and explain our actions, the stories we tell change the way we act in the world.' The dregs of a flawed colonial story must finally be dispensed with and replaced by a conceptual framework with solid foundations that support more accurate and nuanced accounts of Madagascar's past.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0376892925000098.

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