Received: 17 September 2024 | Revised: 23 January 2025 | Accepted: 6 February 2025

DOI: 10.1002/ecm.70011

ECOLOGICAL MONOGRAPHS
ECOLOGICAL SOCIETY OF AMERICA

REVIEW

Advancing transdisciplinary research on Madagascar's grassy biomes to support resilience in ecosystems and livelihoods

Leanne N. Phelps[1,2,3,4] | **Estelle Razanatsoa**[5,6] | **Dylan S. Davis**[3,4,7] | **Jan Hackel**[8,9] | **Tanambelo Rasolondrainy**[10] | **George P. Tiley**[11] | **David Burney**[12] | **Ronadh Cox**[13] | **Laurie Godfrey**[14] | **Gareth P. Hempson**[15,16] | **Sean Hixon**[17,18] | **Tobias Andermann**[19] | **Sylvie Andriambololonera**[20] | **Lala Roger Andriamiarisoa**[20,21] | **Alexandre Antonelli**[22,23,24] | **Guillaume Besnard**[25] | **Chris Birkinshaw**[20] | **William Bond**[22] | **Lounès Chikhi**[25,26] | **Víctor Fernández-García**[27,28] | **Lindsey Gillson**[5] | **Simon Haberle**[29,30] | **James Hansford**[31,32,33] | **Grant S. Joseph**[34] | **Christian A. Kull**[28] | **Chiamaka L. Mangut**[3,4] | **Rob Marchant**[35] | **Vincent Montade**[36] | **Karen V. Pham**[37] | **David Rabehevitra**[11] | **Ute Radespiel**[38] | **Jeannie Raharimampionona**[20] | **Mamy Tiana Rajaonah**[11] | **Nantenaina Rakotomalala**[11] | **Tanjona Ramiadantsoa**[39,40] | **Botovao Auguste Ramiandrisoa**[6,40] | **Hery Lisy Tiana Ranarijaona**[6,41] | **Tianjanahary Randriamboavonjy**[11] | **Fenitra Randrianarimanana**[11,42] | **Fetra Randriatsara**[5] | **Joelisoa Ratsirarson**[43,44] | **Andriantsilavo Hery Isandratana Razafimanantsoa**[5,45] | **Jordi Salmona**[25] | **Karen Samonds**[32] | **Nick Scroxton**[46] | **Colleen Seymour**[34,47] | **Travis S. Steffens**[48,49] | **Helena Teixeira**[38,50] | **Ny Riavo G. Voarintsoa**[51] | **Patrick O. Waeber**[52,53] | **Lucienne Wilmé**[20,54] | **Anne D. Yoder**[55] | **Elliot Convery Fisher**[1,2] | **Cédrique Solofondranohatra**[40] | **Tobias van Elst**[38] | **Brooke Crowley**[56,57] | **Kristina Douglass**[3,4] | **Maria S. Vorontsova**[11] | **Caroline E. R. Lehmann**[1,2]

Brooke Crowley, Kristina Douglass, Maria S. Vorontsova, and Caroline E. R. Lehmann contributed equally to the work reported here.

For affiliations refer to page 19

Ecological Monographs. 2025;95:e70011.
https://doi.org/10.1002/ecm.70011

Correspondence
Leanne N. Phelps
Email: leannenphelps@gmail.com

Funding information
Schweizerischer Nationalfonds zur Förderung der Wissenschaftlichen Forschung, Grant/Award Numbers: P2LAP2_187745, P2LAP2_187745/2, P500PN_206663, P500PN_206663/2; European Union's Horizon 2020, Grant/Award Number: 101026923; Swedish Research Council, Grant/Award Number: 2019-05191; Swedish Foundation for Strategic Environmental Research MISTRA (Project BioPath); Royal Botanic Gardens, Kew; Swiss Network for International Studies; Laboratoire d'Excellence (LABEX), Grant/Award Numbers: ANR-10-LABX-2501, ANR-10-LABX-0041

Handling Editor: Andrew B. Davies

Abstract

Grassy biomes (savanna and grasslands) are globally extensive and host a unique biodiversity that is of central importance to human livelihoods. We focus here on the island of Madagascar—a microcosm of the global tropics, covered in 80% grassy biomes—to illustrate how transdisciplinary approaches to research can clarify ecosystem dynamics, from evolutionary history to human land use. Research on Madagascar's human-environment interactions has sparked debates about the role of past and current land use in shaping grassy biomes (e.g., pastoralism, cultivation, fire use). These debates echo those in other regions globally, and highlight obstacles to understanding and supporting both ecosystem and livelihood resilience. Like many tropical biodiversity hotspots, Madagascar faces converging challenges that can be aided by transdisciplinary research, including food and health insecurity, economic inequities, biodiversity loss, climate change, land conversion, and limited resource access. We present a framework to guide transdisciplinary research centered on improved understanding and management of grassy biomes on Madagascar by: (1) establishing a globally common terminology; (2) summarizing data contributions and scientific knowledge gaps relating to Madagascar's grassy biomes; (3) identifying priority research questions for Madagascar with applicability in other regions; and (4) highlighting transdisciplinary, inclusive approaches to research that can co-benefit people and the ecosystems with which they interact.

KEYWORDS
anthropogenic, disturbance dynamics, ecosystems, grassland, grassy biomes, grassy ecosystems, land conversion, land use and land cover change (LULCC), land use, landscape ecology, livelihoods, open ecosystems, savanna

INTRODUCTION

Covering ~40% of the Earth's vegetated land surface (Buisson et al., 2022; Lehmann et al., 2019; Parr et al., 2014), grassy biomes are open landscapes maintained through a combination of climatic forces and disturbance dynamics. Fire, grazing, and human land use regimes modify and maintain grassy ecosystems, which in turn support millions of livelihoods worldwide (Box 1; Bardgett et al., 2021; Lehmann & Parr, 2016; Osborne et al., 2018; White et al., 2000, 1983; Andela et al., 2017). Grassy biomes are fundamental to human well-being globally, and people play diverse roles in shaping these ecosystems, such as managing herbivory through pastoralism, converting land for cultivation, and prescribed burning for a variety of socio-ecological applications (e.g., Alvarado et al., 2018; Berlinck et al., 2021; Buisson, 2019; Di Lernia & Cremaschi, 1996; Marshall et al., 2018; Mistry et al., 2005; Pastro et al., 2011).

Tropical grassy biomes include savannas and grasslands, which became established during the Late Miocene and Pliocene (8–3 million years ago) through a complex interplay of climate, fire, and herbivory (Bond et al., 2008; Cerling et al., 1997; Edwards et al., 2010; Willis et al., 2008). Despite their relatively young evolutionary age, these ancient grassy biomes can support high levels of biodiversity and endemism (Figure 1; Antonelli et al., 2022; Bond, 2016; Lehmann et al., 2022; Murphy et al., 2016; Parr et al., 2014; Vorontsova et al., 2016), and contribute to shaping biogeographical and biodiversity patterns (e.g., by forming corridors or barriers that can favor differentiation, diversity and micro-endemism between forested areas: Quéméré et al., 2012; Sgarlata et al., 2019; Wilmé et al., 2006). Grassy biomes also make major contributions to global biogeochemical cycling (e.g., by holding large amounts of soil and biomass carbon; Abreu et al., 2017; Grace et al., 2006; Jones et al., 2019; Lange et al., 2015; Zhou et al., 2022), and are foundational environments in which much of human evolution and changes in land use (e.g., the development of food production: pastoralism, cultivation) have taken place (Bengtsson et al., 2019; Cerling et al., 2011;

BOX 1

Recommended grassy biome terminology for transdisciplinary communication, building on previously established definitions (e.g., Aubréville, 1957; Aubréville et al., 1958; White, 1983; Moat & Smith 2007), and incorporating consideration of vegetation function (i.e., plant traits reflecting ecophysiological functioning). Terms include recommended ecosystem types (1–3) and disturbance dynamics (8–10). Due to ambiguity between studies, we do not recommend use of "generalized terms" (5–7) unless accompanied by precise open and closed ecosystem terminology; for mixed vegetation types, where applicable, we recommend the term "vegetation mosaic" (4) with ecosystem types specified. Here, we define core terms for grassy biome research, but additional terms (e.g., wetlands) are also relevant as they can support graminoids and herbivore habitats.

1. **Open ecosystem**: (Malagasy*: [vernacular] *hiaka, monto*; French: *milieu ouvert*) Umbrella term for all ecosystems where plants recruit in sunlit environments due to abiotic factors (e.g., climate, soil chemistry, hydrology) that support discontinuous or absent woody cover (trees, shrubs), or edaphic and/or disturbance processes that prevent formation of a closed vegetation canopy. Examples include shrublands, grasslands, and savannas, often maintained by fire and herbivores.
    1.1 **Grassy biomes**: (Malagasy*: [vernacular] *fatra, fatrambe, banja*; French: *formations graminéennes*; *zones herbeuses*) Umbrella term for ecosystems with a continuous grass-dominated ground layer, with or without woody plants (including grasslands and savannas). Grassy biomes often include non-grass species in the ground layer, for example, sedges and a wide diversity of dicots.
        1.1.1 **Savannas** (or Savannahs): (Malagasy*: [vernacular] *banja*; French: *savane*) Open ecosystems with a ground layer dominated by herbaceous plants and variable densities of woody plants (trees and shrubs), which are typically maintained by fire and/or herbivory. Herbivores tend to play a greater role in controlling woody cover below climate-potential in drier savannas, while fire typically prevents transitions to closed-canopy ecosystems in wetter regions.
        1.1.2 **Grasslands**: (Malagasy*: [vernacular] *bozaka, ahi-dambo***; French: prairies) Open ecosystems dominated by a continuous herbaceous layer with little to no tree cover (e.g., prairie, steppe); however, the transition zone between savanna and grassland can be broad. In grasslands, abiotic factors such as cold and frost or seasonally anoxic water-logged soils typically play a major role in limiting tree establishment, with fire and herbivory playing more secondary roles in restricting tree cover. Grasslands frequently have a species-rich and functionally diverse herbaceous plant community, which is often slow to recover after anthropogenic disturbance (e.g., plowing).
2. **Closed ecosystem** (or forest): (Malagasy*: [vernacular] *ala, kirihitr'ala*; French: *milieu fermé, forêt*) Umbrella term for ecosystems with a continuous vegetation canopy dominated by woody species (i.e., forest, thicket, shrubland), which prevents light from penetrating the understory, and a ground layer dominated by fire-sensitive herbaceous cover (which may include C_3 grasses that tolerate low or mixed light) and leaf litter, where seedlings can recruit in the shade. Forest canopies may be seasonally open (deciduous).
3. **Heathlands** (or ericoid thicket): (Malagasy*: [vernacular] *kirihitra, ala-kirihitra, alamaiky, ringy, anjavidy*; Français: *fourré éricoïde*) A shrubland, shrub ecosystem, or closed-canopy dwarf vegetation dominated by ericoids (Ericaceae species) and similar shrubs. Heathlands can occur in various densities and heights, may include occasional trees, and may transition into other ecosystems (e.g., forest, savanna). They are most abundant at higher elevations and latitudes, but can also occur at lower elevations. Heathlands can include a grassy component, but are often too cool, moist, and dense to support C4 grasses.
4. **Vegetation mosaics**: (Malagasy*: mifangaro zavamaniry; French: *mosaïque de végétation*) Generalized term for a mix of two or more functionally distinct ecosystems in a landscape, for example, open and closed ecosystems, or microhabitats characterized by different processes and functions, for example, a mix of forest patches, fire- or grazing-driven grassland, heathland, and patchy transitions along forest or lake margins. Mosaics are often associated with topographic heterogeneity (e.g., variability in local hydrology, geomorphology, slope, soil, microclimate, fire susceptibility, herbivory), but may share some environmental features between vegetation types (e.g., climate, geology, species overlap). The stability and resilience of mosaics vary, especially depending upon the scale of observation.
5. **Woodland**: (Malagasy*: [vernacular] *ala-tapia, ala malalaka*; *ala ringitra*; Français: *formation arborée*) Generalized term used to refer to ecosystems that contain woody vegetation and are maintained by a

variety of biotic and abiotic factors (e.g., precipitation, seasonality, geology, soils, hydrology, fire, grazing). As functional characteristics central to ecosystem differentiation are often overlooked with this term (Griffith et al., 2017; Ratnam et al., 2011), we recommend avoiding its use without incorporating precise terminology that reflects vegetation function (i.e., vegetation described in terms of "forest" or "savanna" with discussion of relevant disturbance processes). Past applications of this term have varied widely, which can lead to vegetation misclassification, including both open woodlands (savanna) with a fire or herbivory-adapted understory dominated by grasses, and closed woodlands (forest) with a shade-tolerant understory.

6. **Natural vegetation/ecosystems**: (Malagasy*: *zava-maniry voajanahary, tontolo voajanahary*; Français: *végétation/ écosystèmes naturel(le)s*) Generalized term for environments that are relatively unmodified by human activity. However, such environments are either extremely rare or nonexistent today, and nuanced land use impacts are often difficult to observe and measure in the past and present (e.g., Phelps & Kaplan, 2017). We instead recommend a pragmatic approach focused on explicit consideration of both land cover and land use: that is, specifying vegetation type (e.g., "forest," "savanna," "grassland") and characterizing the associated processes, heterogeneity, and extent to which humans and other organisms modify or drive biodiversity and ecosystem function (e.g., as in Phelps & Kaplan, 2017). Highly modified environments include, for example., urban areas, monoculture plantations, and anthropogenically denuded landscapes.
7. **Secondary vegetation**: (Malagasy*: [vernacular] *savoka*; Francais: *végétation secondaire*) Generalized term for vegetation that replaces a previous form or composition. However, this term is frequently used to describe depauperate or species-poor vegetation that replaces "natural" or a previous form of vegetation through anthropogenic disturbance (e.g., as a result of land clearance for agriculture, charcoal production, or tree plantations). While species-poor vegetation can result from anthropogenic modifications, we do not recommend using "secondary vegetation" to describe species-poor vegetation, as all vegetation has been modified to varying degrees. Instead, we recommend that research focuses on explicitly characterizing land cover (e.g., "forest," "savanna," "grassland") and associated disturbance processes, including the qualities and degree of modification, and how these affect vegetation characteristics (e.g., composition, structure, extent). For example, where forest, savanna, and grassland have been degraded or converted, these areas may be referred to as "degraded," "converted," or "species-poor" forest, savanna, or grassland—and described in terms of land use characteristics where relevant (e.g., "rangeland," "pasture," "cropland": Phelps & Kaplan, 2017).
8. **Rangeland** (or pasture): (Malagasy*: [vernacular] kijana; French: *pâturage*) Definitions of rangeland and pasture vary widely (Phelps & Kaplan, 2017), but tend to refer to vegetated land used for partial or full grazing/browsing of livestock.
9. **Grazers, browsers, and mixed feeders**: (Malagasy*: [vernacular] *biby mpiraoka ahitra, biby mpihinan-javamaniry*; Français: *paisseurs, brouteurs et autres herbivores*) Herbivore diets exist on a continuum from grazing to browsing, with diet preferences determined by physiology and morphology (e.g., dentition and digestion), environmental conditions, and competition. Herbivores that rely primarily on grazing (e.g., sheep, cattle) tend to consume ground cover (graminoid grasses and sedges, herbs), while herbivores that rely primarily on browsing (e.g., folivorous lemurs) tend to consume woody shrubs and trees (e.g., leaves, bark). Mixed feeders (e.g., goats, giant tortoises) consume a combination of these different types of plant foods, and can have highly variable diets.
10. **Fire regimes**: (Malagasy*: *toetry ny afo*; Français: *régimes de feu*) Patterns in fire characteristics (e.g., seasonality, frequency, size, intensity) observable at the landscape scale. For example, landscape-scale fires (>21 ha: Giglio et al., 2018; Phelps et al., 2022) on Madagascar range from large, frequent, and regular at high elevations in the Central Highlands, to relatively small, infrequent, and variable in eastern humid bioclimates (Phelps et al., 2022). Small-scale fires (<21 ha) also have cumulatively important impacts, which vary within fire regimes (e.g., Fernández-García & Kull, 2023; Roteta et al., 2019; Zhao, Li, et al., 2021; Fernàndez-García, Phelps et al., 2024). Fires can be ignited by people or lightning, with burned area determined by factors such as precipitation, weather, and other forms of disturbance.

*Malagasy terms are drawn from several dialects, reflecting linguistic diversity across the island. We include both scientific terms and a range of vernacular (italics) terms, with further work required to document extensive and variable Malagasy terminologies.

**Note that this term also describes grasses with spiky leaves, such as *Heteropogon contortus*.

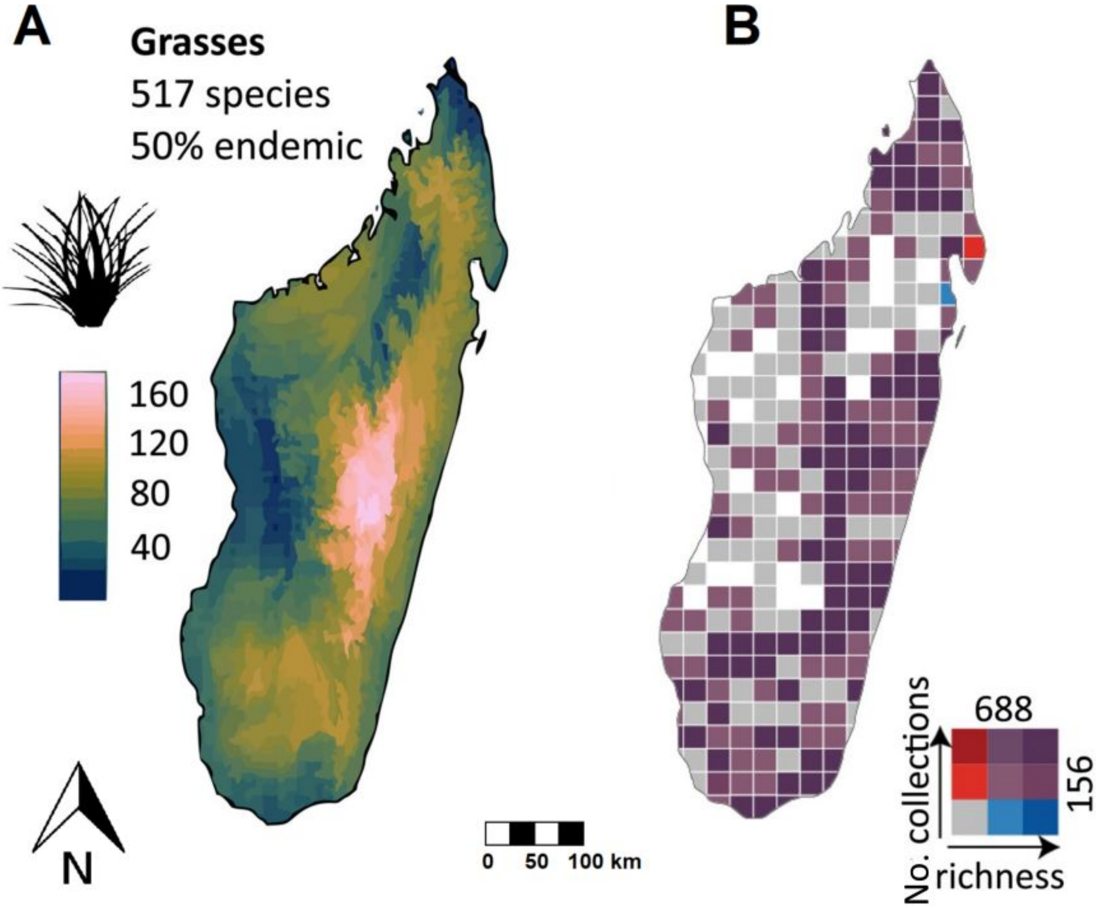


FIGURE 1 Grass (Poaceae) diversity patterns on Madagascar. (A) Species richness based on species distribution modeling with available occurrence records (see Antonelli et al., 2022 for details; 2.5-km^2 resolution). (B) Numbers of specimen records in herbarium collections and combined number of species, per 50 × 50 km grid cell (white denotes an absence of records). Figure adapted from Antonelli et al. (2022).

Domínguez-Rodrigo, 2014; Potts et al., 2018; Strömberg & Staver, 2022). Yet, grassy biomes are often dismissed as degraded or wasteland, without empirical investigation of biodiversity or land use benefits (Bardgett et al., 2021; Bond, 2016; Parr et al., 2014; Stevens et al., 2022; Strömberg & Staver, 2022).

Livelihood and ecosystem health depend on improved understanding of grassy biome dynamics, as illustrated by Madagascar

Like many biodiversity hotspots, the island of Madagascar is confronted with globally relevant challenges of managing biodiversity conservation and ecosystem function while navigating food and health insecurity, economic inequities, including extreme poverty, rapid population growth, unstable access to resources and international investments, and climate change vulnerability (Barrett et al., 2011; Carret, 2013; Eckstein et al., 2018; Glamann et al., 2017; Harvey et al., 2014; Herrera et al., 2021; Makoni, 2021; Ralimanana et al., 2022; Scherer et al., 2020; UNICEF, 2021). As of 2021, Malagasy grassy biomes were reported to provision nearly nine million head of cattle (FAOSTAT, 2021), which offer essential support for livelihoods, including household incomes, insurance against crop failure, and are important elements of cultural identity (Steinfeld et al., 2006; World Bank, 2003).

The Holocene expansion of grassy biomes on Madagascar, and Africa more broadly, is often associated with the spread of agricultural land use (i.e., pastoralism and cultivation) and changes in fire and herbivory (e.g., Madagascar: Burney et al., 2003; Burns et al., 2016; Crowley & Samonds, 2013; Godfrey et al., 2019; Razanatsoa et al., 2022; Voarintsoa et al., 2017; Razafimanantsoa et al., 2024; continental Africa: Phelps, Broennimann, et al., 2020; Phelps, Chevalier, et al., 2020). However, the causal interrelationships between the spread of agriculture and grassy biome expansion are complex and still poorly understood across sub-Saharan Africa, with transdisciplinary research required to disentangle drivers of change, and to advance the understanding of human resilience and adaptation in response to environmental change (e.g., the termination of the African Humid Period, from ca. 5500 years BP: Phelps, Broennimann, et al., 2020; Phelps, Chevalier, et al., 2020; Phelps, Kull, et al., in press; Phelps, et al., 2025b). Recent debates about human-environment interactions on Madagascar highlight opportunities and challenges to tropical grassy biome research and management (e.g., debates about the extent of these biomes prior to human arrivals and the role of people and herbivory in shaping the island's grassy biomes: Alva et al., 2022; Dewar et al., 2013; Douglass, Hixon, et al., 2019; Douglass, Morales, et al., 2019; Douglass, Walz, et al., 2019; Godfrey & Crowley, 2016; Gommery et al., 2011; Hansford et al., 2018; Hixon et al., 2018; Joseph & Seymour, 2020; Lehmann et al., 2022; Vorontsova et al., 2016).

On Madagascar and across the globe, pastoralism can occur in virtually any biome (Phelps & Kaplan, 2017), and is associated with pastoral fires, which are often assumed or hypothesized as a primary driver of grassy biome expansion (e.g., Kaufmann & Tsirahamba, 2006; Phelps et al., 2022; Phelps, Broennimann, et al., 2020; Wright, 2017). However, the long-term drivers of vegetation change in grassy ecosystems are complex and debated, especially regarding the role of Holocene human subsistence practices (e.g., pastoralism and cultivation, and associated fire use: Brierley et al., 2018; Crowther et al., 2016; Dewar & Wright, 1993; Godfrey et al., 2019; Hixon, Curtis, Brenner, et al., 2021; Hixon, Douglass, Godfrey, et al., 2021; Hixon, Douglass, et al., 2021; Manning & Timpson, 2014; Phelps, Broennimann, et al., 2020; Wright, 2017). Understanding the long-term drivers of vegetation change is further complicated by recent large-scale land conversion and degradation tied to colonialism, urbanization, population growth, and global market demands (e.g., for Madagascar: charcoal production and logging: Hoang & Kanemoto, 2021; Zhu, 2018; Jarosz, 1993; Kanemoto, 2021; Moser, 2008; Waeber et al., 2015; Vieilledent et al., 2018). Inadequate management of fire risk (e.g., inappropriate fire suppression leading to increased fuel load; lack of infrastructure to contain forest fires) and extreme weather conditions can also cause fire to escape into and damage forest stands, especially when combined with degradation near forest edges (e.g., Cochrane & Bowman, 2021; Kull & Lehmann, 2022; Veldman et al., 2019; Zhao, Yu, et al., 2021).

Combined with the aforementioned factors, limited or patchy palaeo-record coverage across Africa and ambiguities in vegetation definitions also make it difficult to determine the extent of Holocene vegetation change and the role of human activities (e.g., Fairhead & Leach, 1996; Griffith et al., 2017; Harper et al., 2007; Lambin et al., 2001; Parr et al., 2014; Phelps et al., 2024; Phelps, Broennimann, et al., 2020; Phelps & Kaplan, 2017)—as has been extensively debated for Madagascar—and complicates restoration and conservation targets (Burney et al., 1997, 2003; Bond et al., 2008; Crowley et al., 2021; Godfrey & Crowley, 2016; Vorontsova et al., 2016; albeit see Montade et al., 2024; Razafimanantsoa et al., 2024; Quéměre et al., 2012; Salmona et al., 2017; Teixeira, Montade, et al., 2021; Teixeira, Salmona, et al., 2021; Tiley et al., 2022). Furthermore, biogeophysical feedbacks shape grassy biomes in a variety of ways, but their effects are still poorly known (Armitage et al., 2015; Claussen et al., 1999). Many of these are linked to changes in climate, atmospheric CO_2, hydrology, geomorphology, and competition (Armitage et al., 2015; Bond et al., 2003; Bond & Midgley, 2012; Goel et al., 2020; Ramiadantsoa & Solofondranohatra, 2021). Closing these knowledge gaps requires an assessment of research practices on grassy biome dynamics.

We present a framework to advance transdisciplinary research and management of grassy biomes on Madagascar and their relationship to other biomes, including forests. By focusing on Madagascar as a microcosm of the broader tropics (e.g., Phelps et al., 2022; Phelps et al., in press), our framework is applicable to other ecosystems across the globe and will shed light on challenges and opportunities faced in grassy biome studies more broadly. In the four sections below, we present our Madagascar-centered framework, which (1) outlines a globally common terminology for grassy biome research, (2) summarizes the contributions, limitations, and knowledge gaps of research on Malagasy grassy biomes with relevance to other regions, (3) identifies priority research questions for Madagascar with applicability in other regions, and (4) highlights transdisciplinary approaches that resolve key knowledge gaps and co-benefit ecosystems and livelihoods. Our framework aims to improve scientific understanding, increase transdisciplinary collaboration, and promote more equitable and sustainable management of grassy biomes on Madagascar and globally.

OUT OF THE WOODS: ESTABLISHING GLOBALLY APPLICABLE, FUNCTIONAL TERMINOLOGY FOR GRASSY BIOME RESEARCH

Transdisciplinary engagement is critical for ecosystem restoration and management (Bowman et al., 2020; Knapp & Collins, 2019; Zhao, Yu, et al., 2021). However, a lack of effective communication across studies, disciplines, and stakeholders can result in varied terminology and misunderstandings, and detract from scientific advances, inclusive decision-making, and scientifically informed policy advice (Biggs et al., 2022; Davis, 2020a; Descola, 2013; Gardin, 1980; Harris, 2018). For example, assessments of vegetation distribution and the degree to which it has changed over time vary globally due to different definitions and classifications, especially as these relate to disturbance processes such as land use, fire, and herbivory (e.g., Fairhead & Leach, 1996; Griffith et al., 2017; Harper et al., 2007; Lambin et al., 2001; Phelps & Kaplan, 2017). In particular, definitions often focus on vegetation structure or composition (e.g., canopy cover: Dixon et al., 2014) but lack explicit consideration of vegetation function (i.e., plant traits reflecting ecophysiological functioning), which is needed to adequately define ecosystem function and to avoid vegetation misclassification (Keith et al., 2022). Furthermore, the implications of changing vegetation composition and extent can be perceived and valued differently among stakeholders operating at different scales and with different definitions and environmental baselines (e.g., local communities, government officials, conservationists, scientific researchers: Alleway et al., 2023). As a first step toward improving engagement in grassy biome research and management, we summarize (Box 1) and illustrate (Figures 2 and 3) key grassy biome terminology that is globally applicable.

Major debates about the Holocene history of grassy biomes on Madagascar have been fueled by ambiguity around land cover and land use terms such as "woodland," "grassy biome," "savanna," "grassland," "(pseudo-)steppe," "pasture," "open ecosystems," "natural," "ancient," and "anthropogenic" (Box 1; e.g., Alvarado et al., 2015; Joseph & Seymour, 2020, 2021; Lehmann et al., 2021; Lowry II et al., 1997; Samonds et al., 2019; Solofondranohatra et al., 2020; Vorontsova et al., 2016). These debates reflect pervasive issues with vegetation classifications worldwide, which can stem from difficulties establishing discrete categories for a continuum of vegetation that is: highly variable in space and time; observed with diverse data types and resolutions; and interacting with complex disturbance dynamics that are not easily categorized (e.g., Chazdon et al., 2016; Griffith et al., 2017; Lehmann et al., 2011; Phelps & Kaplan, 2017; Ratnam et al., 2011; Staver et al., 2011). For example, different applications of the umbrella term "woodland" can include or exclude grassy biomes (e.g., "Miombo woodlands" in south-central Africa can occur as savanna or dry forest depending upon disturbance factors). Failure to distinguish between open ecosystems (e.g., heavily wooded savannas, which typically have a shade-intolerant C_4 grassy matrix) and closed ecosystems (i.e., forests, which generally have a sparser understory and do not support C_4 grasses) leads to variability and inaccuracies when calculating deforestation rates and assessing levels of degradation, with major implications for understanding the drivers of vegetation change and developing effective land management strategies (e.g., Bond et al., 2022; Griffith et al., 2017). Furthermore, there is a need for common

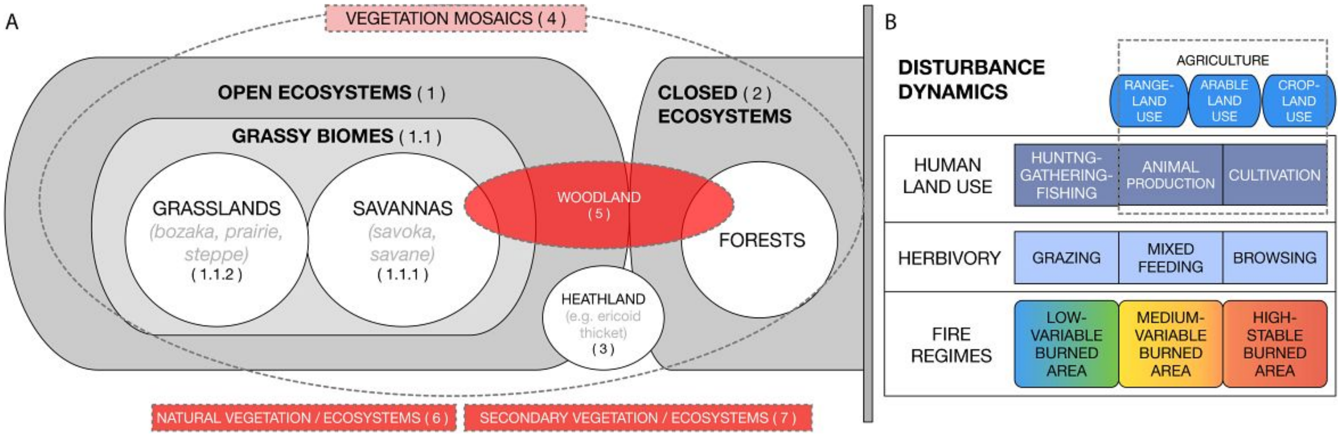


FIGURE 2 Conceptual diagram of key grassy biome terminology (with example illustrations in Figure 3), to navigate pervasive issues with vegetation classifications worldwide (e.g., Chazdon et al., 2016; Griffith et al., 2017; Keith et al., 2022; Lehmann et al., 2011; Phelps & Kaplan, 2017; Ratnam et al., 2011; Staver et al., 2011). Numbers in parentheses correspond to definitions in Box 1. Dotted lines indicate generalized terms, which may apply to closed or open ecosystems. (A) Key vegetation terms and their conceptual relationships. (B) Disturbance dynamics such as human land use, herbivory, and fire, which are conceptually distinct from vegetation cover, and can occur on virtually any vegetation type (Phelps et al., 2022; Phelps & Kaplan, 2017). Ambiguous use of generalized terms such as "woodland," "natural vegetation," or "secondary vegetation" (red) can lead to misunderstandings between studies, and are therefore not recommended unless accompanied by precise terminology. Additional ecosystems not mentioned here (e.g., wetlands) are also relevant; a variety of additional factors influence vegetation change in grassy biomes, but are not the focus of this diagram (e.g., climate, soils, geology, atmospheric CO_2).

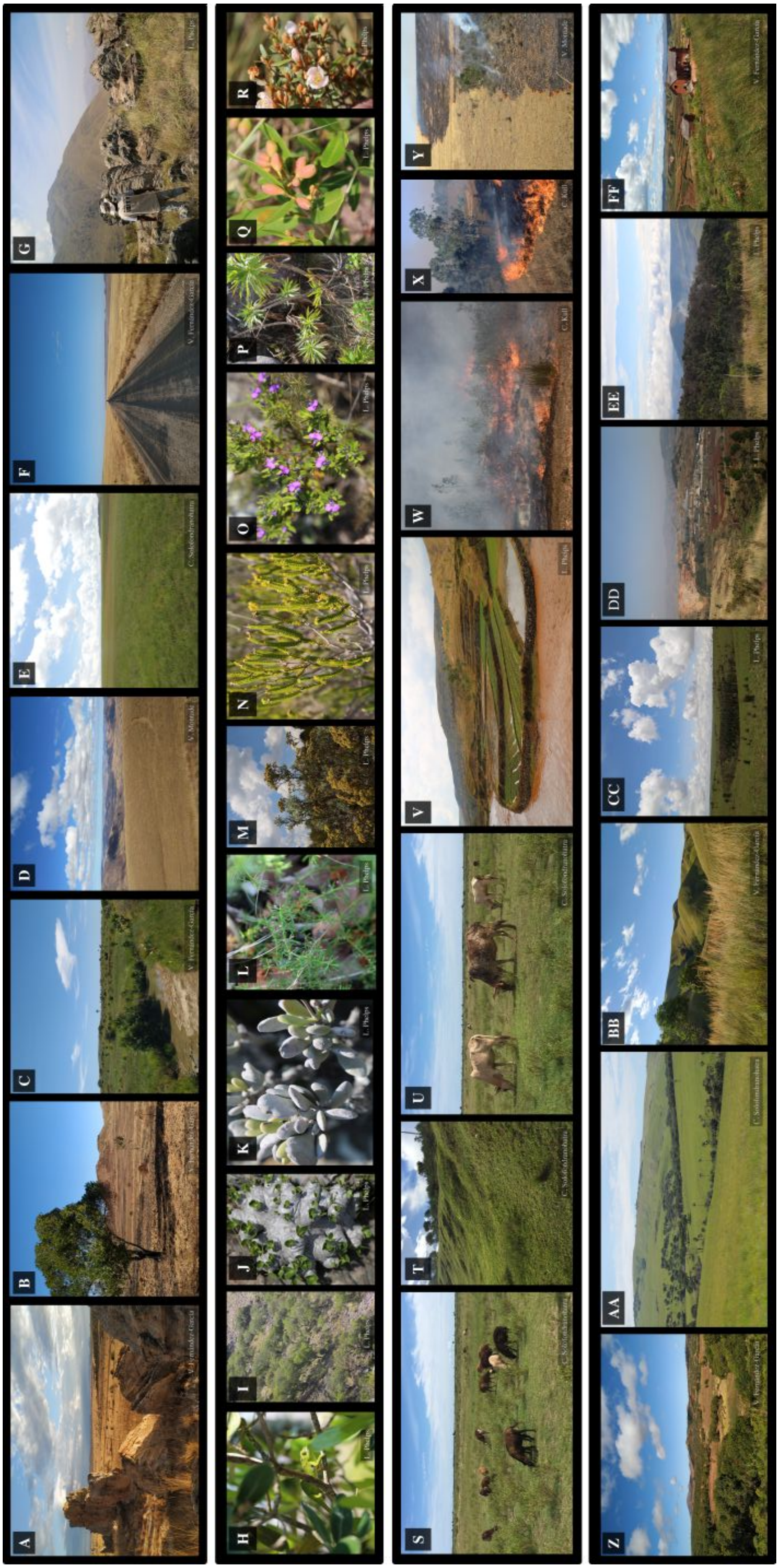


FIGURE 3 (A–G) Examples of grassy biomes in Madagascar's highlands. (H–R) Diversity of species occurring in Madagascar's grassy biomes (many endemic), such as (H) chameleons (*Furcifer minor* [tapia, savanna]), (I) fire-adapted savanna trees (*Uapaca bojeri*), (J, K) succulents ([J] *Pachypodium brevicaule*, [K] *Kalanchoe integrifolia*), (L–R) shrubs ([L] *Asparagus madecassus*, [M] *Helichrysum* sp., [N] Ericaceae, [O] *Polygala grandidieri*, [P] *Dialypetalum compactum*, [Q] *Abrahamia ibityensis*, [R] *Xerochlamys bojeriana*), and orchids. (S–Y) Examples of grassy biome disturbance dynamics, for example, (S–U) livestock herbivory, (V) cropland, and (W–Y) fire. (Z–FF) Examples of vegetation mosaics on Madagascar. Photo credits: (A–C, F, Z, BB, FF) Víctor Fernández-García; (D, Y) Vincent Montade; (E, S–U, AA) Cédrique Solofondranohatra; (G–R, V, CC–EE) Leanne N. Phelps; (W, X) Christian Kull.

recognition that vegetation characteristics extend beyond "grasses" versus "trees" (e.g., Crowley et al., 2021; Godfrey & Crowley, 2016; Solofondranohatra et al., 2020; Vorontsova et al., 2016). Grassy biomes can be composed of a wide variety of graminoids (e.g., grasses, sedges), non-graminoid monocots (e.g., lilies, orchids), herbaceous dicots, and woody plants (e.g., geoxyles [underground trees], trees, shrubs). These different types of vegetation support different types of herbivory and have variable tolerance to other kinds of disturbance (Box 1).

Interpretation of the terms "natural," "ancient," and "anthropogenic" also vary widely—sometimes treated as overlapping and other times treated as mutually exclusive (Joseph & Seymour, 2021; Marchant, 2021; Marchant et al., 2018; Salmona et al., 2017; Silva et al., 2022; Solofondranohatra et al., 2020). Like all modern biomes worldwide, tropical grassy biomes are human-modified to some degree (Ellis et al., 2021), with a variety of effects on ecosystem function and human livelihoods. Landscapes with apparent anthropogenic modifications are often implicitly assumed to have less biodiversity and lower ecosystem value than landscapes that appear less modified, with local land use practices typically assumed to drive loss of biodiversity and ecosystem function (Cronon, 1996; Ellis et al., 2021; Fletcher et al., 2021; Kull et al., 2013; Taylor & Lennon, 2011). However, empirical investigation of the relationships between disturbance, biodiversity, and ecosystem function is required, as different forms and intensities of anthropogenic disturbance can modify biodiversity and the range of available habitats to varying degrees (e.g., Marshall et al., 2018; Mayor et al., 2012; Siebert & Belsky, 2014; Wurz et al., 2022). This issue thus extends into a political space: if common ground and effective management decisions are to be reached, there is a need for multi-scalar research that offers clear definitions and clarity about the values and assumptions of multiple stakeholders.

CONNECTING SILOS: ESTABLISHING DATA TYPES, CONTRIBUTIONS, AND SCOPE

For Madagascar and the broader tropics, long-standing assumptions that grassy biomes are largely degraded landscapes have prevented investigations of: their origins and antiquity; temporal changes in their composition and extent; their contributions to livelihoods and ecosystem function; and the processes that shape them (e.g., land use, fire, herbivory) (Bond & Parr, 2010). Such assumptions can persist due to:

1. Lack of communication and collaboration among disciplines, which can lead to disconnects between different data sources (e.g., between archaeological and palaeo-records and modern environmental information, which typically cover different spatial and temporal scales: Dietl et al., 2015; Marchant et al., 2018);
2. Limited spatio-temporal coverage of modern grassy biome surveys and palaeo-records (e.g., on Madagascar: Broothaerts et al., 2023; Burney, 1987; Burney et al., 2004; Gasse & Van Campo, 1998, 2001; Hagl et al., 2021; Razafimanantsoa, 2022; Teixeira, Montade, et al., 2021; continental Africa: Phelps, Broennimann, et al., 2020; Phelps, Chevalier, et al., 2020);
3. Limited understanding of how long-term disturbance processes have shaped the composition and extent of grassy biomes (e.g., Lambin et al., 2001; Lehmann et al., 2014; Phelps et al., 2022; Phelps & Kaplan, 2017) and limited transdisciplinary communication about ecosystem dynamics in modern grassy biomes (e.g., Hempson et al., 2015, 2019; Lehmann et al., 2011; Osborne et al., 2018; Phelps et al., 2022);
4. In some regions, limited understanding of grassy biome contributions to human livelihoods and culture, and associated biodiversity: that is, poor ability to distinguish among species-rich and species-poor grassy ecosystems and their livelihood contributions; a tendency to focus on agricultural productivity or biodiversity rather than co-beneficial management of ecosystem function and livelihoods (e.g., Lehmann & Parr, 2016; Martin et al., 2022; Parr et al., 2014);
5. Environmental management practices centered on institutions, training, and discourse that are historically dominated by forestry (e.g., Appendix S1: Figure S1; Bond & Parr, 2010).

To foster transdisciplinary engagement in grassy biome research and management, we focus on the tropical microcosm of Madagascar to summarize the ways in which combining different types of datasets can advance the understanding of spatio-temporal dynamics in grassy biomes (Figure 4; Phelps et al., 2024). These datasets include: archaeological, palaeoecological, botanical, faunal, ethnographic, ethnohistorical, functional trait, genetic, and geomorphological data, along with data obtained from remote sensing and ecological models. It is our hope that this will inspire grassy biome data compilations in other tropical regions as well. Integrating different data types gathered at various spatio-temporal scales, from local to continental and daily to geological (Figure 4), can advance research and management of tropical grassy biomes. Each data type has inherent strengths and limitations (Appendix S1: Table S1), and therefore multi-archive approaches can reduce misinterpretations and advance the

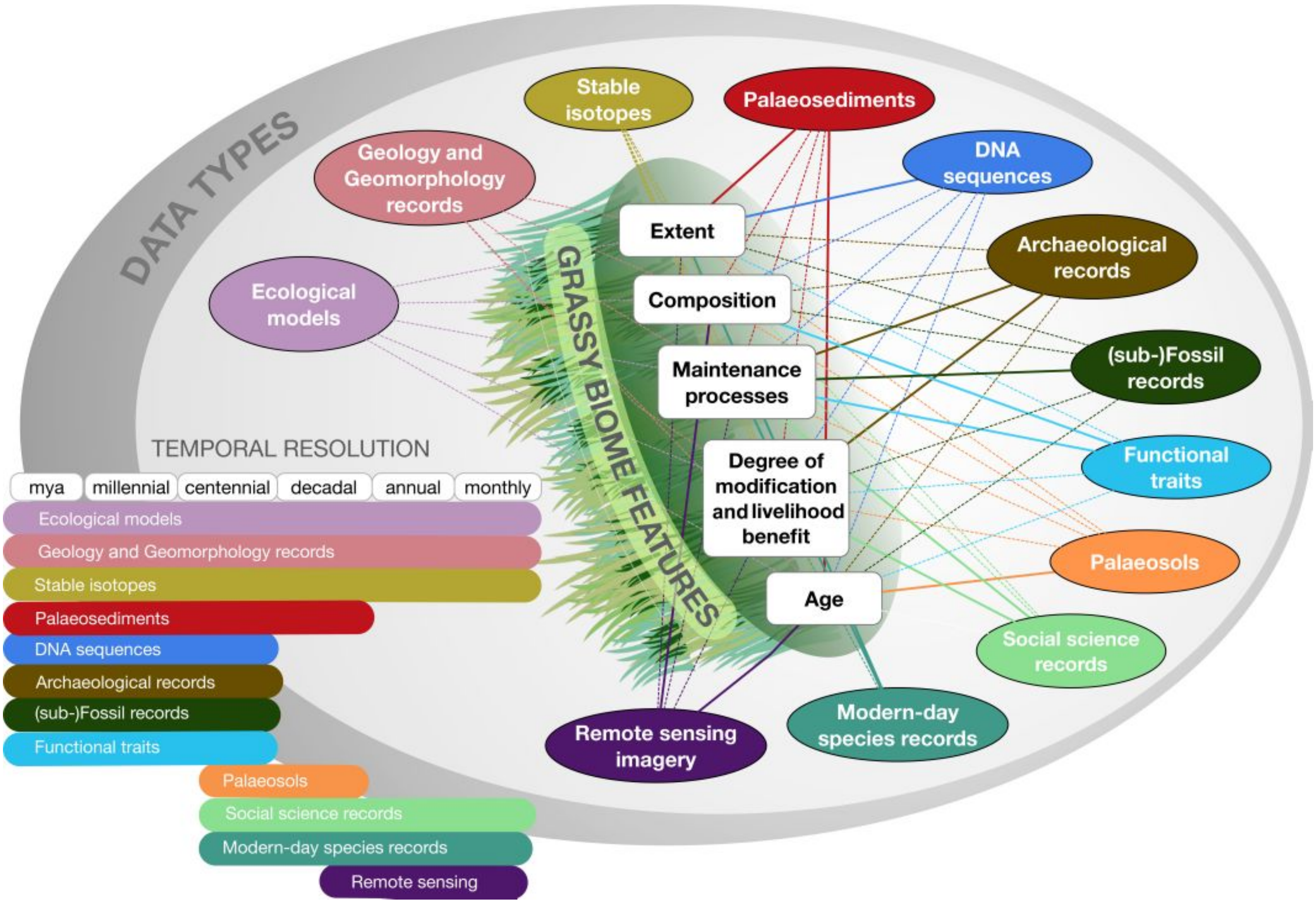


FIGURE 4 Summary of grassy biome data types (Appendix S1: Table S1), their temporal resolution, and relationship to features of vegetation change in grassy biomes. Solid lines: data type provides direct information about a given grassy biome feature; dashed lines: data type offers indirect information about a given grassy biome feature. Some data types can overlap (e.g., for pollen, phytoliths). Illustration credit: Leanne Phelps.

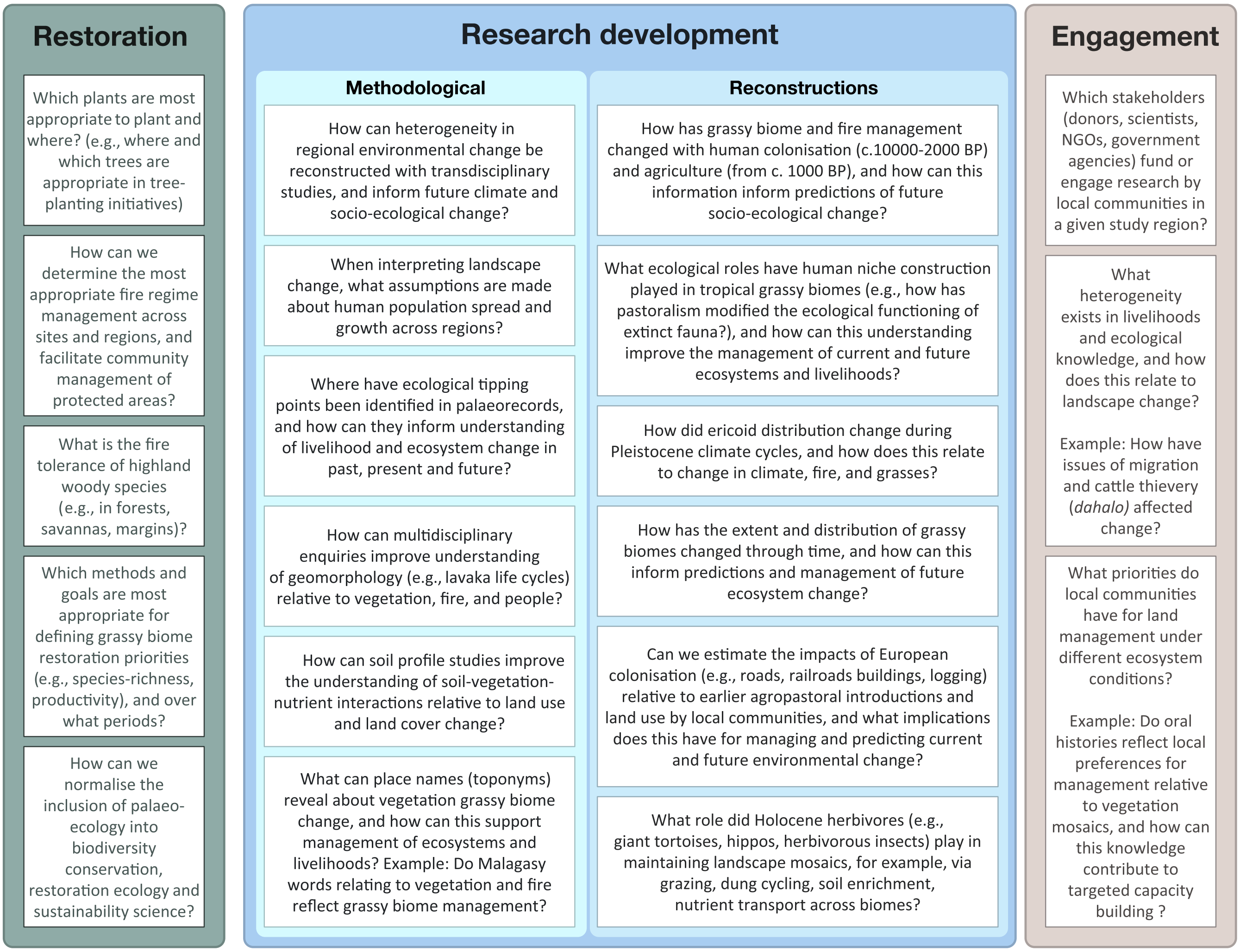
science behind the management of ecosystems and livelihoods.

GREENER PASTURES: TRANSDISCIPLINARY APPROACHES TO GRASSY BIOME RESEARCH, AS ILLUSTRATED BY MADAGASCAR

Effective research and management of grassy biomes requires transdisciplinary approaches that resolve knowledge gaps and foster collaborative and adaptive management of ecosystems and livelihoods. Below, we present 20 key research questions (Figure 5) and three transdisciplinary approaches for advancing our understanding of grassy biomes on Madagascar (Figure 6), which can and should be applied in other regions. Researchers and managers can build on this framework to identify transdisciplinary needs and objectives together with local stakeholders across the tropics (e.g., community members, conservationists, protected area managers, local governmental officials).

Approach 1: Improve integration of past, present, and future datasets in ecosystems research

Combining a variety of data types can offer context about changes in the extent and composition of biomes through time and the drivers of vegetation change (e.g., Figure 4; Appendix S1: Table S1; Antonelli et al., 2022; Ralimanana et al., 2022). This requires data integration across spatial–temporal scales to clarify how past climates and ecological and anthropogenic interactions shape present and future grassy ecosystems (e.g., Alva et al., 2022; Anderson, 2019; Ardalan et al., 2015; Githumbi et al., 2020; Herrera et al., 2017; Wynne-Jones, 2012). For example, there is some consensus regarding the prehuman presence



Restoration

Which plants are most appropriate to plant and where? (e.g., where and which trees are appropriate in tree-planting initiatives)

How can we determine the most appropriate fire regime management across sites and regions, and facilitate community management of protected areas?

What is the fire tolerance of highland woody species (e.g., in forests, savannas, margins)?

Which methods and goals are most appropriate for defining grassy biome restoration priorities (e.g., species-richness, productivity), and over what periods?

How can we normalise the inclusion of palaeo-ecology into biodiversity conservation, restoration ecology and sustainability science?

Research development

Methodological

How can heterogeneity in regional environmental change be reconstructed with transdisciplinary studies, and inform future climate and socio-ecological change?

When interpreting landscape change, what assumptions are made about human population spread and growth across regions?

Where have ecological tipping points been identified in palaeorecords, and how can they inform understanding of livelihood and ecosystem change in past, present and future?

How can multidisciplinary enquiries improve understanding of geomorphology (e.g., lavaka life cycles) relative to vegetation, fire, and people?

How can soil profile studies improve the understanding of soil-vegetation-nutrient interactions relative to land use and land cover change?

What can place names (toponyms) reveal about vegetation grassy biome change, and how can this support management of ecosystems and livelihoods? Example: Do Malagasy words relating to vegetation and fire reflect grassy biome management?

Reconstructions

How has grassy biome and fire management changed with human colonisation (c.10000-2000 BP) and agriculture (from c. 1000 BP), and how can this information inform predictions of future socio-ecological change?

What ecological roles have human niche construction played in tropical grassy biomes (e.g., how has pastoralism modified the ecological functioning of extinct fauna?), and how can this understanding improve the management of current and future ecosystems and livelihoods?

How did ericoid distribution change during Pleistocene climate cycles, and how does this relate to change in climate, fire, and grasses?

How has the extent and distribution of grassy biomes changed through time, and how can this inform predictions and management of future ecosystem change?

Can we estimate the impacts of European colonisation (e.g., roads, railroads buildings, logging) relative to earlier agropastoral introductions and land use by local communities, and what implications does this have for managing and predicting current and future environmental change?

What role did Holocene herbivores (e.g., giant tortoises, hippos, herbivorous insects) play in maintaining landscape mosaics, for example, via grazing, dung cycling, soil enrichment, nutrient transport across biomes?

Engagement

Which stakeholders (donors, scientists, NGOs, government agencies) fund or engage research by local communities in a given study region?

What heterogeneity exists in livelihoods and ecological knowledge, and how does this relate to landscape change?

Example: How have issues of migration and cattle thievery (*dahalo)* affected change?

What priorities do local communities have for land management under different ecosystem conditions?

Example: Do oral histories reflect local preferences for management relative to vegetation mosaics, and how can this knowledge contribute to targeted capacity building ?

FIGURE 5 Top 20 transdisciplinary research questions focused on Madagascar, and of broader applicability in other regions. Questions were collectively prioritized by the coauthors for future research on Madagascar's grassy biomes (see Appendix S1: Table S2 for further questions). Addressing these transdisciplinary research questions will require integration of past, present, and future information, and their implementation can increase the effectiveness of management practices.

of grassy biomes on Madagascar (Antonelli et al., 2022; Hackel et al., 2018; Lehmann et al., 2022; Vorontsova et al., 2016), but the degree to which human land use has modified their extent and composition is debated—as in sub-Saharan Africa more broadly (e.g., Brierley et al., 2018; Phelps, Broennimann, et al., 2020; Wright, 2017). This knowledge gap is perpetuated by limited spatio-temporal coverage and limited integration of datasets stemming from different disciplines. Improved reconstructions and predictions of grassy biome distribution, composition, and land use are needed to help identify effective conservation priorities and strategies to support ecosystem and livelihood resilience under future ecosystem change. Achieving these will require integration of long-term records with varying spatio-temporal coverage and communication among relevant disciplines (e.g., combining palaeoecological, archaeological, ethnohistorical, evolutionary, and ecological datasets; Dietl & Flessa, 2011; Willis & Birks, 2006; Phelps, Jousse et al., 2019; Phelps, Chevalier et al, 2019; Phelps, Gravey et al., 2022; Phelps, et al., 2025a).

Expand the spatial and temporal scales of available data

High-resolution, multi-proxy records (e.g., pollen, charcoal, isotopes, phytoliths, non-pollen palynomorphs) with adequate chronological control and comprehensive coverage of recent ecosystem structure, function, and use are needed to disentangle complex spatio-temporal dynamics in grassy biomes. However, the preservation of multi-proxy palaeo-records tends to be favored by particular conditions (e.g., permanently flooded wetland sites, buffered neutral sediments, or sheltered caves), and the

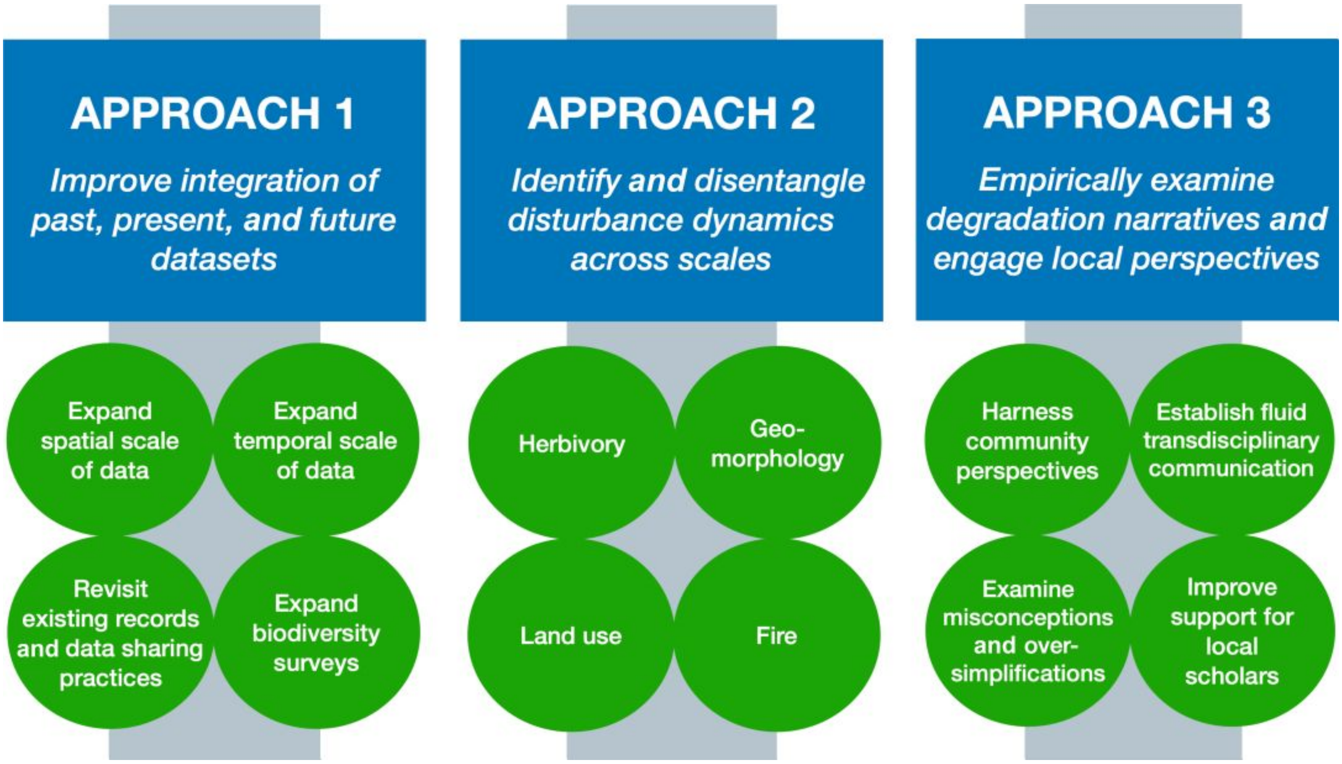


FIGURE 6 Transdisciplinary approaches to advancing research and management of grassy biomes on Madagascar and across the globe.

inaccessibility of some environments limits the spatial coverage of field research. Better incorporation of a variety of survey methods and fossil types that preserve a larger variety of depositional environments can therefore improve the coverage of grassy biome records. These could include expanded sampling of phytoliths, non-pollen palynomorphs, pollen, and macroflora in palaeosols and palaeo-sediments (Strömberg, 2011), and the application of expert knowledge around non-grass pollen indicators (e.g., Phelps, Chevalier, et al., 2020). Aside from select long-term sedimentary and speleothem records (e.g., Broothaerts et al., 2023; Razafimanantsoa et al., 2024; Burney, 1987; Burns et al., 2022; Gasse & Van Campo, 2001; Scroxton et al., 2019; Teixeira, Montade, et al., 2021), most palaeoenvironmental and palaeoclimate records on Madagascar are also limited to the Late Holocene (from ca. 4200 BP: Walker et al., 2019). There is a need for better spatial coverage of longer term records and higher resolution multi-proxy data documenting climate and environmental variability at different scales and under a variety of conditions. One route to better integrating past, present, and future information is to focus research efforts on sites where transdisciplinary, high-resolution datasets can be generated through collaborative, long-term research projects (e.g., Montade et al., 2024; Teixeira, Montade, et al., 2021). By focusing efforts toward improved communication among researchers working at similar locations, we can develop high-resolution analyses to maximize the understanding and management of grassy biomes at different spatio-temporal scales. In addition, it is critical that well-constrained age models are developed that enable inter-archive and inter-site comparisons (e.g. Godfrey et al., 2019); such knowledge is critical for disentangling the drivers of past environmental change and developing accurate estimates of ecosystem change.

Knowledge of the distribution of archaeological settlements and land use change on Madagascar is also limited, with nearly three quarters of the island under-investigated (e.g., in terms of limited survey and excavation, available data, and active field archaeologists; Davis, DiNapoli, et al., 2020; Davis, Andriankaja, et al., 2020). More investigation of historical settlement and land use is required to estimate the effects of past human activities on vegetation change, including food-producing, food-gathering, and associated fire practices. Increasing the spatio-temporal scale and integration of contemporary, historic, and palaeo-records will improve the understanding of livelihood resilience and lead to better predictions of future ecosystem change across heterogeneous landscapes. With improved, cumulative records of land use change, we can also assess the degree to which anthropogenic landscapes are stable ecological components or constitute unstable and emerging ecosystems. For example, to clarify past demographic changes and spatio-temporal dynamics of human and agricultural arrivals on Madagascar, we need to expand archaeological investigations and combine them with additional data, such as demographic inferences based on genetic and genomic data (e.g., Alva et al., 2022; Ardalan et al., 2015; Douglass, Hixon, et al., 2019; Douglass, Morales, et al., 2019; Douglass, Walz, et al., 2019; Hansford et al., 2018; Herrera et al., 2017; Kusuma et al., 2015). Combining archaeological and genetic information with Holocene sedimentary records from lakes, marshes, and wetlands is also crucial for disentangling the drivers of vegetation change, as this provides a deep-time perspective capable of identifying temporal lags in human-environment-climate effects (e.g., Chikhi & Sgarlata, 2022; Li et al., 2020; Quéméré et al., 2012; Razanamahandry et al., 2022; Razanatsoa et al., 2022; Salmona et al., 2017; Teixeira, Montade, et al., 2021; Tiley et al., 2022; Virah-Sawmy et al., 2010; Voarintsoa et al., 2017).

Revisit existing records and improve data sharing practices

Reanalysis, reevaluation, and synthesis of existing and new datasets can improve our ability to reconstruct and predict ecosystem change (Davis, 2020a, 2020b; Davis, Andriankaja, et al., 2020; Davis, DiNapoli, et al., 2020; Douglass, Hixon, et al., 2019; Douglass, Morales, et al., 2019; Douglass, Walz, et al., 2019; Gaillard et al., 2008; Hixon et al., 2022; Phelps, Broennimann, et al., 2020; Phelps, Chevalier, et al., 2020; Ullah, 2015). For instance, synthesis and calibration of palaeosedimentary and archaeological chronologies within and across study sites can clarify the timing and drivers of landscape and vegetation change (e.g., Burney et al., 2003; Godfrey et al., 2019; Phelps, Chevalier, et al., 2020; Stephenson et al., 2021), and improve reconstructions of human demographic change (Douglass, Hixon, et al., 2019; Douglass, Morales, et al., 2019; Douglass, Walz, et al., 2019; Manning & Timpson, 2014). When combined with insights from current socio-ecological contexts and historical sources (e.g., remote sensing, social surveys, genetic and functional trait data, ethnohistorical records), these syntheses can offer deeper understanding and novel interpretations of existing records and past variability, as well as improve predictions of current and future ecosystem change (e.g., Breeze et al., 2015; Coelho et al., 2021; Davis & Douglass, 2020; Quémére et al., 2012; Solofondranohatra et al., 2020). Models based on diverse datasets (e.g., species distribution models, land use change models, dynamic vegetation models, population genetics models), and new statistical (e.g., simulation-based inference, machine learning) and collaborative approaches (e.g., participatory modeling, open source code and data sharing) can also offer novel insights into ecosystem change (Andermann et al., 2022; Brierley et al., 2018; Chikhi & Sgarlata, 2022; Manning & Timpson, 2014; Phelps, Broennimann, et al., 2020; Phelps, Chevalier, et al., 2020; Salmona et al., 2017; Schüssler et al., 2020; Teixeira, Montade, et al., 2021). These approaches to integrating data from various sources and spatio-temporal scales can allow us to: (1) understand the potential lag effects between human activities and their modifications to grassy biome composition and extent; (2) evaluate the degree to which spatio-temporal biases in existing datasets may influence interpretations of vegetation change; (3) extrapolate multi-scalar patterns from local-scale information (e.g., ecosystem expansions and contractions through deep time); and (4) simulate potential future grassy biome conditions.

Open and efficient data sharing practices among research disciplines and teams is key to the integration of past, present, and future information and can permit environmental characterization and comparison among regions, time periods, and disciplines. Oppositely, poor data sharing practices can limit reconstructions and predictions of ecosystem change, in both scale and accuracy. A number of global repositories now exist, through which individual researchers can openly access and share their datasets and support regional compilations of published data (e.g., Neotoma, APD, NOAA Palaeoclimatology Database, PANGAEA, SISAL, Dryad, IsoMad, ENA: Hixon et al., 2024; Hooghiemstra et al., 2006; Phelps, Broennimann, et al., 2020; Phelps, Chevalier, et al., 2020; Vincens et al., 2007). However, global inequities in access to scientific publishing and infrastructure can lead to regional disparities in the production and access to scientific knowledge (e.g., Vorontsova et al., 2020) and require targeted efforts to improve access and regional representation (e.g., Open Research Africa; African BioGenome Project).

Expand biodiversity surveys

Relationships between grasses and extinct megafauna on Madagascar (e.g., elephant birds, tortoises, and pygmy hippopotamuses) have received extensive research attention and debate in recent years (e.g., Bond et al., 2008; Crowley et al., 2021; Crowley, Godfrey, et al., 2023; Hixon et al., 2024; Godfrey & Crowley, 2016; Hagl et al., 2021; Hansford & Turvey, 2022; Joseph & Seymour, 2021; Nanjarisoa et al., 2017; Rakotomalala et al., 2022; Solofondranohatra et al., 2020; Tiley et al., 2024). However, relationships between invertebrate and plant biodiversity (e.g., butterflies, termites, ants, earthworms, grasshoppers) are under-explored (e.g., Bond et al., 2022; Iannella et al., 2019; Vorontsova et al., 2020). Expanded field surveys are needed to better establish habitat associations for multiple taxa and groups in different grassy biomes. Lack of plant taxonomic expertise is also a hindrance to evidence-based management and conservation strategies across the globe (e.g., Ahrends et al., 2011). Few Malagasy botanists specialize in grass identification, with the number of grass specialists increasing from zero in 2010 to eight in 2022 (M.S. Vorontsova, personal communication). Even fewer botanists specialize in other grassy biome plants (e.g., herbaceous dicots, ericoids, sedges, non-graminoid monocots such as lilies and orchids, and geoxyles). Moreover, the taxonomy of heaths (Ericaceae) on Madagascar is out of date, with ongoing research aiming to address this knowledge gap (e.g. Hackel et al., 2024). In particular, the genus *Erica* is likely key to understanding grassland-shrubland-savanna dynamics, but the genus is poorly represented in herbaria. Investment in training and resources, for example, for specimen collections and to support Malagasy taxonomists, should be a priority.

Research on the distribution, abundance, and demography of plants and animals associated with forests or open ecosystems in the past and present can also illuminate landscape history, especially where they present as mosaic landscapes; however, studies on these topics have been geographically biased toward northern Madagascar (but see Andriambeloson et al., 2021; Godfrey et al., 2021), and taxonomically biased toward rodents, lemurs, and trees (e.g., Andriambeloson et al., 2021; Chikhi & Sgarlata, 2022; Crowley et al., 2018; Muldoon et al., 2017; Quéméré et al., 2010, 2012; Rakotoarisoa et al., 2013; Salmona et al., 2017, 2020, 2023; Teixeira, Montade, et al., 2021; Teixeira, Salmona, et al., 2021; Tiley et al., 2022). Future research needs to cover more regions and taxa. There is also a need for natural history research to develop realistic parameter estimates for demographic studies (e.g., generation time and mutation rate: Tiley et al., 2020), and for studies of related plant and animal genomes that can help to calibrate the timing of demographic changes for human-introduced species (e.g., bushpigs, rats, cats, dogs, banana, taro, rice, yam, coconut, sorghum, sugar cane, indian saffron, and possibly guinea fowl: Ardalan et al., 2015; Balboa et al., 2024; Beaujard, 2011; Blench, 2010; Crowther et al., 2016; Goodman et al., 2013; Herrera et al., 2017; Hixon, Curtis, Brenner, et al., 2021; Hixon, Douglass, Godfrey, et al., 2021; Hixon, Douglass, Hixon, et al., 2021; Kull et al., 2012; Kusuma et al., 2015; Lee et al., 2020; Sauther et al., 2020). Such data may be instrumental in reconstructing the spatio-temporal extent, diversity, and demographic history of extinct species that may have used or maintained open habitats prior to human colonization of Madagascar (e.g., hippopotamuses, elephant birds, tortoises; Hansford & Turvey, 2022; Kehlmaier et al., 2023). Increased availability of reference "barcode" DNA sequences and environmental DNA from soil or feces can also improve the identification of species overlooked in biodiversity surveys (e.g., distinguishing grass species; Ragupathy et al., 2009). With the use of ancient DNA, these approaches can extend back in time to reveal past vegetation and faunal dynamics (Orlando et al., 2021; Pedersen et al., 2015).

Approach 2: Identify and disentangle disturbance dynamics and biogeophysical feedbacks across spatio-temporal scales

Globally, disturbance dynamics (e.g., land use, herbivory, fire) and a variety of other factors (e.g., atmospheric CO_2, geomorphology, hydrology) have substantial and variable impacts on grassy biome form and function (e.g., Archibald et al., 2019; Armitage et al., 2015; Bond et al., 2003; Bond & Midgley, 2012; Claussen et al., 1999; Goel et al., 2020; Lehmann et al., 2011; Ramiadantsoa & Solofondranohatra, 2021), but these are difficult to disentangle and are poorly accounted for in estimates of vegetation change. Effective ecosystem management is therefore limited by poor understanding of how different disturbance dynamics interact with flora, fauna, geomorphology, and soils over millennial scales and how these dynamics influence the extent and composition of grassy biomes. In particular, there is a need to better understand how different land use systems have interacted with fire and vegetation change in the past and present (e.g., Archibald et al., 2019; Phelps & Kaplan, 2017).

Disentangling the drivers of change in grassy biomes requires analysis of multiple study sites with a broad range of independently derived palaeoenvironmental proxies (e.g., pollen, charcoal, XRF spectra, isotope and other biomarkers, grain size, diatoms: Broothaerts et al., 2023; Mayle & Iriarte, 2014). To address disconnects in the spatio-temporal scales of palaeo- and present-day ecological information, functional ecology experiments and high-resolution palaeo-records are critical for interpreting long-term disturbance dynamics in grassy biomes. Research on long-term disturbance dynamics in key grassy biome regions, such as Madagascar's Central Highlands, can facilitate adaptive and effective grassy biome management with co-benefits for biodiversity, ecosystem function, and human livelihoods. Geochemical analyses of sediment and soil samples (e.g., elemental and isotopic composition, radiocarbon dating) can also help with reconstructing recent and long-term links between vegetation, climate, fire, and land use across diverse landscapes (e.g., Razafimanantsoa, 2022; Razanamahandry et al., 2022).

Herbivory

Existing research on Madagascar's grassy biomes demonstrates a critical need to better understand how herbivores may have influenced vegetation composition and extent prior to human colonization, and how this relates to human arrivals, subsequent environmental changes, and modern ecosystem functioning (Burney et al., 2003; Godfrey et al., 2019: i.e., domestic animals from c. 1200 BP and cultivation from c. 1000 BP: e.g., Crowther et al., 2016; Dewar & Wright, 1993; Razanatsoa et al., 2022). Understanding of changing faunal diets, habitats, and ecology can be facilitated through expanded research around isotopes (e.g. Phelps, et al., 2025b), faunal morphology and feeding behavior, coprophilous fungi, plant functional traits, genetic and genomic data, and a variety of modeling approaches. Grassy biome management on the island can also be improved by investigating the roles of wild and domestic fauna in driving Holocene vegetation dynamics, and comparing these with African savanna ecology more broadly (Pringle et al., 2023), particularly regarding changes between herbaceous (e.g., grasses, sedges, and herbaceous dicots) and woody vegetation (e.g., trees, shrubs).

Many isotopic studies on Madagascar have focused on the relative proportions of C_3 versus C_4 plants in extinct megafaunal diets (e.g., Crowley et al., 2021; Godfrey & Crowley, 2016; Hixon, Curtis, Brenner, et al., 2021; Hixon, Douglass, Godfrey, et al., 2021; Hixon, Douglass, et al., 2021). This work is based on the premise that trees, shrubs, and herbs use C_3 photosynthesis while most tropical grasses use the C_4 photosynthetic pathway. However, open biomes can include both C_4 and C_3 taxa, requiring expanded spatio-temporal investigation of a variety of grassy biome plants (e.g., Bond et al., 2008; Hempson et al., 2015). Further, most work characterizing the isotopic signatures of modern vegetation has focused on vegetation outside of Madagascar's grassy biomes (but see Crowley, Schmidt, et al., 2023). More research is therefore needed to characterize the isotopic signatures of plants in Madagascar's open environments (especially for a range of grasses, herbs, sedges, and ericoids); these data can, in turn, be used to reconstruct presence, and possibly relative abundance, of different types of vegetation in the past using pollen, phytoliths, speleothems, soil organic matter, osseous tissues from herbivores, and other proxies (e.g., Aleman et al., 2012; Crowley et al., 2021; Faina et al., 2021; Hixon, Curtis, Brenner, et al., 2021; Hixon, Douglass, Godfrey, et al., 2021; Hixon, Douglass, et al., 2021; Razanamahandry et al., 2022). Expanding this research will also enable comparison of grassy ecosystems between Madagascar and other parts of the tropics (e.g., Bakker et al., 2016; Gill, 2014; Staver et al., 2021; Phelps, et al., 2025b).

Improved understanding of herbivore dynamics can also come from "cafeteria" experiments, which investigate the dietary preferences of herbivores when presented with different environments and food choices (e.g., Burleigh & Arnold, 1986; Cerling et al., 2008; van der Sluis et al., 2014), with the caveat that extant fauna and environments may not be exact analogues for extinct megafauna and the conditions they experienced. Aldabra tortoises were recently introduced in northwest Madagascar (Anjajavy reserve) and may provide an ideal case study for such experiments (Pedrono et al., 2020). Documentation of the spectrum of functional traits that reflect herbivore attraction to, and avoidance of, different types of plants within grassy biomes (e.g., grasses, herbs, sedges, trees, and shrubs, including succulents and ericoids) would be particularly informative (e.g., Archibald et al., 2019). Further research on fire-herbivory interactions and how these relate to biodiversity is also needed to understand and maximize benefits among livelihoods, ecosystem function, and biodiversity (e.g., Hempson et al., 2019; Martin et al., 2022).

Fire

There is an increasing need to determine and calibrate recent and past fire regimes on Madagascar (e.g., relating to fire emissions and carbon storage: Hawthorne et al., 2018), clarify the processes that have shaped them through time (e.g., changes in climate, vegetation, land use, and herbivory), and evaluate how they relate to tropical fire regimes more broadly (e.g., Case & Staver, 2016; Laris et al., 2020; Phelps et al., 2022; Singh et al., 2023, 2024). In particular, studies on the relationships between fire regimes, small-scale fires, and the complex drivers of landscape degradation are needed. For recent decades, remote sensing information (e.g., MODIS-derived burned area products: Giglio et al., 2018) has facilitated characterization and comparison of fire regimes at the landscape scale (e.g., Phelps et al., 2022). The increasing availability of high-resolution satellite images (e.g., Sentinel-2 since 2015) has also enabled detection of small-scale fires, which can cumulatively make up large portions of burned area (Fernández-García & Kull, 2023; Ramo et al., 2021; Roteta et al., 2019; Fernández-García, Phelps et al., 2024).

Knowledge of ancient fire regimes is considerably more limited. New studies and methodological applications are required to link long-term fire patterns to adaptive fire management strategies today (e.g. Novenko, et al., 2022a; Novenko, et al., 2022b). For example, high-resolution charcoal analysis of palaeo-sediments and soils can help to disentangle Holocene changes in fire-human-vegetation relationships (e.g., fire intensity; Hawthorne et al., 2018; Mustaphi et al., 2022). These long-term data will help improve predictions of future fire-vegetation relationships, which are central to informing decisions around fire risk associated with land conversion, tree planting, and ecosystem restoration (e.g., balancing essential timber and fuel wood while ensuring careful management of high flammable species; Kull, 2004; Phelps et al., 2022; Veldman et al., 2019).

Land use

Combined with empirical investigation of fire, herbivory, and biodiversity patterns, improved characterization of land use processes in the past and present can help to maximize benefits between livelihoods and ecosystem function (Phelps & Kaplan, 2017; Phelps, Chevalier et al., 2020; Phelps, Broennimann et al., 2020; Phelps, Davis et al., in press; Morrison et al., 2021), e.g., by accurately predicting ecosystem change, informing ecosystem restoration efforts through participatory land use mapping, and developing adaptive land management strategies. In particular, despite being central to human livelihoods, animal husbandry is often overlooked in studies of land use and land cover change, due to lacking characterization of land use systems and poor differentiation between land cover and land use (Phelps & Kaplan, 2017). Improved coverage of social science surveys and ethnohistorical records can help to clarify the functions, cultural significance, and distribution of different land use practices, as well as how land use interacts with biodiversity and ecosystem function across heterogeneous landscapes (e.g., ethnographic, ethnobotanical, and economic-demographic-livelihood; e.g. Randall, 2015).

Geomorphology

Evaluating changes in landforms over different time scales can provide insight into past changes in vegetation cover and land use (e.g. Liu et al., 2024). Erosional gullies, called lavaka (meaning “hole” in Malagasy), are the most visible aspect of hillslope erosion on Madagascar. They were prominent before human arrivals, and may be particularly informative (Mietton et al., 2006, 2014; Wells & Andriamihaja, 1997). In other regions, erosional gullies can also be referred to as Vocorocas (i.e., in Brazil: Chaves, 1994; Vieira, 2008), or beng gang (i.e., in China: Jiongxin, 1996; Liao et al., 2019; Wei et al., 2021). Although initial work has established the broad-scale controls of lavaka formation and dynamics on Madagascar (e.g., Broothaerts et al., 2023; Brosens et al., 2022; Brosens et al., 2023; Cox et al., 2010; Cox, King Phillips et al., 2024; Wang et al., 2021; Wells & Andriamihaja, 1997), few studies have quantitatively and critically addressed questions about their long-term development, including the role of different human land uses, and how lavaka formation processes relate to other aspects of erosion and landform change (e.g., Gosling et al., 2012; Scholtz et al., 2014; Zhou et al., 2022). For example, Brosens et al. (2022) estimated that the number of erosional gullies in the Lake Alaotra region (northeast Central Highlands) grew rapidly from 1949 to 2010 CE and inferred that the regional rate of lavaka formation and sediment loss increased around the same time as human settlement, ca. 1000 BP. However, longitudinal analysis contradicts these findings, showing instead that lavaka erosional activity decreased in the same area and over the same time period (Cox, King Phillips, et al., 2024).

There are many uncertainties in the understanding of lavaka life cycles, and of gullies in general; these can vary (sub-)regionally (Voarintsoa et al., 2012), and are not sufficiently constrained to ensure reliable model outputs. Studies on the long-term rates of lavaka formation and stabilization are needed that can contextualize recent rates of vegetation change and soil erosion using aerial photography, satellite imagery, isotopic analysis (e.g., Igbokwe et al., 2008; Mabit et al., 2018). Future approaches could include mass-balance modeling to test landscape stability, which requires reliable data on volume losses and landscape lowering rates (e.g., Brosens et al., 2023).

Equally important is the analysis of how lavaka dynamics impact land use, soil, and vegetation change; and analyzing human interactions with lavaka is required to understand spatio-temporal heterogeneity in their historical relationships (e.g., Razanamahandry et al., 2022). Recent work has found that lavaka provide patch environments and fire refugia for trees and shrubs in the grassy highlands (Cox, Carrère, et al., 2024). However, the extent to which Malagasy farmers integrate lavaka into their land husbandry, taking advantage of higher moisture levels and more fertile substrates, is only now beginning to be examined (Cox, Carrère, et al., 2024). Knowledge is also still limited regarding how geomorphological change on Madagascar shaped biodiversity patterns in grassy biomes before human arrival (Stephenson et al., 2021). It is clear, however, that narratives of human causation for geomorphologic change—on Madagascar and in other former European colonies—are often oversimplified, as the geomorphology, geology, soils, vegetation, and land use are highly complex and multi-factored, requiring improved documentation (e.g., Collins et al., 2022; Cox, Carrère, et al., 2024; Cox, King Phillips, et al., 2024; Crowley & Sparks, 2018; Dewitte et al., 2013; Lehmann et al., 2022; Vågen, 2006; Voarintsoa et al., 2012). Useful future studies will investigate how a variety of geomorphic factors have affected Holocene vegetation dynamics and clarify the roles that people have played.

Approach 3: Empirically examine degradation narratives and engage local perspectives in scientific research

There is a need to shift scientific narratives and communication away from widespread simplistic assumptions, and toward empirical and nuanced investigation of the complex drivers underpinning vegetation change and landscape degradation (e.g., fire-degradation relationships across ecosystems: Bliege Bird et al., 2020; Kull, 2000; Phelps et al., 2022). This will not only deepen the understanding of vegetation change and guide land management, but also encourage scientifically informed exchanges between researchers, policy makers, and those living in and interacting with grassy biomes. There is a perpetual need for collaboration between researchers and local, regional, and (inter)national institutions, as well as directly with local stakeholders, to root research and management in local socio-ecological context (i.e., livelihood demands and local perspectives), communicate results appropriately, and bolster informed land stewardship. In particular, ethnographic and ethnohistorical accounts are required to understand how diverse stakeholders from local communities perceive and engage with grassy biomes (e.g., Kariuki et al., 2022). Transdisciplinary engagement can improve the tools and topics used to inform ethnographic inquiries, and maximize their relevance to effective and co-beneficial land management decisions.

Harness community perspectives and establish fluid lines of communication between research, management, and stakeholders

Visual and auditory communication tools provide powerful field resources to facilitate stakeholder engagement and collaboration around grassy biome research and management (e.g., Newman et al., 2020). For example, spatial and temporal dimensions of grassy biome evolution and stewardship can be explored through collaborative mapping exchanges (Capitani et al., 2016; Dunn, 2007; Kariuki et al., 2021, 2022; Larrain & McCall, 2019; Ramirez-Gomez et al., 2015), strategy gaming workshops (Bodonirina et al., 2018; Ravaka et al., 2021; Reibelt et al., 2021; Waeber et al., 2021), online conversation forums, virtual reality and 3D simulations (e.g., Davis et al., 2021; Fisher et al., 2019), web-accessible video clips surrounding community, conservation, and research knowledge (Colloredo-Mansfeld et al., 2020), animations (e.g., Development Corridors Partnership, 2021), posters, radio shows, podcasts, and artwork (e.g., Wang et al., 2017; Feom'bezo [voices of the Vezo] radio show). These communication tools require translation into international and local languages, and often technology and internet access. Direct involvement of local stakeholders in research is also needed, through researchers traveling to communities or delegations of community members visiting research institutions, to establish communication, brainstorm research plans, and develop communication networks among stakeholders from different regions (e.g., Vezo ecological exchange project: Douglass, Hixon, et al., 2019; Douglass, Morales, et al., 2019; Douglass, Walz, et al., 2019).

Given that stakeholders are typically diverse groups of people with different knowledge, perspectives, and opinions, ample resources and time are required to develop meaningful engagement between researchers and local communities, and to build trust and transparent, reflective communication. In addition, researchers need to strive to represent all local views fully and honestly, and avoid selectively emphasizing views that support their own. Collaboration with local land users can also improve scientific understanding of recent political, economic, and social change, and how these factors may relate to land cover changes observed with remote sensing. Funding is needed to support such communication initiatives, which can leverage impactful, long-term contributions to land management. Furthermore, providing support, training, and opportunities for local scholars can help to improve the recognition and uptake of community perspectives in research and land management (e.g., Razanatsoa, Andriantsaralaza, et al., 2021). Such measures can bolster adaptive land management decisions at multiple levels, improve the accessibility and relevance of scientific research to a broader audience, and develop best research practices and ethics (Davis et al., 2021; Schneider et al., 2020; Wilmé et al., 2016).

Open and direct lines of communication (e.g., those developed through participatory work: Douglass & Rasolondrainy, 2021; Garcia et al., 2022; Kariuki et al., 2022) are essential for supporting effective, up-to-date, and adaptive management strategies. Policy and public opinion can take long periods of time to incorporate scientific research findings, especially when messages are complex and nuanced. However, established lines of communication between researchers and land use managers can facilitate adaptive, collaborative research actions on more reasonable timescales with appropriate stakeholders. Proactive communication campaigns with local stakeholders are desperately needed to inform scientific inquiries and to steer research toward questions of topical importance to grassy biome management.

Identify and overcome misconceptions and oversimplifications in scientific research

There is a need to expand research beyond oversimplifications of ecosystem characteristics—“natural versus anthropogenic,” “ancient versus anthropogenic,” “grassland versus woodland,” “tree versus grass,” “grazer versus browser”—toward fuller and more nuanced investigation of ecosystem diversity and function. In particular, more information is needed regarding the biodiversity and disturbance characteristics, such as fire and herbivory functional traits, for a range of C_3 and C_4 plants. This is especially important for C_3 plants that can form large components of grassy biomes (e.g., herbaceous dicots, ericoids, non-graminoid monocots such as lilies and orchids, geoxyles, C_3 grasses, and sedges; Hempson et al., 2015). Basic characterization of biodiversity and land use practices is also needed to reverse narratives that all grassy biomes are similar and of limited ecological importance, expand understanding of fire patterns and use, and promote effective biodiversity management (e.g., Haines-Young, 2009; Kull & Lehmann, 2022; Lehmann et al., 2022; Marchant, 2010; Phelps et al., 2022). Further, interdisciplinary exploration is needed to clarify how trees and shrubs occurring in grassy biomes, such as *Uapaca bojeri* (tapia), *Sarcolaena oblongifolia*, and *Faurea forficuliflora*, have evolved, or how their distribution has changed in terms of woody germination and recruitment, composition and structure, and decadal dynamics observed with remote sensing imagery. To address these knowledge gaps, more nuanced investigation of human-environment interaction is needed, which considers human modifications as part of nature, but also seeks to empirically identify regional heterogeneity and interrelationships between biodiversity and disturbance dynamics in grassy ecosystems across the globe (e.g., Burney, 1987; Lehmann et al., 2011, 2022; Phelps & Kaplan, 2017; Phelps, Broennimann et al., 2020; Phelps, Chevalier et al., 2020; Davis et al., 2024; Phelps et al., 2022; Phelps, et al., 2025b). Practical future studies will inform adaptive land management strategies by disentangling the variety of ways in which both human land use and other drivers of environmental change modify landscapes (e.g., Razanatsoa, Virah-Sawmy, et al., 2021).

CONCLUSION

Transdisciplinary understanding of vegetation dynamics in tropical grassy biomes is urgently needed to support sustainable ecosystems and livelihoods globally. We provide a framework that offers four contributions to improving research and management of grassy biomes by focusing on Madagascar as a microcosm of the global tropics: (1) a globally common terminology reflecting ecosystem function and disturbance processes; (2) a summary of current data contributions and knowledge gaps for research on Madagascar’s grassy biomes; (3) 20 Madagascar-inspired research questions to move grassy biome science and management forward; and (4) three key approaches to fostering transdisciplinary, inclusive research and management practices: improved integration of past, present, and future datasets; enhanced understanding of disturbance dynamics; and examination of degradation narratives and bolstering local perspectives. Our framework offers a foundation for grassy biome research that can support more optimal management of biodiversity, livelihoods, and ecosystem function—both on Madagascar and across the globe.

AUTHOR CONTRIBUTIONS

Manuscript conception and design was initiated by Leanne N. Phelps, Caroline E. R. Lehmann, Jan Hackel, Kristina Douglass, Dylan S. Davis, Estelle Razanatsoa, George P. Tiley, Brooke Crowley, and Maria S. Vorontsova, leading to an international, interdisciplinary workshop on July 27–30, 2021. During the workshop, coauthors participated in interactive activities to establish manuscript content. The first manuscript draft was led by workshop co-organizers following the workshop (Leanne N. Phelps, Dylan S. Davis, Jan Hackel, Estelle Razanatsoa, Tanambelo Rasolondrainy), developed with co-advisors (Caroline E. R. Lehmann, Kristina Douglass, Maria S. Vorontsova, Brooke Crowley), and revised by coauthors. Figures were developed by Leanne N. Phelps, with input from Dylan S. Davis and Jan Hackel. The second and third manuscript drafts and data compilation were led by Leanne N. Phelps and developed online among coauthors. Workshop content contributions and/or manuscript revisions were contributed by all coauthors. Author order reflects tiers, organized alphabetically: (1) lead and corresponding author, (2) co-organizer, (3) outstanding contributions, (4) core contributions, (5) supplementary contributions, (6) co-advisor.

AFFILIATIONS

[1]School of Geosciences, University of Edinburgh, Edinburgh, UK
[2]Taxonomy and Macroecology, Royal Botanic Garden Edinburgh, Edinburgh, UK
[3]Columbia Climate School, New York, New York, USA
[4]Division of Biology and Paleoenvironment, Lamont-Doherty Earth Observatory, Palisades, New York, USA
[5]Plant Conservation Unit, Department of Biological Sciences, University of Cape Town, Cape Town, South Africa
[6]Ecole Doctorale Ecosystèmes Naturels [EDEN], University of Mahajanga, Mahajanga, Madagascar
[7]Columbia Center for Archaeology, Columbia University, New York, New York, USA
[8]Department of Ecology, Environment and Plant Sciences (DEEP), Stockholm University, Stockholm, Sweden
[9]Department of Biology, University of Marburg, Marburg, Germany
[10]Centre de documentation et de recherche sur l'art et les traditions orales à Madagascar, Toliara, Madagascar
[11]Kew Madagascar, Royal Botanic Gardens, Kew, Antananarivo, Madagascar
[12]Makauwahi Cave Reserve, Kalaheo, Hawaii, USA
[13]Geosciences Department, Williams College, Williamstown, Massachusetts, USA
[14]Department of Anthropology, University of Massachusetts, Amherst, Massachusetts, USA
[15]School of Biodiversity, One Health & Veterinary Medicine, University of Glasgow, Glasgow, UK
[16]Centre for African Ecology, School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, South Africa
[17]Department of Integrative Biology, Oregon State University, Corvallis, Oregon, USA
[18]Max Planck Institute of Geoanthropology, Jena, Germany
[19]Department of Organismal Biology, SciLifeLab, Uppsala University, Uppsala, Sweden
[20]Missouri Botanical Garden, Madagascar Research and Conservation Program, Antananarivo, Madagascar
[21]Missouri Botanical Garden Madagascar, Plants Taxonomy, Antananarivo, Madagascar
[22]Science Directorate, Royal Botanic Gardens, Kew, Richmond, Surrey, UK
[23]Gothenburg Global Biodiversity Centre, Department of Biological and Environmental Sciences, University of Gothenburg, Gothenburg, Sweden
[24]Department of Biology, University of Oxford, Oxford, UK
[25]CNRS-IRD-TINP-UT3, UMR5300, Centre de Recherche sur la Biodiversité et l'Environnement (CRBE), Université Paul Sabatier, Toulouse, France
[26]Instituto Gulbenkian de Ciência, Oeiras, Portugal
[27]Ecology, Faculty of Biology and Environmental Sciences, University of León, León, Spain
[28]Institute of Geography and Sustainability, University of Lausanne, Lausanne, Switzerland
[29]School of Culture, History and Language, The Australian National University, Canberra, Australian Capital Territory, Australia
[30]ARC Centre of Excellence for Indigenous and Environmental Histories and Futures, Australian National University, Canberra, Australian Capital Territory, Australia
[31]Institute of Zoology of the Zoological Society of London, London, UK
[32]Department of Biological Sciences, Northern Illinois University, DeKalb, Illinois, USA
[33]Department of Earth Sciences, University College London, London, UK
[34]DSI-NRF Centre of Excellence, Department of Biological Sciences, FitzPatrick Institute of African Ornithology, University of Cape Town, Cape Town, South Africa
[35]York Environmental Sustainability Institute, University of York, York, North Yorkshire, UK
[36]ISEM, University of Montpellier, CNRS, IRD, Montpellier, France
[37]Department of Geosciences, Pennsylvania State University, University Park, Pennsylvania, USA
[38]Institute of Zoology, University of Veterinary Medicine Hannover, Hannover, Germany
[39]Department of Integrative Biology, University of Wisconsin-Madison, Madison, Wisconsin, USA
[40]Madagascar Biodiversity Center, Antananarivo, Madagascar
[41]Faculté des Sciences, de Technologies et de l'Environnement [FSTE], University of Mahajanga, Mahajanga, Madagascar
[42]Faculté des Sciences, Mention Biologie et Ecologie Vegetales, Universite d'Antananarivo, Antananarivo, Madagascar
[43]Department of Agroecology, Biodiversity and Climate Change, School of Agronomy, University of Antananarivo, Antananarivo, Madagascar
[44]Department of Forestry and Environment, School of Agronomy, University of Antananarivo, Antananarivo, Madagascar
[45]Human Evolution Research Institute, Department of Geological Sciences, University of Cape Town, Cape Town, South Africa

[46]UCD School of Earth Sciences, University College Dublin, Dublin, Ireland
[47]South African National Biodiversity Institute, Claremont, South Africa
[48]Department of Sociology and Anthropology, University of Guelph, Guelph, Ontario, Canada
[49]Planet Madagascar, Guelph, Ontario, Canada
[50]UMR ENTROPIE (Université de La Réunion, IRD, CNRS, IFREMER, Université de Nouvelle-Calédonie), Saint-Denis, France
[51]Department of Earth and Atmospheric Sciences, University of Houston, Houston, Texas, USA
[52]Forest Policy and International Forest Management, Bern University of Applied Sciences, Zollikofen, Switzerland
[53]Ecosystem Management, ETH Zurich, Zurich, Switzerland
[54]World Resources Institute Africa, Madagascar Program, Antananarivo, Madagascar
[55]Department of Biology, Duke University, Durham, North Carolina, USA
[56]Department of Geosciences, University of Cincinnati, Cincinnati, Ohio, USA
[57]Department of Anthropology, University of Cincinnati, Cincinnati, Ohio, USA

ACKNOWLEDGMENTS

This manuscript resulted from the international Malagasy Grassy Biomes workshop (27–30 July, 2021) and established the *Malagasy Grassy Biomes working group*. This research was funded by the Swiss National Science Foundation (SNSF) (Postdoc.Mobility Grant: P500PN_206663, P500PN_206663/2; Early Postdoc.Mobility Grant: P2LAP2_187745, P2LAP2_187745/2), awarded to Leanne N. Phelps. Dylan S. Davis was supported by the National Science Foundation (USA) SBE Postdoctoral Fellowship (SMA-2203789). Jan Hackel was funded by a Future Leader in Plant and Fungal Science fellowship from the Royal Botanic Gardens, Kew. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 101026923, awarded to George P. Tiley. Alexandre Antonelli acknowledges financial support from the Swedish Research Council (2019-05191), the Swedish Foundation for Strategic Environmental Research MISTRA (Project BioPath), and the Royal Botanic Gardens, Kew. Ronadh Cox was supported by the National Science Foundation (USA: EAR-0921962, EAR-0415439). Christian A. Kull and Víctor Fernández-García were supported by the Swiss Network for International Studies. Guillaume Besnard, Lounès Chikhi, are Jordi Salmona are members of the CRBE laboratory, which is supported by the Laboratoire d'Excellence (LabEx) CEBA (grant ANR-10-LABX-25-01) and LabEx TULIP (grant ANR-10-LABX-0041), both managed by the Agence Nationale de la Recherche in France. Elliot Convery Fisher was supported by a NERC E4 Doctoral Training Programme PhD studentship (Grant No. NE/S007407/1). We acknowledge species ID credit (iNaturalist) in Figure 3b to: Franck Rakotonasolo, David Rabehevitra, Andry Rakotoarisoa, Maria S. Vorontsova, Chris Anderson, and Andry Ny Aina Ary Misa.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data (Phelps et al., 2024) are available in Dryad: https://doi.org/10.5061/dryad.1zcrjdg0p.

ORCID

Leanne N. Phelps https://orcid.org/0000-0002-7385-3907
Estelle Razanatsoa https://orcid.org/0000-0002-7219-1411
Dylan S. Davis https://orcid.org/0000-0002-5783-3578
Jan Hackel https://orcid.org/0000-0002-9657-5372
Tanambelo Rasolondrainy https://orcid.org/0000-0002-3962-1504
George P. Tiley https://orcid.org/0000-0003-0053-0207
David Burney https://orcid.org/0000-0002-1029-8926
Ronadh Cox https://orcid.org/0000-0002-1743-2702
Laurie Godfrey https://orcid.org/0000-0001-9997-0207
Gareth P. Hempson https://orcid.org/0000-0001-8055-4895
Sean Hixon https://orcid.org/0000-0001-6147-7118
Tobias Andermann https://orcid.org/0000-0002-0932-1623
Alexandre Antonelli https://orcid.org/0000-0003-1842-9297
Guillaume Besnard https://orcid.org/0000-0003-2275-6012
William Bond https://orcid.org/0000-0002-3441-2084
Lounès Chikhi https://orcid.org/0000-0002-1140-0718
Víctor Fernández-García https://orcid.org/0000-0003-3217-3814
Simon Haberle https://orcid.org/0000-0001-5802-6535
James Hansford https://orcid.org/0000-0002-5702-8915
Grant S. Joseph https://orcid.org/0000-0002-8731-9828
Christian A. Kull https://orcid.org/0000-0002-7516-7898

Vincent Montade https://orcid.org/0000-0002-8518-2610
Tanjona Ramiadantsoa https://orcid.org/0000-0003-4689-0267
Andriantsilavo Hery
Isandratana Razafimanantsoa https://orcid.org/0000-0002-9933-6991
Nick Scroxton https://orcid.org/0000-0003-2315-9199
Colleen Seymour https://orcid.org/0000-0002-6729-2576
Helena Teixeira https://orcid.org/0000-0001-9032-4575
Patrick O. Waeber https://orcid.org/0000-0002-3229-0124
Lucienne Wilmé https://orcid.org/0000-0002-8344-1957
Brooke Crowley https://orcid.org/0000-0002-8462-6806
Kristina Douglass https://orcid.org/0000-0003-0931-3428
Maria S. Vorontsova https://orcid.org/0000-0003-0899-1120
Caroline E. R. Lehmann https://orcid.org/0000-0002-6825-124X

REFERENCES

Abreu, R. C. R., W. A. Hoffmann, H. L. Vasconcelos, N. A. Pilon, D. R. Rossatto, and G. Durigan. 2017. "The Biodiversity Cost of Carbon Sequestration in Tropical Savanna." *Science Advances* 3: e1701284.

Ahrends, A., C. Rahbek, M. T. Bulling, N. D. Burgess, P. J. Platts, J. C. Lovett, V. W. Kindemba, et al. 2011. "Conservation and the Botanist Effect." *Biological Conservation* 144(1): 131–140.

Aleman, J., B. Leys, R. Apema, I. Bentaleb, M. A. Dubois, B. Lamba, J. Lebamba, et al. 2012. "Reconstructing Savanna Tree Cover from Pollen, Phytoliths and Stable Carbon Isotopes." *Journal of Vegetation Science* 23: 187–197. https://doi.org/10.1111/j.1654-1103.2011.01335.x.

Alleway, H. K., E. S. Klein, L. Cameron, K. Douglass, I. Govia, C. Guell, M. Lim, L. Robin, and R. H. Thurstan. 2023. "The Shifting Baseline Syndrome as a Connective Concept for More Informed and Just Responses to Global Environmental Change." *People and Nature* 5(3): 885–896. https://doi.org/10.1002/pan3.10473.

Alva, O., A. Leroy, M. Heiske, V. Pereda-Loth, L. Tisseyre, A. Boland, J. F. Deleuze, et al. 2022. "The Loss of Biodiversity in Madagascar Is Contemporaneous with Major Demographic Events." *Current Biology* 32: 4997–5007.e5. https://doi.org/10.1016/j.cub.2022.09.060.

Alvarado, S. T., E. Buisson, S. M. Carrière, H. Rabarison, C. Rajeriarison, M. Andrianjafy, F. M. Randriatsivery, et al. 2015. "Achieving Sustainable Conservation in Madagascar: The Case of the Newly Established Ibity Mountain Protected Area." *Tropical Conservation Science* 8(2): 367–395.

Alvarado, S. T., T. S. F. Silva, and S. Archibald. 2018. "Management Impacts on Fire Occurrence: A Comparison of Fire Regimes of African and South American Tropical Savannas in Different Protected Areas." *Journal of Environmental Management* 218: 79–87. https://doi.org/10.1016/j.jenvman.2018.04.004.

Andela, N., D. C. Morton, L. Giglio, Y. Chen, G. R. van der Werf, P. S. Kasibhatla, R. S. DeFries, et al. 2017. "A Human-Driven Decline in Global Burned Area." *Science* 356(6345): 1356–62.

Andermann, T., C. A. E. Strömberg, A. Antonelli, and D. Silvestro. 2022. "The Origin and Evolution of Open Habitats in North America Inferred by Bayesian Deep Learning Models." *Nature Communications* 13(1): 4833. https://doi.org/10.1038/s41467-022-32300-5.

Anderson, A. 2019. "The Peopling of Madagascar." In *Oxford Research Encyclopedia of Asian History*, edited by D. Ludden. New York: Oxford University Press.

Andriambeloson, J. B., M. B. Blanco, A. Andriantsalohimisantatra, T. V. Rivoharison, N. Walker, C. Birkinshaw, and A. D. Yoder. 2021. "Living in Tiny Fragments: A Glimpse at the Ecology of Goodman's Mouse Lemurs (*Microcebus lehilahytsara*) in the Relic Forest of Ankafobe, Central Highlands, Madagascar." *Primates* 62(6): 887–896. https://doi.org/10.1007/s10329-021-00947-1.

Antonelli, A., R. J. Smith, A. L. Perrigo, A. Crottini, J. Hackel, W. Testo, H. Farooq, et al. 2022. "Madagascar's Extraordinary Biodiversity: Evolution, Distribution, and Use." *Science* 378(6623): eabf0869. https://doi.org/10.1126/science.abf0869.

Archibald, S. A., G. P. Hempson, and C. E. R. Lehmann. 2019. "A Unified Framework for Plant Life-History Strategies Shaped by Fire and Herbivory." *New Phytologist* 224(4): 1490–1503. https://doi.org/10.1111/nph.15986.

Ardalan, A., M. C. Oskarsson, B. Van Asch, E. Rabakonandriania, and P. Savolainen. 2015. "African Origin for Madagascan Dogs Revealed by mtDNA Analysis." *Royal Society Open Science* 2(5): 140552. https://doi.org/10.1098/rsos.140552.

Armitage, S. J., C. S. Bristow, and N. A. Drake. 2015. "West African Monsoon Dynamics Inferred from Abrupt Fluctuations of Lake Mega-Chad." *Proceedings of the National Academy of Sciences of the United States of America* 112(28): 8543–48. https://doi.org/10.1073/pnas.1417655112.

Aubréville, A. 1957. "Accord à Yangambi sur la nomenclature des types africains de végétation." *BOIS & Forets Des Tropiques* 51: 23–27.

Aubréville, A., P. Duvigneaud, A. C. Hoyle, R. W. Keay, F. A. Mendonca, and R. E. C. Pichi-Sermolli. 1958. *Carte de la végétation de l'Afrique au sud du Tropique du Cancer*. Paris: AETFAT/UNESCO.

Bakker, E. S., J. L. Gill, C. N. Johnson, F. W. M. Vera, C. J. Sandom, G. P. Asner, and J.-C. Svenning. 2016. "Combining Paleo-Data and Modern Exclosure Experiments to Assess the Impact of Megafauna Extinctions on Woody Vegetation." *Proceedings of the National Academy of Sciences of the United States of America* 113(4): 847–855. https://doi.org/10.1073/pnas.1502545112.

Balboa, R. F., L. D. Bertola, A. Brüniche-Olsen, M. S. Rasmussen, X. Liu, G. Besnard, J. Salmona, et al. 2024. "African Bushpigs Exhibit Porous Species Boundaries and Appeared in Madagascar Concurrently with Human Arrival." *Nature Communications* 15(1): 172. https://doi.org/10.1038/s41467-023-44105-1.

Bardgett, R. D., J. M. Bullock, S. Lavorel, P. Manning, U. Schaffner, N. Ostle, M. Chomel, et al. 2021. "Combating Global Grassland Degradation." *Nature Reviews Earth & Environment* 2: 720–735.

Barrett, C. B., A. J. Travis, and P. Dasgupta. 2011. "On Biodiversity Conservation and Poverty Traps." *108* 108(34): 13907–12. https://doi.org/10.1073/pnas.1011521108.

Beaujard, P. 2011. "The First Migrants to Madagascar and Their Introduction of Plants: Linguistic and Ethnological Evidence." *Azania* 46(2): 169–189. https://doi.org/10.1080/0067270X.2011.580142.

Bengtsson, J., J. M. Bullock, B. Egoh, C. Everson, T. Everson, T. O'Connor, P. J. O'Farrell, H. G. Smith, and R. Lindborg. 2019. "Grasslands—More Important for Ecosystem Services than You Might Think." *Ecosphere* 10(2): e02582. https://doi.org/10.1002/ecs2.2582.

Berlinck, C. N., L. H. A. Lima, and E. A. R. Carvalho. 2021. "Historical Survey of Research Related to Fire Management and Fauna Conservation in the World and in Brazil." *Biota Neotropica* 21(3): e20201144. https://doi.org/10.1590/1676-0611-BN-2020-1144.

Biggs, R., H. S. Clements, G. S. Cumming, G. Cundill, A. de Vos, M. Hamann, L. Luvuno, et al. 2022. "Social-Ecological Change: Insights from the Southern African Program on Ecosystem Change and Society." *Ecosystems and People* 18(1): 447–468. https://doi.org/10.1080/26395916.2022.2097478.

Blench, R. 2010. "New Evidence for the Austronesian Impact on the East African Coast." In *The Global Origins and Development of Seafaring*, edited by C. Anderson, J. Barrett, and K. Boyle, 239–248. Cambridge: McDonald Institute for Archaeological Research.

Bliege Bird, R., C. McGuire, D. W. Bird, M. H. Price, D. Zeanah, and D. G. Nimmo. 2020. "Fire Mosaics and Habitat Choice in Nomadic Foragers." *Proceedings of the National Academy of Sciences of the United States of America* 117(23): 201921709. https://doi.org/10.1073/pnas.1921709117.

Bodonirina, N., L. M. Reibelt, N. Stoudmann, J. Chamagne, T. G. Jones, A. Ravaka, H. V. Ranjaharivelo, et al. 2018. "Approaching Local Perceptions of Forest Governance and Livelihood Challenges with Companion Modeling from a Case Study around Zahamena National Park, Madagascar." *Forests* 9(10): 624. https://doi.org/10.3390/f9100624.

Bond, W. J. 2016. "Ancient Grasslands at Risk." *Science* 351(6269): 120–22. https://doi.org/10.1126/science.aad5132.

Bond, W. J., G. F. Midgley, and F. I. Woodward. 2003. "The Importance of Low Atmospheric CO_2 and Fire in Promoting the Spread of Grasslands and Savannas." *Global Change Biology* 9: 973–982. https://doi.org/10.1046/j.1365-2486.2003.00577.x.

Bond, W. J., J. A. Silander, and J. Ratsirarson. 2022. "Madagascar's Grassy Biomes Are Ancient and There Is Much to Learn about Their Ecology and Evolution." *Journal of Biogeography* 50(3): 614–621. https://doi.org/10.1111/jbi.14494.

Bond, W. J., J. A. Silander Jr, J. Ranaivonasy, and J. Ratsirarson. 2008. "The Antiquity of Madagascar's Grasslands and the Rise of C_4 Grassy Biomes." *Journal of Biogeography* 35: 1743–58.

Bond, W. J., and C. L. Parr. 2010. "Beyond the Forest Edge: Ecology, Diversity and Conservation of the Grassy Biomes." *Biological Conservation* 143(10): 2395–2404. https://doi.org/10.1016/j.biocon.2009.12.012.

Bond, W. J., and G. F. Midgley. 2012. "Carbon Dioxide and the Uneasy Interactions of Trees and Savannah Grasses." *Philosophical Transactions of the Royal Society B* 367: 601–612.

Bowman, D. M., C. A. Kolden, J. T. Abatzoglou, F. H. Johnston, G. R. van der Werf, and M. Flannigan. 2020. "Vegetation Fires in the Anthropocene." *Nature Reviews Earth & Environment* 1(10): 500–515. https://doi.org/10.1038/s43017-020-0085-3.

Breeze, P. S., N. A. Drake, H. S. Groucutt, A. Parton, R. P. Jennings, T. S. White, L. Clark-Balzan, et al. 2015. "Remote Sensing and GIS Techniques for Reconstructing Arabian Palaeohydrology and Identifying Archaeological Sites." *Quaternary International* 382(September): 98–119. https://doi.org/10.1016/j.quaint.2015.01.022.

Brierley, C., K. Manning, and M. Maslin. 2018. "Pastoralism May Have Delayed the End of the Green Sahara." *Nature Communications* 9(1): 4018. https://doi.org/10.1038/s41467-018-06321-y.

Broothaerts, N., V. F. Razanamahandry, L. Brosens, B. Campforts, L. Jacobs, T. Razafimbelo, T. Rafolisy, G. Verstraeten, S. Bouillon, and G. Govers. 2023. "Vegetation Changes and Sediment Dynamics in the Lake Alaotra Region, Central Madagascar." *The Holocene* 33: 459–470. https://doi.org/10.1177/09596836221145376.

Brosens, L., N. Broothaerts, B. Campforts, L. Jacobs, V. F. Razanamahandry, Q. van Moerbeke, S. Bouillon, T. Razafimbelo, T. Rafolisy, and G. Govers. 2022. "Under Pressure: Rapid Lavaka Erosion and Floodplain Sedimentation in Central Madagascar." *Science of the Total Environment* 806: 150483. https://doi.org/10.1016/j.scitotenv.2021.150483.

Brosens, L., R. Cox, B. Campforts, L. Jacobs, V. Vanacker, P. Bierman, V. F. Razanamahandry, et al. 2023. "The Slow Downwearing of Madagascar: Inferring Patterns and Controls on Long-Term Basin-Averaged Erosion Rates from In-Situ 10Be at the Catchment and Regional Level." *Earth Surface Processes and Landforms* 48(9): 1765–82. https://doi.org/10.1002/esp.5586.

Buisson, E. 2019. "Resilience and Restoration of Tropical and Subtropical Grasslands, Savannas, and Grassy Woodlands." *Biological Reviews* 94: 590–609. https://doi.org/10.1111/brv.12470.

Buisson, E., S. Archibald, A. Fidelis, and K. N. Siding. 2022. "Ancient Grasslands Guide Ambitious Goals in Grassland Restoration." *Science* 377(6606): 594–98. https://doi.org/10.1126/science.abo4605.

Burleigh, R., and E. N. Arnold. 1986. "Age and Dietary Differences of Recently Extinct Indian Ocean Tortoises (Geochelone s. lat.) Revealed by Carbon Isotope Analysis." *Proceedings of the Royal Society of London, Series B, Biological Sciences* 227: 137–144.

Burney, D. A. 1987. "Late Quaternary Stratigraphic Charcoal Records from Madagascar." *Quaternary Research* 28(2): 274–280. https://doi.org/10.1016/0033-5894(87)90065-2.

Burney, D. A., G. S. Robinson, and L. P. Burney. 2003. "*Sporormiella* and the Late Holocene Extinctions in Madagascar." *Proceedings of the National Academy of Sciences of the United States of America* 100: 10800–10805.

Burney, D. A., H. F. James, F. V. Grady, J.-G. Rafamantanatsoa, W. H. Ramilisonina, and J. B. Cowart. 1997. "Environmental Change, Extinction, and Human Activity: Evidence from Caves in NW Madagascar." *Journal of Biogeography* 24: 755–767. https://doi.org/10.1046/j.1365-2699.1997.00146.x.

Burney, D. A., L. P. Burney, L. R. Godfrey, W. L. Jungers, S. M. Goodman, H. T. Wright, and A. J. Jull. 2004. "A Chronology for Late Prehistoric Madagascar." *Journal of Human Evolution* 47(1–2): 25–63. https://doi.org/10.1016/j.jhevol.2004.05.005.

Burns, S. J., D. McGee, N. Scroxton, C. W. Kinsley, L. R. Godfrey, P. Faina, and L. Ranivoharimanana. 2022. "Southern Hemisphere Controls on ITCZ Variability in Southwest Madagascar over the Past 117,000 Years." *Quaternary Science Reviews* 276: 107317.

Burns, S. J., L. R. Godfrey, P. Faina, B. McGee, B. Hardt, L. Ranivoharimanana, and J. Randrianasy. 2016. "Rapid Human-Induced Landscape Transformation in Madagascar at the End of the First Millennium of the Common Era." *Quaternary Science Reviews* 134: 92–99.

Capitani, C., K. Mukama, B. Mbilinyi, I. O. Malugu, P. K. Munishi, N. D. Burgess, P. J. Platts, S. M. Sallu, and R. Marchant. 2016. "From Local Scenarios to National Maps: A Participatory Framework for Envisioning the Future of Tanzania." *Ecology and Society* 21(3): art4. https://doi.org/10.5751/ES-08565-210304.

Carret, J.-C. 2013. *Madagascar – Country Environmental Analysis (CEA): Taking Stock and Moving Forward*. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/599641468054534317/Madagascar-Country-Environmental-Analysis-CEA-taking-stock-and-moving-forward.

Case, M. F., and A. C. Staver. 2016. "Fire Prevents Woody Encroachment Only at Higher-than-Historical Frequencies in a South African Savanna." *Journal of Applied Ecology* 54: 955–962.

Cerling, T. E., J. G. Wynn, S. A. Andanje, M. I. Bird, D. K. Korir, N. E. Levin, W. Mace, A. N. Macharia, J. Quade, and C. H. Remien. 2011. "Woody Cover and Hominin Environments in the Past 6 Million Years." *Nature* 476(7358): 51–56. https://doi.org/10.1038/nature10306.

Cerling, T. E., J. M. Harris, J. A. Hart, P. Kaleme, H. Klingel, M. G. Leakey, N. E. Levin, R. L. Lewison, and B. H. Passey. 2008. "Stable Isotope Ecology of the Common Hippopotamus." *Journal of Zoology* 276: 204–212.

Cerling, T. E., J. M. Harris, B. J. MacFadden, M. G. Leakey, J. Quade, V. Eisenmann, and J. R. Ehleringer. 1997. "Global Vegetation Change through the Miocene/Pliocene Boundary." *Nature* 389: 153–58. https://doi.org/10.1038/38229.

Chaves, H. M. L. 1994. "Método estocástico para a estimativa da erosão em sulcos e voçorocas." *Revista Barsileira de Ciecncia do Solo Campinas* 18: 285–294.

Chazdon, R. L., P. H. S. Brancalion, L. Laestadius, A. Bennett-Curry, K. Buckingham, C. Kumar, J. Moll-Rocek, I. C. G. Vieira, and S. J. Wilson. 2016. "When Is a Forest a Forest? Forest Concepts and Definitions in the Era of Forest and Landscape Restoration." *Ambio* 45: 538–550. https://doi.org/10.1007/s13280-016-0772-y.

Chikhi, L., and G. M. Sgarlata. 2022. "Genetics of Malagasy Mammals: An Overview." In *The New Natural History of Madagascar*, Vol. 2, edited by S. Goodman. Princeton, NJ: Princeton University Press.

Claussen, M., C. Kubatzki, V. Brovkin, A. Ganopolski, P. Hoelzmann, and H. J. Pachur. 1999. "Simulation of an Abrupt Change in Saharan Vegetation in the Mid-Holocene." *Geophysical Research Letters* 26(14): 2037–40. https://doi.org/10.1029/1999GL900494.

Cochrane, M. A., and D. M. J. S. Bowman. 2021. "Manage Fire Regimes, Not Fires." *Nature Geoscience* 14: 455–57. https://doi.org/10.1038/s41561-021-00791-4.

Coelho, J. O., R. L. Anemone, and S. Carvalho. 2021. "Unsupervised Learning of Satellite Images Enhances Discovery of Late Miocene Fossil Sites in the Urema Rift, Gorongosa, Mozambique." *PeerJ* 9(June): e11573. https://doi.org/10.7717/peerj.11573.

Collins, A. S., J. R. Ali, and T. Razakamanana. 2022. "Introduction to the Geology of Madagascar." In *The New Natural History of Madagascar*, Vol. 1. Chapter 2., edited by S. Goodman. Princeton, NJ: Princeton University Press.

Colloredo-Mansfeld, M., F. J. Laso, and J. Arce-Nazario. 2020. "UAV-Based Participatory Mapping: Examining Local Agricultural Knowledge in the Galapagos." *Drones* 4(4): 62. https://doi.org/10.3390/drones4040062.

Cox, R., A. Carrère, A. F. M. Rakotondrazafy, and N. R. Voarintsoa. 2024. "Lavaka (Erosional Gullies) Provide Productive Patch Environments for Flora and Farming in Madagascar's Grassy Highlands." *Plants, People, Planet* 6(2): 287–303. https://doi.org/10.1002/ppp3.10440.

Cox, R., D. B. Zentner, A. F. M. Rakotondrazafy, and C. F. Rasoazanamparany. 2010. "Shakedown in Madagascar: Occurrence of Lavakas (Erosional Gullies) Associated with Seismic Activity." *Geology* 38: 179–182. https://doi.org/10.1130/G30670.1.

Cox, R., E. King Phillips, and A. F. M. Rakotondrazafy. 2024. "Gullying and Landscape Evolution: Lavaka in Lac Alaotra, Madagascar Shed Light on Rates of Change and Non-Anthropogenic Controls." *Science Advances* 10: eadi0316. https://doi.org/10.1126/sciadv.adi0316.

Cronon, W. 1996. "The Trouble with Wilderness: Or, Getting Back to the Wrong Nature." *Environmental History* 1: 7–28. https://doi.org/10.2307/3985059.

Crowley, B. E., H. S. Schmidt, and M. S. Vorontsova. 2023. "Carbon Isotope Values for Grasses in Madagascar's Central Highlands Establish Baselines for Historical and Palaeoecological Research." *Plants, People, Planet* 5(6): 869–884. https://doi.org/10.1002/ppp3.10358.

Crowley, B. E., I. Castro, V. Soarimalala, and S. M. Goodman. 2018. "Isotopic Evidence for Niche Partitioning and the Influence of Anthropogenic Disturbance on Endemic and Introduced Rodents in Central Madagascar." *The Science of Nature* 105: 44. https://doi.org/10.1007/s00114-018-1564-y.

Crowley, B. E., L. R. Godfrey, J. P. Hansford, and K. E. Samonds. 2021. "Seeing the Forest for the Trees—And the Grasses: Revisiting the Evidence for Grazer-Maintained Grasslands in Madagascar's Central Highlands." *Proceedings of the Royal Society B: Biological Sciences* 288: 20201785.

Crowley, B. E., L. R. Godfrey, and K. E. Samonds. 2023. "What Can Hippopotamus Isotopes Tell Us about Past Distributions of C4 Grassy Biomes on Madagascar?" *Plants, People, Planet* 5(6): 997–1010. https://doi.org/10.1002/ppp3.10402.

Crowley, B. E., and J. A. Sparks. 2018. "Geology." In *Les Aires Protégées Terrestres de Madagascar: Leur Histoire, Description et Biote/The Terrestrial Protected Areas of Madagascar: Their History, Description, and Biota*, edited by S. M. Goodman, M. J. Raherilalao, and S. Wolhauser, 169–180. Association Vahatra: Antananarivo.

Crowley, B. E., and K. E. Samonds. 2013. "Stable Carbon Isotope Values Confirm a Recent Increase in Grasslands in Northwestern Madagascar." *The Holocene* 23(7): 1066–73. https://doi.org/10.1177/0959683613484675.

Crowther, A., L. Lucas, R. Helm, M. Horton, C. Shipton, H. T. Wright, S. Walshaw, et al. 2016. "Ancient Crops Provide First Archaeological Signature of the Westward Austronesian Expansion." *Proceedings of the National Academy of Sciences of* *the United States of America* 113(24): 6635–40. https://doi.org/10.1073/pnas.1522714113.

Davis, D. S. 2019. "Object-Based Image Analysis: A Review of Developments and Future Directions of Automated Feature Detection in Landscape Archaeology." *Archaeological Prospection* 26(2): 155–163. https://doi.org/10.1002/arp.1730.

Davis, D. S. 2020a. "Studying Human Responses to Environmental Change: Trends and Trajectories of Archaeological Research." *Environmental Archaeology* 25(4): 367–380. https://doi.org/10.1080/14614103.2019.1639338.

Davis, D. S. 2020b. "Defining What We Study: The Contribution of Machine Automation in Archaeological Research." *Digital Applications in Archaeology and Cultural Heritage* 18: e00152. https://doi.org/10.1016/j.daach.2020.e00152.

Davis, D. S., B. Tucker, R. Justome, Z. M. Chrisostome, B. V. Pierre, A. I. Domic, L. N. Phelps, et al. 2024. "Archaeology, Ethnography, and Geosciences Reveal Central Role of Traditional Lifeways in Shaping Madagascar's Dry Forests." *Journal of Social Archaeology* 24(3): 221–245. https://doi.org/10.1177/14696053241260032.

Davis, D. S., D. Buffa, T. Rasolondrainy, E. Creswell, C. Anyanwu, A. Ibirogba, C. Randolph, et al. 2021. "The Aerial Panopticon and the Ethics of Archaeological Remote Sensing in Sacred Cultural Spaces." *Archaeological Prospection* 28(3): 305–320. https://doi.org/10.1002/arp.1819.

Davis, D. S., R. J. DiNapoli, M. C. Sanger, and C. P. Lipo. 2020. "The Integration of Lidar and Legacy Datasets Provides Improved Explanations for the Spatial Patterning of Shell Rings in the American Southeast." *Advances in Archaeological Practice* 8(4): 361–375. https://doi.org/10.1017/aap.2020.18.

Davis, D. S., V. Andriankaja, T. L. Carnat, Z. M. Chrisostome, C. Colombe, F. Fenomanana, L. Hubertine, et al. 2020. "Satellite-Based Remote Sensing Rapidly Reveals Extensive Record of Holocene Coastal Settlement on Madagascar." *Journal of Archaeological Science* 115: 105097. https://doi.org/10.1016/j.jas.2020.105097.

Davis, D. S., and K. Douglass. 2020. "Aerial and Spaceborne Remote Sensing in African Archaeology: A Review of Current Research and Potential Future Avenues." *African Archaeological Review* 37(1): 9–24. https://doi.org/10.1007/s10437-020-09373-y.

Descola, P. 2013. *Beyond Nature and Culture*. Chicago, IL: University of Chicago Press.

Development Corridors Partnership. 2021. "Sustainable and Equitable Development Corridors for Africa|The Development Corridors Partnership [Video]." YouTube. https://youtu.be/z04oi6x8sPo.

Dewar, R. E., C. Radimilahy, H. T. Wright, Z. Jacobs, G. O. Kelly, and F. Verna. 2013. "Stone Tools and Foraging in Northern Madagascar Challenge Holocene Extinction Models." *Proceedings of the National Academy of Sciences of the United States of America* 110(31): 12583–88.

Dewar, R. E., and H. T. Wright. 1993. "The Culture History of Madagascar." *Journal of World Prehistory* 7: 417–466. https://doi.org/10.1007/BF00997802.

Dewitte, O., A. Jones, O. Spaargaren, H. Breuning-Madsen, M. Brossard, A. Dampha, J. Deckers, et al. 2013. "Harmonisation of the Soil Map of Africa at the Continental Scale." *Geoderma* 211-212: 138–153. https://doi.org/10.1016/j.geoderma.2013.07.007.

Di Lernia, S., and M. Cremaschi. 1996. "Taming Barbary Sheep: Wild Animal Management by Early Holocene Hunter-Gatherers at Uan Afuda (Libyan Sahara)." *Nyame Akuma* 46: 43–54.

Dietl, G. P., S. M. Kidwell, M. Brenner, D. A. Burney, K. W. Flessa, S. T. Jackson, and P. I. Koch. 2015. "Conservation Paleobiology: Leveraging Knowledge of the Past to Inform Conservation and Restoration." *Annual Reviews of Earth and Planetary Sciences* 43: 3.1–3.25. https://doi.org/10.1146/annurev-earth-040610-133349.

Dietl, G. P., and K. W. Flessa. 2011. "Conservation Paleobiology: Putting the Dead to Work." *Trends in Ecology & Evolution* 26(1): 30–37.

Dixon, A. P., D. Faber-Langendoen, C. Josse, J. Morrison, and C. J. Loucks. 2014. "Distribution Mapping of World Grassland Types." *Journal of Biogeography* 41: 2003–19. https://doi.org/10.1111/jbi.12381.

Domínguez-Rodrigo, M. 2014. "Is the "Savanna Hypothesis" a Dead Concept for Explaining the Emergence of the Earliest Hominins?" *Current Anthropology* 55: 59–81.

Douglass, K., E. Q. Morales, G. Manahira, F. Fenomanana, R. Samba, F. Lahiniriko, Z. M. Chrisostome, et al. 2019. "Toward a Just and Inclusive Environmental Archaeology of Southwest Madagascar." *Journal of Social Archaeology* 19(3): 307–332. https://doi.org/10.1177/1469605319862072.

Douglass, K., J. Walz, E. Quintana-Morales, R. Marcus, G. Myers, and J. Pollini. 2019. "Historical Perspectives on Contemporary Human-Environment Dynamics in Southeast Africa." *Conservation Biology* 33(2): 260–274. https://doi.org/10.1111/cobi.13244.

Douglass, K., S. Hixon, H. T. Wright, L. R. Godfrey, B. E. Crowley, B. Manjakahery, T. Rasolondrainy, Z. Crossland, and C. Radimilahy. 2019. "A Critical Review of Radiocarbon Dates Clarifies the Human Settlement of Madagascar." *Quaternary Science Reviews* 221: 105878.

Douglass, K., and T. Rasolondrainy. 2021. "Social Memory and Niche Construction in a Hypervariable Environment." *American Journal of Human Biology* 33: e23557. https://doi.org/10.1002/ajhb.23557.

Dunn, C. E. 2007. "Participatory GIS—A People's GIS?" *Progress in Human Geography* 31(5): 616–637. https://doi.org/10.1177/0309132507081493.

Eckstein, D., M.-L. Hutfils, and M. Winges. 2018. *Global Climate Risk Index 2019. Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2017 and 1998 to 2017*. Bonn: Germanwatch Nord-Süd Initiative e.V. https://germanwatch.org/en/16046.

Edwards, E. J., C. P. Osborne, C. A. E. Strömberg, S. A. Smith, and C4 Grasses Consortium. 2010. "The Origins of C_4 Grasslands: Integrating Evolutionary and Ecosystem Science." *Science* 328(5978): 587–591. https://doi.org/10.1126/science.1177216.

Ellis, E. C., N. Gauthier, K. Klein Goldewijk, R. Bliege Bird, N. Boivin, S. Díaz, D. Q. Fuller, et al. 2021. "People Have Shaped Most of Terrestrial Nature for at Least 12,000 Years." *Proceedings of the National Academy of Sciences of the United States of America* 118(17): e2023483118. https://doi.org/10.1073/pnas.202348311.

Faina, P., S. J. Burns, L. R. Godfrey, B. E. Crowley, N. Scroxton, D. McGee, M. R. Sutherland, and L. Ranivoharimanana. 2021. "Comparing the Paleoclimates of Northwestern and Southwestern Madagascar during the Late Holocene: Implications for the Role of Climate in Megafaunal Extinction." *Malagasy Nature* 15: 108–127.

Fairhead, J., and M. Leach. 1996. *Misreading the African Landscapes: Society and Ecology in a Forest-Savanna Mosaic*, Vol. 90. Cambridge: Cambridge University Press.

FAO. 2021. "FAOSTAT. Crops and Livestock Products (Madagascar)." https://www.fao.org/faostat/en/#data/QCL.

Fernández-García, V., L. N. Phelps, T. Strydom, et al. 2024. "Fire regimes of Southeastern Africa are better predicted by Sentinel-2 than MODIS." *ESS Open Archive*. http://doi.org/10.22541/essoar.173282212.20545644/v1.

Fernández-García, V., and C. A. Kull. 2023. "Refining Historical Burned Area Data from Satellite Observations." *International Journal of Applied Earth Observation and Geoinformation* 120: 103350. https://doi.org/10.1016/j.jag.2023.103350.

Fisher, R., S. Heckbert, J. M. L. Villalobos, and S. Sutton. 2019. "Augmenting Physical 3D Models with Projected Information to Support Environmental Knowledge Exchange." *Applied Geography* 112: 102095. https://doi.org/10.1016/j.apgeog.2019.102095.

Fletcher, M.-S., R. Hamilton, W. Dressler, and L. Palmer. 2021. "Indigenous Knowledge and the Shackles of Wilderness." *Proceedings of the National Academy of Sciences of the United States of America* 118(40): e2022218118. https://doi.org/10.1073/pnas.2022218118.

Gaillard, M. J., S. Sugita, J. Bunting, J. Dearing, and F. Bittmann. 2008. "Human Impact on Terrestrial Ecosystems, Pollen Calibration and Quantitative Reconstruction of Past Land-Cover." *Vegetation History and Archaeobotany* 17: 415–18. https://doi.org/10.1007/s00334-008-0170-x.

Garcia, C. A., S. Savilaakso, R. W. Verburg, N. Stoudmann, P. Fernbach, S. A. Sloman, G. D. Peterson, et al. 2022. "Strategy Games to Improve Environmental Policymaking." *Nature Sustainability* 5: 464–471. https://doi.org/10.1038/s41893-022-00881-0.

Gardin, J.-C. 1980. *Archaeological Constructs: An Aspect of Theoretical Archaeology*. Cambridge (New York): Cambridge University Press.

Gasse, F., and E. Van Campo. 1998. "A 40,000-Yr Pollen and Diatom Record from Lake Tritrivakely, Madagascar, in the Southern Tropics." *Quaternary Research* 49(3): 299–311. https://doi.org/10.1006/qres.1998.1967.

Gasse, F., and E. Van Campo. 2001. "Late Quaternary Environmental Changes from a Pollen and Diatom Record in the Southern Tropics (Lake Tritrivakely, Madagascar)." *Palaeogeography, Palaeoclimatology, Palaeoecology* 167(3–4): 287–308.

Giglio, L., L. Boschetti, D. P. Roy, M. L. Humber, and C. O. Justice. 2018. "The Collection 6 MODIS Burned Area Mapping Algorithm and Product." *Remote Sensing of Environment* 217: 72–85. https://doi.org/10.1016/j.rse.2018.08.005.

Gill, J. L. 2014. "Ecological Impacts of the Late Quaternary Megaherbivore Extinctions." *The New Phytologist* 201: 1163–69. https://doi.org/10.1111/nph.12576.

Githumbi, E., R. Marchant, and D. Olago. 2020. "Using the Past to Inform a Sustainable Future: Palaeoecological Insights from East Africa." In *Africa and the Sustainable Development Goals*, edited by M. Ramutsindela and D. Mickler, 187–195. Cham: Springer.

Glamann, J., J. Hanspach, D. J. Abson, N. Collier, and J. Fischer. 2017. "The Intersection of Food Security and Biodiversity Conservation: A Review." *Regional Environmental Change* 17: 1303–13.

Godfrey, L. R., B. E. Crowley, K. M. Muldoon, S. J. Burns, N. Scroxton, Z. S. Klukkert, L. Ranivoharimanana, et al. 2021. "Teasing Apart Impacts of Human Activity and Regional Drought on Madagascar's Large Vertebrate Fauna: Insights from New Excavations at Tsimanampesotse and Antsirafaly." *Frontiers in Ecology and Evolution* 9: 742203.

Godfrey, L. R., N. Scroxton, B. E. Crowley, S. J. Burns, M. R. Sutherland, V. R. Pérez, P. Faina, D. McGee, and L. Ranivoharimanana. 2019. "A New Interpretation of Madagascar's Megafaunal Decline: The "Subsistence Shift Hypothesis"." *Journal of Human Evolution* 130: 126–140. https://doi.org/10.1016/j.jhevol.2019.03.002.

Godfrey, L. R., and B. E. Crowley. 2016. "Madagascar's Ephemeral Palaeo-Grazer Guild: Who Ate the Ancient C4 Grasses?" *Proceedings of the Royal Society B – Biological Sciences* 283(1834): 20160360. https://doi.org/10.1098/rspb.2016.0360.

Goel, N., E. S. Van Vleck, J. C. Aleman, and A. C. Staver. 2020. "Dispersal Limitation and Fire Feedbacks Maintain Mesic Savannas in Madagascar." *Ecology* 101(12): e03177. https://doi.org/10.1002/ecy.3177.

Gommery, D., B. Ramanivosoa, M. Faure, C. Guerin, P. Kerloc'h, F. Senegas, and H. Randrianantenaina. 2011. "Oldest Evidence of Human Activities in Madagascar on Subfossil Hippopotamus Bones from Anjohibe (Mahajanga Province)." *Comptes Rendus – Palevol* 10: 271–78.

Goodman, S. M., M. J. Raherilalao, and K. Muldoon. 2013. "Bird Fossils from Ankilitelo Cave: Inference about Holocene Environmental Changes in Southwestern Madagascar." *Zootaxa* 3750: 534–548. https://doi.org/10.11646/zootaxa.3750.5.6.

Gosling, C. M., J. P. G. M. Cromsigt, N. Mpanza, and H. Olff. 2012. "Effects of Erosion From Mounds of Different Termite Genera on Distinct Functional Grassland Types in an African Savannah." *Ecosystems* 15: 128–139. https://doi.org/10.1007/s10021-011-9497-8.

Grace, J., J. S. José, P. Meir, H. S. Miranda, and R. A. Montes. 2006. "Productivity and Carbon Fluxes of Tropical Savannas." *Journal of Biogeography* 33: 387–400.

Griffith, D. M., C. E. R. Lehmann, C. A. E. Strömberg, C. L. Parr, R. T. Pennington, M. Sankaran, J. Ratnam, et al. 2017. "Comment on "The Extent of Forest in Dryland Biomes"." *Science* 358(6365): eaao1309. https://doi.org/10.1126/science.aao1309.

Hackel, J., H I Andriantsilavo, Razafimanantsoa Vincent Porcher, Michael D Pirie. Heathers (*Erica*, Ericaceae) of Madagascar: Taxonomy, Evolution, Ecology and Uses. 2024. hal-04833832. http://doi.org/10.3897/arphapreprints.e141580.

Hackel, J., M. S. Vorontsova, O. P. Nanjarisoa, R. C. Hall, J. Razanatsoa, P. Malakasi, and G. Besnard. 2018. "Grass Diversification in Madagascar: In Situ Radiation of Two Large C_3 Shade Clades and Support for a Miocene to Pliocene Origin of C_4 Grassy Biomes." *Journal of Biogeography* 45(4): 750–761.

Hagl, P. A., R. Gargiulo, M. F. Fay, C. Solofondranohatra, J. Salmona, U. Suescun, N. Rakotomalala, et al. 2021. "Geographical Structure of Genetic Diversity in *Loudetia simplex* (Poaceae) in Madagascar and South Africa." *Botanical Journal of the Linnean Society* 196(1): 81–99.

Haines-Young. 2009. "Land Use and Biodiversity Relationships." *Land Use Policy* 26(S1): S178–S186. https://doi.org/10.1016/j.landusepol.2009.08.009.

Hansford, J., P. C. Wright, A. Rasoamiaramanana, V. R. Pérez, L. R. Godfrey, D. Errickson, T. Thompson, and S. T. Turvey. 2018. "Early Holocene Human Presence in Madagascar Evidenced by Exploitation of Avian Megafauna." *Science Advances* 4: eaat6925.

Hansford, J. P., and S. T. Turvey. 2022. "Dietary Isotopes of Madagascar's Extinct Megafauna Reveal Holocene Browsing and Grazing Guilds." *Biology Letters* 18: 20220094.

Harper, G., M. Steininger, C. Tucker, D. Juhn, and F. Hawkins. 2007. "Fifty Years of Deforestation and Forest Fragmentation in Madagascar." *Environmental Conservation* 34(4): 325–333. https://doi.org/10.1017/S0376892907004262.

Harris, A. 2018. *Description and Comparison in Cultural Anthropology*. Routledge, New York.

Harvey, C. A., Z. L. Rakotobe, N. S. Rao, R. Dave, H. Razafimahatratra, R. Hasinandrianina Rabarijohn, H. Rajaofara, and J. L. MacKinnon. 2014. "Extreme Vulnerability of Smallholder Farmers to Agricultural Risks and Climate Change in Madagascar." *Philosophical Transactions of the Royal Society B* 369(1639): 20130089. https://doi.org/10.1098/rstb.2013.0089.

Hawthorne, D., C. J. Courtney Mustaphi, J. C. Aleman, O. Blarquez, D. Colombaroli, A. L. Daniau, J. R. Marlon, et al. 2018. "Global Modern Charcoal Dataset (GMCD): A Tool for Exploring Proxy-Fire Linkages and Spatial Patterns of Biomass Burning." *Quaternary International* 488: 3–17. https://doi.org/10.1016/j.quaint.2017.03.046.

Hempson, G. P., S. Archibald, J. E. Donaldson, and C. E. R. Lehmann. 2019. "Alternate Grassy Ecosystem States Are Determined by Palatability-Flammability Trade-Offs." *Trends in Ecology & Evolution* 34(4): 286–290. https://doi.org/10.1016/j.tree.2019.01.007.

Hempson, G. P., S. A. Archibald, S. Archibald, W. J. Bond, R. P. Ellis, C. C. Grant, F. J. Kruger, et al. 2015. "Ecology of Grazing Lawns in Africa." *Biological Reviews* 90(3): 979–994. https://doi.org/10.1111/brv.12145.

Herrera, J. P., J. Y. Rabezara, N. A. F. Ravelomanantsoa, M. Metz, C. France, A. Owens, M. Pender, C. L. Nunn, and R. A. Kramer. 2021. "Food Insecurity Related to Agricultural Practices and Household Characteristics in Rural Communities of Northeast Madagascar." *Food Security* 13: 1393–1405. https://doi.org/10.1007/s12571-021-01179-3.

Herrera, M. B., V. A. Thomson, J. J. Wadley, P. J. Piper, S. Sulandari, A. B. Dharmayanthi, S. Kraitsek, J. Gongora, and J. J. Austin. 2017. "East African Origins for Madagascan Chickens as Indicated by Mitochondrial DNA." *Royal Society Open Science* 4(3): 160787.

Hixon, S., K. G. Douglass, S. W. Hixon, B. E. Crowley, L. M. A. Rakotozafy, G. Clark, A. Anderson, et al. 2021. "Late Holocene Spread of Pastoralism Coincides with Endemic Megafaunal Extinction on Madagascar." *Proceedings of the Royal Society B: Biological Sciences* 288(1955): 20211204. https://doi.org/10.1098/rspb.2021.1204.

Hixon, S. W., A. I. Domic, K. G. Douglass, P. Roberts, L. Eccles, M. Buckley, S. Ivory, S. Noe, and D. J. Kennett. 2022. "Cutmarked Bone of Drought-Tolerant Extinct Megafauna Deposited with Traces of Fire, Human Foraging, and Introduced Animals in SW Madagascar." *Scientific Reports* 12: 18504. https://doi.org/10.1038/s41598-022-22980-w.

Hixon, S. W., E. A. Elliott Smith, B. E. Crowley, G. H. Perry, J. Randrianasy, J. F. Ranaivoarisoa, D. J. Kennett, and S. D. Newsome. 2018. "Nitrogen Isotope (δ15N) Patterns for Amino Acids in Lemur Bones Are Inconsistent with Aridity Driving Megafaunal Extinction in South-Western Madagascar." *Journal of Quaternary Science* 33(8): 958–968.

Hixon, S. W., J. H. Curtis, M. Brenner, K. G. Douglass, A. I. Domic, B. J. Culleton, S. J. Ivory, and D. J. Kennett. 2021. "Drought Coincided with, but Does Not Explain, Late Holocene Megafauna Extinctions in SW Madagascar." *Climate* 9(9): 138. https://doi.org/10.3390/cli9090138.

Hixon, S. W., K. G. Douglass, L. R. Godfrey, L. Eccles, B. E. Crowley, L. M. A. Rakotozafy, G. Clark, et al. 2021. "Ecological Consequences of a Millennium of Introduced Dogs on Madagascar." *Frontiers in Ecology and Evolution* 9: 689559. https://doi.org/10.3389/fevo.2021.689559.

Hixon, S. W., R. Fernandes, A. Andriamahaihavana, A. L. Baden, M. B. Blanco, G. Caulier, M. Dammhahn, et al. 2024. "Introducing IsoMad, a Compilation of Isotopic Datasets for Madagascar." *Scientific Data* 11(857).

Hoang, N. T., and K. Kanemoto. 2021. "Mapping the Deforestation Footprint of Nations Reveals Growing Threat to Tropical Forests." *Nature Ecology & Evolution* 5: 845–853. https://doi.org/10.1038/s41559-021-01417-z.

Hooghiemstra, H., A.-M. Lézine, S. A. G. Leroy, L. Dupont, and F. Marret. 2006. "Late Quaternary Palynology in Marine Sediments: A Synthesis of the Understanding of Pollen Distribution Patterns in the NW African Setting." *Quaternary International* 148(1): 29–44. https://doi.org/10.1016/j.quaint.2005.11.005.

Iannella, M., P. D'Alessandro, and M. Biondi. 2019. "Entomological Knowledge in Madagascar by GBIF Datasets: Estimates on the Coverage and Possible Biases (Insecta)." *Fragmenta Entomologica* 51: 1–10. https://doi.org/10.13133/2284-4880/329.

Igbokwe, J. I., J. O. Akinyede, B. Dang, T. Alaga, M. N. Ono, V. C. Nnodu, and L. O. Anike. 2008. "Mapping and Monitoring the Impacts of Flood and Erosion in South Eastern Nigeria with Satellite Remote Sensing and Geographic Information System." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 37: 865–872.

Jarosz, L. 1993. "Defining and Explaining Tropical Deforestation: Shifting Cultivation and Population Growth in Colonial Madagascar (1896–1940)." *Economic Geography* 69(4): 366–379.

Jiongxin, X. 1996. "Benggang Erosion: The Influencing Factors." *Catena* 27: 249–263.

Jones, M. W., C. Santín, G. R. van der Werf, and S. H. Doerr. 2019. "Global Fire Emissions Buffered by the Production of Pyrogenic Carbon." *Nature Geoscience* 12: 742–47. https://doi.org/10.1038/s41561-019-0403-x.

Joseph, G. S., and C. L. Seymour. 2020. "Madagascan Highlands: Originally Woodland and Forest Containing Endemic Grasses, Not Grazing-Adapted Grassland." *Proceedings of the Royal Society B* 287: 20201956.

Joseph, G. S., and C. L. Seymour. 2021. "The Unlikely 'Antiquity of Madagascar's Grasslands': Disproportionately Forest-Limited

Endemic Fauna Support Anthropogenic Transformation from Woodland." *Journal of Biogeography* 48(8): 2111–15. https://doi.org/10.1111/jbi.14132.

Kariuki, R. W., C. Capitani, L. K. Munishi, A. Shoemaker, C. J. Courtney Mustaphi, N. William, P. J. Lane, and R. Marchant. 2022. "Serengeti's Futures: Exploring Land Use and Land Cover Change Scenarios to Craft Pathways for Meeting Conservation and Development Goals. Frontiers in Conservation." *Science* 3: 92.

Kariuki, R. W., L. K. Munishi, C. J. Courtney-Mustaphi, C. Capitani, A. Shoemaker, P. J. Lane, and R. Marchant. 2021. "Integrating Stakeholders' Perspectives and Spatial Modelling to Develop Scenarios of Future Land Use and Land Cover Change in Northern Tanzania." *PLoS One* 16(2): e0245516.

Kaufmann, J. C., and S. Tsirahamba. 2006. "Forests and Thorns: Conditions of Change Affecting Mahafale Pastoralists in Southwestern Madagascar." *Conservation and Society* 4(2): 231.

Kehlmaier, C., E. Gracia, J. R. Ali, P. D. Campbell, S. D. Chapman, V. Deepak, F. Ihlow, et al. 2023. "Ancient DNA Elucidates the Lost World of Western Indian Ocean Giant Tortoises and Reveals a New Extinct Species from Madagascar." *Sciences Advances* 9: eabq2574.

Keith, D. A., J. R. Ferrer-Paris, E. Nicholson, M. J. Bishop, B. A. Polidoro, E. Ramirez-Llodra, M. G. Tozer, et al. 2022. "A Function-Based Typology for Earth's Ecosystems." *Nature* 610: 513–18.

King Phillips, E. J., R. Cox, and J. P. Harrington. 2016. "Monitoring Evolution of Lavakas (Gullies) in the Alaotra-Mangoro District of Eastern Madagascar Using 20th Century Air Photos and 21st Century Ortho-Imagery: Geological Society of America Abstracts with Programs v. 48." https://doi.org/10.1130/abs/2016AM-283682.

Knapp, A. K., and S. L. Collins. 2019. "Reimagining NEON Operations: We Can Do Better." *Bioscience* 69(12): 956–59. https://doi.org/10.1093/biosci/biz119.

Kull, C. A. 2000. "Deforestation, Erosion, and Fire: Degradation Myths in the Environmental History of Madagascar." *Environment and History* 6(4): 423–450. https://doi.org/10.3197/096734000129342361.

Kull, C. A. 2004. *Isle of Fire: The Political Ecology of Landscape Burning on Madagascar*. Chicago, IL: University of Chicago Press.

Kull, C. A., J. Tassin, S. Moreau, H. R. Ramiarantsoa, C. Blanc-Pamard, and S. M. Carrière. 2012. "The Introduced Flora of Madagascar." *Biological Invasions* 14: 875–888. https://doi.org/10.1007/s10530-011-0124-6.

Kull, C. A., S. M. Carriere, S. Moreau, H. Rakoto Ramiarantsoa, C. Blanc-Pamard, and J. Tassin. 2013. "Melting Pots of Biodiversity: Tropical Smallholder Farm Landscapes as Guarantors of Sustainability." *Environment* 55(2): 6–15. https://doi.org/10.1080/00139157.2013.765307.

Kull, C. A., and C. E. R. Lehmann. 2022. "Fire in Highland Grasslands: Uses, Ecology, and History." In *The New Natural History of Madagascar*, Vol. 1. Part 5 (Human Ecology)., edited by S. Goodman, 197–203. Princeton, NJ: Princeton University Press.

Kusuma, P., M. P. Cox, D. Pierron, H. Razafindrazaka, N. Brucato, L. Tonasso, H. L. Suryadi, T. Letellier, H. Sudoyo, and F. X. Ricaut. 2015. "Mitochondrial DNA and the Y Chromosome Suggest the Settlement of Madagascar by Indonesian Sea Nomad Populations." *BMC Genomics* 16(1): 191. https://doi.org/10.1186/s12864-015-1394-7.

Lambin, E. F., B. L. Turner, H. J. Geist, S. B. Agbola, A. Angelsen, J. W. Bruce, O. T. Coomes, et al. 2001. "The Causes of Land-Use and Land-Cover Change: Moving beyond the Myths." *Global Environmental Change* 11: 261–69.

Lange, M., N. Eisenhauer, C. A. Sierra, H. Bessler, C. Engels, R. I. Griffiths, P. G. Mellado-Vázquez, et al. 2015. "Plant Diversity Increases Soil Microbial Activity and Soil Carbon Storage." *Nature Communications* 6: 6707. https://doi.org/10.1038/ncomms7707.

Laris, P., R. Jacobs, M. Koné, F. Dembélé, and C. M. Rodrigue. 2020. "Determinants of Fire Intensity in Working Landscapes of an African Savanna." *Fire Ecology* 16: 27. https://doi.org/10.1186/s42408-020-00085-x.

Larrain, A. A., and M. K. McCall. 2019. "Participatory Mapping and Participatory GIS for Historical and Archaeological Landscape Studies: A Critical Review." *Journal of Archaeological Method and Theory* 26(2): 643–678. https://doi.org/10.1007/s10816-018-9385-z.

Lee, C., J. Day, S. M. Goodman, M. Pedrono, G. Besnard, L. Frantz, P. J. Taylor, M. J. Herrera, and J. Gongora. 2020. "Genetic Origins and Diversity of Bushpigs from Madagascar (*Potamochoerus larvatus*, Family Suidae)." *Scientific Reports* 10: 20629.

Lehmann, C. E. R., and C. L. Parr. 2016. "Tropical Grassy Biomes: Linking Ecology, Human Use and Conservation." *Philosophical Transactions of the Royal Society B* 371(1703): 20160329. https://doi.org/10.1098/rstb.2016.0329.

Lehmann, C. E. R., C. L. Solofondranohatra, J. A. Morton, L. N. Phelps, H. Ralimanana, J. Razanatsoa, V. Rakotoarimanana, and M. S. Vorontsova. 2022. "The Grassy Ecosystems of Madagascar." In *The New Natural History of Madagascar*, Vol. 1. Section 4 (Forest and Grassland Ecology)., edited by S. Goodman, 152–168. Princeton, NJ: Princeton University Press.

Lehmann, C. E. R., C. L. Solofondranohatra, and M. S. Vorontsova. 2021. "Beyond Ancient Versus Anthropogenic for Madagascar's Grassy Ecosystems. A Reply to: Crowley et al. (2021)." *Proceedings of the Royal Society B: Biological Sciences* 288: 20210388.

Lehmann, C. E. R., D. M. Griffith, K. J. Simpson, T. M. Anderson, S. Archibald, D. J. Beerling, W. J. Bond, et al. 2019. "Functional Diversification Enabled Grassy Biomes to Fill Global Climate Space." BioRxiv. 583625. https://doi.org/10.1101/583625.

Lehmann, C. E. R., S. A. Archibald, W. A. Hoffmann, and W. J. Bond. 2011. "Deciphering the Distribution of the Savanna Biome." *New Phytologist* 191(1): 197–209.

Lehmann, C. E. R., T. M. Anderson, M. Sankaran, S. I. Higgins, S. Archibald, W. A. Hoffmann, N. P. Nanan, et al. 2014. "Savanna Vegetation-Fire-Climate Relationships Differ Among Continents." *Science* 343(6170): 548–552.

Li, H., A. Sinha, A. Anquetil André, C. Spötl, H. B. Vonhof, A. Meunier, G. Kathayat, et al. 2020. "A Multimillennial Climatic Context for the Megafaunal Extinctions in Madagascar and Mascarene Islands." *Science Advances* 6(42): eabb2459. https://doi.org/10.1126/sciadv.abb2459.

Liao, Y., Z. Yuan, M. Zheng, D. Li, X. Nie, X. Wu, B. Huang, Z. Xie, and C. Tang. 2019. “The Spatial Distribution of Benggang and the Factors That Influence It.” *Land Degradation & Development* 30: 2323–35.

Liu, Y., Y. Wang, S. D. Willett, N. E. Zimmermann, and L. Pellissier. 2024. “Escarpment Evolution Drives the Diversification of the Madagascar Flora.” *Science* 383(6683): 653–58. https://doi.org/10.1126/science.adi0833.

Lowry, P. P., II, G. E. Schatz, and P. B. Phillipson. 1997. “The Classification of Natural and Anthropogenic Vegetation in Madagascar.” In *Natural Change and Human Impact in Madagascar*, edited by S. M. Goodman and B. D. Patterson, 93–123. Washington DC: Smithsonian Institution Press.

Mabit, L., C. Bernard, A. Lee Zhi Yi, E. Fulajtar, G. Dercon, M. Zaman, A. Toloza, and L. Heng. 2018. “Promoting the Use of Isotopic Techniques to Combat Soil Erosion: An Overview of the Key Role Played by the SWMCN Subprogramme of the Joint FAO/IAEA Division over the Last 20 Years.” *Land Degradation and Development* 29(9): 3077–91. https://doi.org/10.1002/ldr.3016.

Makoni, M. 2021. “Southern Madagascar Faces “Shocking” Lack of Food.” *The Lancet* 397(10291): 2239. https://doi.org/10.1016/S0140-6736(21)01296-4.

Manning, K., and A. Timpson. 2014. “The Demographic Response to Holocene Climate Change in the Sahara.” *Quaternary Science Reviews* 101: 28–35. https://doi.org/10.1016/j.quascirev.2014.07.003.

Marchant, R. 2021. “Origins and Migration: Environmental and Cultural Change over the Last 300,000 Years in East Africa.” In *East Africa’s Human Environment Interactions* 39–114. Cham: Palgrave Macmillan.

Marchant, R., S. Richer, O. Boles, C. Capitani, C. J. Courtney-Mustaphi, P. Lane, M. E. Prendergast, et al. 2018. “Drivers and Trajectories of Land Cover Change in East Africa: Human and Environmental Interactions from 6000 Years Ago to Present.” *Earth-Science Reviews* 178: 322–378.

Marchant, R. 2010. “Understanding Complexity in Savannas: Climate, Biodiversity and People.” *Current Opinion in Environmental Sustainability* 2(1-2): 101–8. https://doi.org/10.1016/j.cosust.2010.03.001.

Marshall, F., R. E. B. Reid, S. Goldstein, M. Storozum, A. Wreschnig, L. Hu, P. Kiura, R. Shahack-Gross, and S. H. Ambrose. 2018. “Ancient Herders Enriched and Restructured African Grasslands.” *Nature* 561: 387–390. https://doi.org/10.1038/s41586-018-0456-9.

Martin, D. A., F. Andrianisaina, T. R. Fulgence, K. Osen, A. A. Rakotomalala, E. Raveloaritiana, M. R. Soazafy, et al. 2022. “Land-Use Trajectories for Sustainable Land System Transformations: Identifying Leverage Points in a Global Biodiversity Hotspot.” *Proceedings of the National Academy of Sciences of the United States of America* 119(7): e2107747119.

Mayle, F. E., and J. Iriarte. 2014. “Integrated Palaeoecology and Archaeology – A Powerful Approach for Understanding Pre-Columbian Amazonia.” *Journal of Archaeological Science* 51: 54–64.

Mayor, S. J., J. F. Cahill, F. He, P. Sólymos, and S. Boutin. 2012. “Regional Boreal Biodiversity Peaks at Intermediate Human Disturbance.” *Nature Communications* 3(1): 1–6.

Mietton, M., J.-C. Leprun, R. Andrianaivoarivony, M. Dubar, M. Beiner, J. Erismann, F. Bonnier, E. Grisorio, J. Rafanomezana, and P. Grandjean. 2006. “Ancienneté et vitesse d’érosion des lavaka à Madagascar.” In *Erosion et gestion conservatoire de l’eau et de la fertilité des sols: actes des journées scientifiques du réseau Erosion et GCES de l’AUF*, edited by S. Ratsivalaka, G. Serpantié, G. De Noni, and E. Roose, 87–94. Paris: Contemporary Archives Editions.

Mietton, M., S. Cordier, M. Frechen, M. Dubar, M. Beiner, and R. Andrianaivoarivony. 2014. “New Insights into the Age and Formation of the Ankarokaroka Lavaka and Its Associated Sandy Cover (NW Madagascar, Ankarafantsika Natural Reserve).” *Earth Surface Processes and Landforms* 39: 1467–77. https://doi.org/10.1002/esp.3536.

Mistry, J., A. Berardi, V. Andrade, T. Krahô, P. Krahô, and O. Leonardos. 2005. “Indigenous Fire Management in the Cerrado of Brazil: The Case of the Krahô of Tocantíns.” *Human Ecology* 33(3): 365–386. https://doi.org/10.1007/s10745-005-4143-8.

Moat, J., and P. Smith. 2007. *Atlas of the Vegetation of Madagascar, Atlas de la Végétation de Madagascar*. Kew: Kew Publishing, Royal Botanical Gardens.

Montade, V., L. Bremond, H. Teixeira, T. Kasper, G. Daut, S. Rouland, E. Rasoamanana, et al. 2024. “Montane Rainforest Dynamics Under Changes in Climate and Human Impact During the Past Millennia in Northern Madagascar.” *Royal Society Open Science* 11(8): 230930. https://doi.org/10.1098/rsos.230930.

Morrison, K. D., E. Hammer, O. Boles, et al. 2021. “Mapping Past Human Land Use Using Archaeological Data: A New Classification for Global Land Use Synthesis and Data Harmonization.” *PLoS One* 16: e0246662. https://doi.org/10.1371/journal.pone.0246662.

Moser, C. 2008. “An Economic Analysis of Deforestation in Madagascar in the 1990s.” *Environmental Sciences* 5(2): 91–108. https://doi.org/10.1080/15693430801912170.

Muldoon, K. M., L. R. Godfrey, B. E. Crowley, and E. L. Simons. 2017. “Predation on Subfossil *Prolemur simus* by Multiple Predator Species at Ankarana Massif, Northern Madagascar.” *International Journal of Primatology* 38(1): 58–79. https://doi.org/10.1007/s10764-016-9944-7.

Murphy, B. P., A. N. Andersen, and C. L. Parr. 2016. “The Underestimated Biodiversity of Tropical Grassy Biomes.” *Philosophical Transactions of the Royal Society B* 371(1703): 20150319. https://doi.org/10.1098/rstb.2015.0319.

Mustaphi, C. J., S. M. Rucina, and R. Marchant. 2022. “Late Pleistocene Montane Forest Fire Return Interval Estimates from Mount Kenya.” *Journal of Quaternary Science* 38(2): 146–159. https://doi.org/10.1002/jqs.3466.

Nanjarisoa, O. P., G. Besnard, H. Ralimanana, V. Jeannoda, and M. S. Vorontsova. 2017. “Grass Survey of the Itremo Massif Records Endemic Central Highland Grasses.” *Madagascar Conservation & Development* 12: 34–40.

Newman, R. J. S., C. Capitani, C. Courtney-Mustaphi, J. P. R. Thorn, R. Kariuki, C. Enns, and R. Marchant. 2020. “Integrating Insights from Social-Ecological Interactions into Sustainable Land Use Change Scenarios for Small Islands in the Western Indian Ocean.” *Sustainability* 12(4): 1340.

Novenko, E. Y., N. G. Mazei, D. A. Kupriyanov, K. V. Babeshko, M. V. Kusilman, I. S. Zyuganova, A. N. Tsyganov, Y. A. Mazei, L. N. Phelps, and B. A. Davis. 2022a. "A 1300-Year Multi-Proxy Palaeoecological Record From the Northwest Putorana Plateau (Russian Subarctic): Environmental Changes, Vegetation Dynamics and Fire History." *Holocene* 33 (2): 181–193. https://doi.org/10.1177/09596836221131693.

Novenko, E. Y., D. A. Kupryanov, N. G. Mazei, A. S. Prokushkin, L. N. Phelps, A. Buri, and B. A. S. Davis. 2022b. "Evidence that Modern Fires May Be Unprecedented During the Last 3400 Years in Permafrost Zone of Central Siberia, Russia." *Environmental Research Letters* 17(2): 025004. https://doi.org/10.1088/1748-9326/ac4b53.

Orlando, L., R. Allaby, P. Skoglund, C. Der Sarkissian, P. W. Stockhammer, M. C. Ávila-Arcos, Q. Fu, et al. 2021. "Ancient DNA Analysis." *Nature Reviews Methods Primers* 1(1): 14. https://doi.org/10.1038/s43586-020-00011-0.

Osborne, C. P., T. Charles-Dominique, N. Stevens, W. J. Bond, G. Midgley, and C. E. R. Lehmann. 2018. "Human Impacts in African Savannas Are Mediated by Plant Functional Traits." *New Phytologist* 220(1): 10–24. https://doi.org/10.1111/nph.15236.

Parr, C. L., C. E. R. Lehmann, W. J. Bond, W. A. Hoffmann, and A. N. Andersen. 2014. "Tropical Grassy Biomes: Misunderstood, Neglected, and under Threat." *Trends in Ecology & Evolution* 29: 205–213.

Pastro, L. A., C. R. Dickman, and M. Letnic. 2011. "Burning for Biodiversity or Burning Biodiversity? Prescribed Burn vs. Wildfire Impacts on Plants, Lizards, and Mammals." *Ecological Applications* 21(8): 3238–53. https://doi.org/10.1890/10-2351.1.

Pedersen, M. W., S. Overballe-Petersen, L. Ermini, C. D. Sarkissian, J. Haile, M. Hellstrom, J. Spens, et al. 2015. "Ancient and Modern Environmental DNA." *Philosophical Transactions of the Royal Society B: Biological Sciences* 370: 20130383.

Pedrono, M., E. Rambeloson, and A. Clausen. 2020. "Giant Tortoises Make a Comeback in Madagascar." *Nature* 587: 548.

Phelps, L. N., C. A. Kull, and C. E. R. Lehmann "A Comparative Perspective on Grassy Biomes in Madagascar in Continental Africa: From Evolutionary to Anthropogenic Influences." In *The Malagasy World, Routledge Worlds*, edited by Z. Crossland, K. Douglass, and C. Radimilahy. London, UK: Routledge. in press

Phelps, L. N., D. S. Davis, J. C. Chen, et al. 2025a. "Summarised Livelihoods Information Associated With: "Africa-Wide Diversification of Livelihoods Strategies: Isotopic Insights Into Holocene Human Adaptations to Climate Change"." *Dryad*. https://doi.org/10.5061/dryad.6djh9w1b0.

Phelps, L. N., D. S. Davis, J. C. Chen, S. Monroe, C. Mangut, C. E. R. Lehmann, and K. Douglass 2025b. "Africa-Wide Diversification of Livelihoods Strategies: Isotopic Insights Into Holocene Human Adaptations to Climate Change." *One Earth*, 8: 101304.

Phelps, L. N., E. Razanatsoa, D. S. Davis, J. Hackel, T. Rasolondrainy, G. P. Tiley, B. David, et al. 2024. "Data From: Advancing Transdisciplinary Research on Grassy Biomes to Support Resilience in Tropical Ecosystems and Livelihoods." Dataset. Dryad. https://doi.org/10.5061/dryad.1zcrjdg0p.

Phelps, L. N., H. Jousse, K. Manning, O. Broennimann, A. Timpson, G. Mariethoz, D. A. Fordham, T. M. Shanahan, B. A. S. Davis, and A. Guisan. 2019a. "Faunal Dataset: Reconstructing Climatic Niche Breadth of Land Use for Animal Production During the African Holocene." *PANGAEA*. https://doi.org/10.1594/PANGAEA.904942.

Phelps, L. N., M. Chevalier, T. M. Shanahan, J. C. Aleman, C. Courtney-Mustaphi, C. A. Kiahtipes, O. Broennimann, et al. 2020. "Asymmetric Response of Forest and Grassy Biomes to Climate Variability across the African Humid Period: Influenced by Anthropogenic Disturbance?" *Ecography* 43: 1118–42. https://doi.org/10.1111/ecog.04990.

Phelps, L. N., M. Chevalier, T. M. Shanahan, et al. 2019b. "Pollen Dataset for "Asymmetric Response of Forest and Grassy Biomes to Climate Variability Across the African Humid Period: Influenced by Anthropogenic Disturbance?"." *PANGAEA*. https://doi.org/10.1594/PANGAEA.905309.

Phelps, L. N., M. Gravey, N. Andela, et al. 2022. "Madagascar's Fire Regimes Challenge Global Assumptions About Landscape Degradation." *Dryad*. https://doi.org/10.5061/dryad.2ngf1vhqr.

Phelps, L. N., N. Andela, M. Gravey, D. Davis, C. A. Kull, K. Douglass, and C. E. R. Lehmann. 2022. "Madagascar's Fire Regimes Challenge Global Assumptions about Landscape Degradation." *Global Change Biology* 28(23): 6944–60.

Phelps, L. N., O. Broennimann, K. Manning, A. Timpson, H. Jousse, G. Mariethoz, D. A. Fordham, T. M. Shanahan, B. A. S. Davis, and A. Guisan. 2020. "Reconstructing the Climatic Niche Breadth of Land Use for Animal Production during the African Holocene." *Global Ecology and Biogeography* 29(1): 127–147.

Phelps, L. N., and J. O. Kaplan. 2017. "Land Use for Animal Production in Global Change Studies: Defining and Characterizing a Framework." *Global Change Biology* 23: 4457–71. https://doi.org/10.1111/gcb.13732.

Potts, R., A. K. Behrensmeyer, J. T. Faith, C. A. Tryon, A. S. Brooks, J. E. Yellen, A. L. Deino, et al. 2018. "Environmental Dynamics during the Onset of the Middle Stone Age in Eastern Africa." *Science* 360(6384): 86–90. https://doi.org/10.1126/science.aao2200.

Pringle, R. M., J. O. Abraham, T. M. Anderson, T. C. Coverdale, A. B. Davies, C. L. Dutton, A. Gaylard, et al. 2023. "Impacts of Large Herbivores on Terrestrial Ecosystems." *Current Biology* 33(11): R584–R610. https://doi.org/10.1016/j.cub.2023.04.024.

Quéméré, E., B. Crouau-Roy, C. Rabarivola, E. E. Louis, Jr., and L. Chikhi. 2010. "Landscape Genetics of an Endangered Lemur (*Propithecus tattersalli*) within its Entire Fragmented Range." *Molecular Ecology* 19: 1606–21. https://doi.org/10.1111/j.1365-294X.2010.04581.x.

Quémére, E., X. Amelot, J. Pierson, B. Crouau-Roy, and L. Chikhi. 2012. "Genetic Data Suggest a Natural Prehuman Origin of Open Habitats in Northern Madagascar and Question the Deforestation Narrative in this Region." *Proceedings of the National Academy of Sciences of the United States of America* 109: 13028–33. https://doi.org/10.1073/pnas.1200153109.

Ragupathy, S., S. G. Newmaster, M. Murugesan, and V. Balasubramaniam. 2009. "DNA Barcoding Discriminates a New Cryptic Grass Species Revealed in an Ethnobotany Study by the Hill Tribes of the Western Ghats in Southern India."

Molecular Ecology Resources 9: 164–171. https://doi.org/10.1111/j.1755-0998.2009.02641.x.

Rakotoarisoa, J. E., M. Raheriarisena, and S. M. Goodman. 2013. "Late Quaternary Climatic Vegetational Shifts in an Ecological Transition Zone of Northern Madagascar: Insights from Genetic Analyses of Two Endemic Rodent Species." *Journal of Evolutionary Biology* 26(5): 1019–34.

Rakotomalala, N. H., A. M. Andriamanohera, D. Rabehevitra, L. C. Solofondranohatra, V. Jeannoda, A. Ranaivojaona, H. Ralimanana, and M. S. Vorontsova. 2022. "Grasses of the Isalo National Park, Madagascar – Checklist, Origins, and Significance." *Madagascar Conservation Development* 16(1): 14–24. https://doi.org/10.4314/mcd.v16i1.1.

Ralimanana, H., A. L. Perrigo, R. J. Smith, J. S. Borrell, S. Faurby, M. T. Rajaonah, T. Randriamboavonjy, et al. 2022. "Madagascar's Extraordinary Biodiversity: Threats and Opportunities." *Science* 378(6623): eadf1466. https://doi.org/10.1126/science.adf1466.

Ramiadantsoa, T., and C. L. Solofondranohatra. 2021. "Nontrivial Responses of Vegetation to Compound Disturbances: A Case Study of Malagasy Grasslands." *Malagasy Nature* 15(3): 29–40.

Ramirez-Gomez, S. O., C. A. Torres-Vitolas, S. O. I. Ramirez-Gomez, K. Schreckenberg, M. Honzák, G. S. Cruz-Garcia, S. Willcock, et al. 2015. "Analysis of Ecosystem Services Provision in the Colombian Amazon Using Participatory Research and Mapping Techniques." *Ecosystem Services* 13: 93–107. https://doi.org/10.1016/j.ecoser.2014.12.009.

Ramo, R., E. Roteta, I. Bistinas, D. van Wees, A. Bastarrika, E. Chuvieco, and G. R. van der Werf. 2021. "African Burned Area and Fire Carbon Emissions Are Strongly Impacted by Small Fires Undetected by Coarse Resolution Satellite Data." *Proceedings of the National Academy of Sciences of the United States of America* 118(9): e2011160118. https://doi.org/10.1073/pnas.2011160118.

Randall, S. 2015. "Where Have All the Nomads Gone?: Fifty Years of Statistical and Demographic Invisibilities of African Mobile Pastoralists." *Pastoralism* 5: 22.

Ratnam, J., W. J. Bond, R. J. Fensham, W. A. Hoffmann, S. Archibald, C. E. R. Lehmann, M. T. Anderson, S. I. Higgins, and M. Sankaran. 2011. "When Is a 'Forest' a Savanna, and Why Does It Matter?" *Global Ecology and Biogeography* 20(5): 653–660. https://doi.org/10.1111/j.1466-8238.2010.00634.x.

Ravaka, A., B. S. Ramamonjisoa, H. R. Ratsimba, and A. N. Ratovoson. 2021. "Circuit court du marché des produits agricoles: pour une gestion efficace du paysage ouvert, cas du bassin-versant de Maningory, Madagascar." *Madagascar Conservation & Development,* 16, no. 2S: 41–47. https://doi.org/10.4314/mcd.wetlands.2.

Razafimanantsoa, A. H. I. 2022. *Holocene Vegetation History and Environmental Change in the Forest-Grassland Mosaic of the Central Highlands of Madagascar*. Cape Town: Faculty of Science, Department of Biological Sciences, University of Cape Town. http://hdl.handle.net/11427/36720.

Razafimanantsoa, A. H. I., W. J. Bond, and L. Gillson. 2024. "Vegetation Dynamics and Drivers of Change in the Central Highlands of Madagascar During the Last 6300 Years: Pre- and Post-Human Settlement." *Holocene* 35(4): 460–470.

Razanamahandry, V. F., M. Dewaele, G. Govers, L. Brosens, B. Campforts, L. Jacobs, T. Razafimbelo, T. Rafolisy, and S. Bouillon. 2022. "Stable Isotope Profiles of Soil Organic Carbon in Forested and Grassland Landscapes in the Lake Alaotra Basin (Madagascar): Insights in Past Vegetation Changes." *Biogeosciences* 19: 3825–41. https://doi.org/10.5194/bg-19-3825-2022.

Razanatsoa, E., L. Gillson, M. Virah-Sawmy, and S. Woodborne. 2022. "Synergy between Climate and Human Land-Use Maintained Open Vegetation in Southwest Madagascar over the Last Millennium." *The Holocene* 32(1–2): 57–69. https://doi.org/10.1177/09596836211041731.

Razanatsoa, E., M. Virah-Sawmy, S. Woodborne, C. Callanan, and L. Gillson. 2021. "Subsistence Strategies Adaptation of the Mikea Foragers from Southwest Madagascar in the Face of Climate Change." *Malagasy Nature* 15: 41–55. http://www.vahatra.mg/volume15/MN15_Chapitre%2003_Razanatsoa.pdf.

Razanatsoa, E., S. M. Andriantsaralaza, S. Andriantsaralaza, S. M. Holmes, O. S. Rakotonarivo, A. N. Ratsifandrihamanana, L. Randriamiharisoa, et al. 2021. "Fostering Local Involvement for Biodiversity Conservation in Tropical Regions: Lessons from Madagascar during the COVID-19 Pandemic." *Biotropica* 53(4): 994–1003. https://doi.org/10.1111/btp.12967.

Reibelt, L. M., G. Moser, A. Dray, I. H. Randriamalala, J. Chamagne, B. Ramamonjisoa, L. G. Barrios, C. Garcia, and P. O. Waeber. 2021. "Tool Development to Understand Rural Resource Users' Land Use and Impacts on Land Type Changes in Madagascar." *Madagascar Conservation & Development* 16, no. 2S: 15–24. https://doi.org/10.4314/mcd.wetlands.3.

Roteta, E., A. Bastarrika, M. Padilla, T. Storm, and E. Chuvieco. 2019. "Development of a Sentinel-2 Burned Area Algorithm: Generation of a Small Fire Database for Sub-Saharan Africa." *Remote Sensing of Environment* 222: 1–17. https://doi.org/10.1016/j.rse.2018.12.011.

Salmona, J., A. Dresen, A. E. Ranaivoson, S. Manzi, B. Le Pors, C. Hong-Wa, J. Razanatsoa, et al. 2023. "How Ancient Forest Fragmentation and Riparian Connectivity Generate High Levels of Genetic Diversity in a Micro-Endemic Malagasy Tree." *Molecular Ecology* 32: 299–315. https://doi.org/10.1111/mec.16759.

Salmona, J., J. K. Olofsson, C. Hong-Wa, J. Razanatsoa, F. Rakotonasolo, H. Ralimanana, T. Randriamboavonjy, U. Suescun, M. S. Vorontsova, and G. Besnard. 2020. "Late Miocene Origin and Recent Population Collapse of the Malagasy Savanna Olive Tree (*Noronhia lowryi*)." *Biological Journal of the Linnean Society* 129: 227–243.

Salmona, J., R. Heller, E. Quéméré, and L. Chikhi. 2017. "Climate Change and Human Colonization Triggered Habitat Loss and Fragmentation in Madagascar." *Molecular Ecology* 26(19): 5203–22. https://doi.org/10.1111/mec.14173.

Samonds K. E., B. E. Crowley, T. R. N. Rasolofomanana, M. C. Andriambelomanana, H. T. Andrianavalona, T. N. Ramihangihajason, R. Rakotozandry, et al. 2019. "A New Late Pleistocene Subfossil Site (Tsaramody, Sambaina Basin, Central Madagascar) with Implications for the Chronology of Habitat and Megafaunal Community Change on Madagascar's Central Highlands." *Journal of Quaternary Science* 34(6): 389–392. https://doi.org/10.1002/jqs.3096.

Sauther, M. L., F. Bertolini, L. J. Dollar, J. Pomerantz, P. C. Alves, B. Gandolfi, J. D. Kurushima, et al. 2020. "Taxonomic Identification of Madagascar's Free-Ranging "Forest Cats"." *Conservation Genetics* 21: 443–451. https://doi.org/10.1007/s10592-020-01261-x.

Schüssler, D., J. Mantilla-Contreras, R. Stadtmann, J. H. Ratsimbazafy, and U. Radespiel. 2020. "Identification of

Crucial Stepping Stone Habitats for Biodiversity Conservation in Northeastern Madagascar Using Remote Sensing and Comparative Predictive Modeling." *Biodiversity and Conservation* 29: 2161–84. https://doi.org/10.1007/s10531-020-01965-z.

Scherer, L., J.-C. Svening, J.-C. Svenning, J. Huang, C. L. Seymour, B. Sandel, N. Mueller, et al. 2020. "Global Priorities of Environmental Issues to Combat Food Insecurity and Biodiversity Loss." *Science of the Total Environment* 730: 139096. https://doi.org/10.1016/j.scitotenv.2020.139096.

Schneider, F., M. Feurer, L. M. Lundsgaard-Hansen, M. Win, N. Cing Don, K. Nydegger, C. Oberlack, et al. 2020. "Sustainable Development under Competing Claims on Land: Three Pathways between Land-Use Changes, Ecosystem Services and Human Well-Being." *The European Journal of Development Research* 32(2): 316–337. https://doi.org/10.1057/s41287-020-00268-x.

Scholtz, R., G. A. Kiker, I. P. J. Smit, and F. J. Venter. 2014. "Identifying Drivers That Influence the Spatial Distribution of Woody Vegetation in Kruger National Park, South Africa." *Ecosphere* 5(6): 71. https://doi.org/10.1890/ES14-00034.1.

Scroxton, N., S. J. Burns, K. McGee, B. Hardt, L. R. Godfrey, L. Ranivoharimanana, and P. Faina. 2019. "Competing Temperature and Atmospheric Circulation Effects on Southwest Madagascan Rainfall during the Last Deglaciation." *Paleoceanography and Paleoclimatology* 34(2): 275–286. https://doi.org/10.1029/2018PA003466.

Sgarlata, G. M., J. Salmona, B. le Pors, E. Rasolondraibe, F. Jan, T. Ralantoharijaona, A. Rakotonanahary, et al. 2019. "Genetic and Morphological Diversity of Mouse Lemurs (*Microcebus* spp.) in Northern Madagascar: The Discovery of a Putative New Species?" *American Journal of Primatology* 81: e23070. https://doi.org/10.1002/ajp.23070.

Siebert, S. F., and J. M. Belsky. 2014. "Historic Livelihoods and Land Uses as Ecological Disturbances and their Role in Enhancing Biodiversity: An Example from Bhutan." *Biological Conservation* 177: 82–89.

Silva, F., F. Coward, K. Davies, S. Elliott, E. Jenkins, A. C. Newton, P. Riris, et al. 2022. "Developing Transdisciplinary Approaches to Sustainability Challenges: The Need to Model Socio-Environmental Systems in the *Longue durée*." *Sustainability* 14(16): 10234.

Singh, J., J. E. Donaldson, S. Archibald, C. L. Parr, M. D. Voysey, and A. B. Davies. 2024. "Small-Scale Fires Interact with Herbivore Feedbacks to Create Persistent Grazing Lawn Environments." *Journal of Applied Ecology* 61: 1531–45. https://doi.org/10.1111/1365-2664.14645.

Singh, J., P. B. Boucher, E. G. Hockridge, and A. B. Davies. 2023. "Effects of Long-Term Fixed Fire Regimes on African Savanna Vegetation Biomass, Vertical Structure and Tree Stem Density." *Journal of Applied Ecology* 60: 1223–38. https://doi.org/10.1111/1365-2664.14435.

Solofondranohatra, C. L., M. S. Vorontsova, G. P. Hempson, J. Hackel, S. Cable, J. Vololoniaina, and C. E. R. Lehmann. 2020. "Fire and Grazing Determined Grasslands of Central Madagascar Represent Ancient Assemblages." *Proceedings of the Royal Society B* 287(1927): 20200598. https://doi.org/10.1098/rspb.2020.0598.

Staver, A. C., J. O. Abraham, G. P. Hempson, A. T. Karp, and J. T. Faith. 2021. "The Past, Present, and Future of Herbivore Impacts on Savanna Vegetation." *Journal of Ecology* 109: 2804–22. https://doi.org/10.1111/1365-2745.13685.

Staver, A. C., S. Archibald, and S. A. Levin. 2011. "The Global Extent and Determinants of Savanna and Forest as Alternative Biome States." *Science* 334: 230–32.

Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales, and C. De Haan. 2006. *Livestock's Long Shadow: Environmental Issues and Options*. Rome: Food and Agriculture Organization of the United Nations. 390 pp.

Stephenson, S. N., N. J. White, A. Carter, D. Seward, P. W. Ball, and M. Klöcking. 2021. "Cenozoic Dynamic Topography of Madagascar." *Geochemistry, Geophysics, Geosystems* 22: e2020GC009624.

Stevens, N., W. Bond, A. Feurdean, et al. 2022. "Grassy Ecosystems in the Anthropocene." *Annual Review of Environment and Resources* 47: 261–289.

Strömberg, C. A. E. 2011. "Evolution of Grasses and Grassland Ecosystems." *Annual Review of Earth and Planetary Sciences* 39(1): 517–544. https://doi.org/10.1146/annurev-earth-040809-152402.

Strömberg, C. A. E., and A. C. Staver. 2022. "The History and Challenge of Grassy Biomes." *Science* 377(6606): 592–93.

Taylor, K., and J. Lennon. 2011. "Cultural Landscapes: A Bridge between Culture and Nature?" *International Journal of Heritage Studies* 17(6): 537–554. https://doi.org/10.1080/13527258.2011.618246.

Teixeira, H., J. Salmona, A. Arredondo, B. Mourato, S. Manzi, R. Rakotondravony, O. Mazet, L. Chikhi, J. Metzger, and U. Radespiel. 2021. "Impact of Model Assumptions on Demographic Inferences – The Case Study of Two Sympatric Mouse Lemurs in Northwestern Madagascar." *BMC Ecology and Evolution* 21: 197. https://doi.org/10.1186/s12862-021-01929-z.

Teixeira, H., V. Montade, J. Salmona, J. Metzger, L. Bremond, T. Kasper, G. Daut, et al. 2021. "Past Environmental Changes Affected Lemur Population Dynamics Prior to Human Impact in Madagascar." *Communications Biology* 4: 1084.

Tiley, G. P., A. A. Crowl, T. O. M. Almary, W. Q. Luke, C. L. Solofondranohatra, G. Besnard, C. E. Lehmann, A. D. Yoder, and M. S. Vorontsova. 2024. "Genetic Variation in *Loudetia simplex* Supports the Presence of Ancient Grasslands in Madagascar." *Plants, People, Planet* 6: 315–329.

Tiley, G. P., J. W. Poelstra, M. dos Reis, Z. Yang, and A. D. Yoder. 2020. "Molecular Clocks without Rocks: New Solutions for Old Problems." *Trends in Genetics* 36: 845–856.

Tiley, G. P., T. van Elst, H. Teixeira, D. Schüßler, J. Salmona, M. B. Blanco, J. M. Ralison, et al. 2022. "Population Genomic Structure in Goodman's Mouse Lemur Reveals Long-Standing Separation of Madagascar's Central Highlands and Eastern Rainforests." *Molecular Ecology* 31: 4901–18.

Ullah, I. I. T. 2015. "Integrating Older Survey Data into Modern Research Paradigms: Identifying and Correcting Spatial Error in "Legacy" Datasets." *Advances in Archaeological Practice* 3(4): 331–350.

UNICEF. 2021. Annual Report

Vågen, T.-G. 2006. "Remote Sensing of Complex Land Use Change Trajectories—A Case Study from the Highlands of Madagascar." *Agriculture, Ecosystems & Environment* 115(1–4): 219–228. https://doi.org/10.1016/j.agee.2006.01.007.

van der Sluis, L. G., H. I. Hollund, M. Buckley, P. G. De Louw, K. F. Rijsdijk, and H. Kars. 2014. "Combining Histology, Stable Isotope Analysis and ZooMS Collagen Fingerprinting to Investigate the Taphonomic History and Dietary Behaviour of

Extinct Giant Tortoises from the Mare Aux Songes Deposit on Mauritius." *Palaeogeography, Palaeoclimatology, Palaeoecology* 416: 80–91. https://doi.org/10.1016/j.palaeo.2014.06.003.

Veldman, J. W., J. C. Aleman, S. T. Alvarado, T. M. Anderson, S. Archibald, W. J. Bond, T. W. Boutton, et al. 2019. "Comment on "The Global Tree Restoration Potential"." *Science* 366: eaay7976. https://doi.org/10.1126/science.aay7976.

Vieilledent, G., C. Grinand, F. A. Rakotomalala, R. Ranaivosoa, J.-R. Rakotoarijaona, T. F. Allnutt, and F. Achard. 2018. "Combining Global Tree Cover Loss Data with Historical National Forest Cover Maps to Look at Six Decades of Deforestation and Forest Fragmentation on Madagascar." *Biological Conservation* 222: 189–197. https://doi.org/10.1016/j.biocon.2018.04.008.

Vieira, A. F. G. 2008. Desenvolvimento e distribuição de voçorocas em Manaus (AM): principais fatores controladores e impactos urbano-ambientais PhD Thesis, Universidade Federal de Santa Catarina, p. 310.

Vincens, A., A.-M. Lézine, G. Buchet, D. Lewden, and A. Le Thomas. 2007. "African Pollen Database Inventory of Tree and Shrub Pollen Types." *Review of Palaeobotany and Palynology* 145(1–2): 135–141. https://doi.org/10.1016/j.revpalbo.2006.09.004.

Virah-Sawmy, M., K. J. Willis, and L. Gillson. 2010. "Evidence for Drought and Forest Declines during the Recent Megafaunal Extinctions in Madagascar." *Journal of Biogeography* 37(3): 506–519. https://doi.org/10.1111/j.1365-2699.2009.02203.x.

Voarintsoa, N. R. G., L. Wang, L. B. Railsback, G. A. Brook, F. Liang, H. Cheng, and R. L. Edwards. 2017. "Multiple Proxy Analyses of a U/Th-Dated Stalagmite to Reconstruct Paleoenvironmental Changes in Northwestern Madagascar between 370 CE and 1300 CE." *Palaeogeography, Palaeoclimatology, Palaeoecology* 469: 138–155.

Voarintsoa, N. R. G., R. Cox, M. O. M. Razanatseheno, and A. F. M. Rakotondrazafy. 2012. "Relation between Bedrock Geology, Topography and Lavaka Distribution in Madagascar." *South African Journal of Geology* 115(2): 225–250.

Vorontsova, M. S., G. Besnard, F. Forest, P. Malakasi, J. Moat, W. D. Clayton, S. Z. Ficinski, et al. 2016. "Madagascar's Grasses and Grasslands: Anthropogenic or Natural?" *Proceedings of the Royal Society B* 283: 20152262.

Vorontsova, M. S., P. P. Lowry, S. R. Andriambololonera, L. Wilmé, A. Rasolohery, R. Govaerts, S. Z. Ficinski, and A. M. Humphreys. 2020. "Inequality in Plant Diversity Knowledge and Unrecorded Plant Extinctions: An Example from the Grasses of Madagascar." *Plants, People, Planet* 3(1): 45–60.

Waeber, P. O., A. De Grave, L. Wilmé, and C. Garcia. 2021. "Play, Learn, Explore: Grasping Complexity through Gaming and Photography." *Madagascar Conservation & Development* 16, no. (2S): 41–47. https://doi.org/10.4314/mcd.wetlands.1.

Waeber, P. O., L. Wilmé, B. Ramamonjisoa, C. Garcia, D. Rakotomalala, Z. H. Rabemananjara, C. A. Kull, J. U. Ganzhorn, and J. P. Sorg. 2015. "Dry Forests in Madagascar: Neglected and under Pressure." *International Forestry Review* 17(2): 127–148.

Walker, M., P. Gibbard, M. J. Head, M. Berkelhammer, S. Björck, H. Cheng, L. C. Cwynar, et al. 2019. "Formal Subdivision of the Holocene Series/Epoch: A Summary." *Journal of the Geological Society of India* 93: 135–141. https://doi.org/10.1007/s12594-019-1141-9.

Wang, Q., S. Coemans, R. Siegesmund, and K. Hannes. 2017. "Arts-Based Methods in Socially Engaged Research Practice: A Classification Framework." *Art/Research International* 2(2): 5-39. https://doi.org/10.18432/R26G8P.

Wang, Y., S. D. Willett, D. Wu, N. Haghipour, and M. Christl. 2021. "Retreat of the Great Escarpment of Madagascar from Geomorphic Analysis and Cosmogenic 10Be Concentrations." *Geochemistry, Geophysics, Geosystems* 22: e2021GC009979. https://doi.org/10.1029/2021GC009979.

Wei, Y., Z. Liu, X. Wu, Y. Zhang, T. Cui, C. Cai, Z. Guo, J. Wang, and D. Cheng. 2021. "Can Benggang Be Regarded as Gully Erosion?" *Catena* 207: 105648.

Wells, N. A., and B. Andriamihaja. 1997. "Extreme Gully Erosion in Madagascar and Its Natural and Anthropogenic Causes." In *Natural Change and Human Impact in Madagascar*, edited by S. M. Goodman and B. D. Patterson, 44–74. Washington: Smithsonian Institution Press.

White, F. 1983. *The Vegetation of Africa: A Descriptive Memoir to Accompany the UNESCO/AETFAT/UNSO Vegetation Map of Africa*. Paris: UNESCO.

White, R. P., S. Murray, M. Rohweder, S. D. Prince, and K. M. Thompson. 2000. *Pilot analysis of global ecosystems: Grassland Ecosystems*. World Resources Institute, Washington D.C.

Willis, K. J., L. Gillson, and M. Virah-Sawmy. 2008. "Nature or Nurture: The Ambiguity of C_4 Grasslands in Madagascar." *Journal of Biogeography* 35(10): 1741–42. https://doi.org/10.1111/j.1365-2699.2008.01985.x.

Willis, K. J., and H. J. B. Birks. 2006. "What Is Natural? The Need for a Long-Term Perspective in Biodiversity Conservation." *Science* 314(5803): 1261–65. https://doi.org/10.1126/science.1122667.

Wilmé, L., P. O. Waeber, F. Moutou, C. J. Gardner, O. Razafindratsima, J. Sparks, C. A. Kull, et al. 2016. "A Proposal for Ethical Research Conduct in Madagascar." *Madagascar Conservation and Development* 11(1): 36–39. https://doi.org/10.4314/mcd.v11i1.8.

Wilmé, L., S. M. Goodman, and J. U. Ganzhorn. 2006. "Biogeographic Evolution of Madagascar's Microendemic Biota." *Science* 312: 1063–65.

World Bank. 2003. *Madagascar Rural and Environment Sector Review* Volume I: Main Report. Report No. 26106-MG Washington D.C: World Bank.

Wright, D. 2017. "Humans as Agents in the Termination of the African Humid Period." *Frontiers in Earth Science* 5(4).

Wurz, A., T. Tscharntke, D. A. Martin, K. Osen, A. A. N. A. Rakotomalala, E. Raveloaritiana, F. Andrianisaina, et al. 2022. "Win-Win Opportunities Combining High Yields with High Multi-Taxa Biodiversity in Tropical Agroforestry." *Nature Communications* 13: 4127. https://doi.org/10.1038/s41467-022-30866-8.

Wynne-Jones, S. 2012. "Pastoralists, Warriors and Colonists: The Archaeology of Southern Madagascar." *Antiquity* 86(331): 272.

Zhao, W., X. Yu, and C. Xu. 2021. "Social-Ecological System Management in Drylands: Experiences from Chinese Ecosystem Research Network." *Current Opinion in Environmental Sustainability* 48: 93–102. https://doi.org/10.1016/j.cosust.2020.11.006.

Zhao, Z., W. Li, P. Ciais, M. Santoro, O. Cartus, S. Peng, Y. Yin, et al. 2021. "Fire Enhances Forest Degradation within Forest Edge Zones in Africa." *Nature Geoscience* 14: 479–483. https://doi.org/10.1038/s41561-021-00763-8.

Zhou, Y., J. Singh, J. R. Butnor, C. Coetsee, P. B. Boucher, M. F. Case, E. G. Hockridge, A. B. Davies, and A. C. Staver. 2022.

"Limited Increases in Savanna Carbon Stocks over Decades of Fire Suppression." *Nature* 603(7901): 445–49. https://doi.org/10.1038/s41586-022-04438-1.

Zhu, A. 2018. "Hot Money, Cold Beer: Navigating the Vanilla and Rosewood Export Economies in Northeastern Madagascar." *American Ethnologist* 45: 253–267. https://doi.org/10.1111/amet.12636.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Phelps, Leanne N., Estelle Razanatsoa, Dylan S. Davis, Jan Hackel, Tanambelo Rasolondrainy, George P. Tiley, David Burney, et al. 2025. "Advancing Transdisciplinary Research on Madagascar's Grassy Biomes to Support Resilience in Ecosystems and Livelihoods." *Ecological Monographs* 95(2): e70011. https://doi.org/10.1002/ecm.70011