A Practitioner-Led Transdisciplinary Process for Adaptive Fire Management in Madagascar's Protected Areas

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ABSTRACT

Fire management in protected areas is constrained by gaps between scientific knowledge, practitioner experience, and institutional frameworks. Such constraints restrict how existing expertise is mobilised, formalised, and translated into alternative fire management practice, meaning fire management plans frequently fail to reflect the diverse socio-ecological contexts in which practitioners operate.

We present a practitioner-led, transdisciplinary process designed to initiate addressing this challenge across six protected areas in Madagascar, here fire is both ecologically significant and politically sensitive, and where persistent divides remain between research, policy, and on-the-ground implementation. Our approach integrates five sequential activities: (1) peer exchange and experiential learning; (2) prioritisation of fire management objectives; (3) analysis of stakeholder roles, influence, and constraints; (4) development of spatially grounded, context-specific fire management plans; and (5) dialogue with senior institutional stakeholders to situate priorities within existing governance frameworks.

This Perspective provides a structured and inclusive process for how peer exchange, shared analytical tools, and protected spaces for reflection supported practitioners to reframe fire as a governable management tool and to articulate actionable, context-specific planning. We reflect on emergent lessons relevant to researchers and practitioners seeking to design transdisciplinary fire management initiatives in resource-constrained and politically complex tropical ecosystems.

INTRODUCTION

Fire shapes tropical ecosystems through vegetation structure, biodiversity, and function, and underpins the livelihoods of millions of people worldwide (Hoffmann et al. 2012; Lehmann and Parr 2016). In Madagascar, where fire-dependent landscapes have evolved over millennia producing mosaics of grasslands, savannas, and forest that support pastoralism, agriculture and fire-adapted natural resources (Kull 2004; Razanatsoa et al. 2022; Lehmann et al. 2022). Despite fire's importance to cultural practices and land-use systems, it is a persistent source of tension within conservation policy and governance (Convery-Fisher et al. 2025).

Protected areas (PAs), which aim to advance biodiversity conservation alongside rural development, operate under institutional mandates that restrict almost all burning within their strict conservation core zones (Rakotobe and Stevens 2024; Devenish et al. *under review*). Protected area managers therefore face a dilemma to protect ecological processes shaped by fire, support communities who rely on burning, and comply with legal frameworks that discourage it. The challenge of managing fire well across competing ecological, social and political demands is therefore central to Malagasy conservation and reflects wider tensions across tropical fire-prone regions.

Effective fire management must reduce risks to people and infrastructure while sustaining the ecological and social functions that many landscapes depend upon. Achieving this balance requires ecological understanding, political judgement, social negotiation, technical expertise and close engagement with the priorities and

constraints of the people who depend on fire-shaped systems (Copes-Gerbitz et al. 2024; Govender et al. 2022). While there is often broad agreement on these principles, conservation planning seldom turns knowledge into effective action (Shuman et al. 2022). In Madagascar and elsewhere, scientific, practitioner, and community perspectives frequently operate in parallel rather than through formal processes that enable shared analysis, resulting in fire management strategies that are neither grounded in local realities and nor workable in practice (Phelps et al. 2025; Knight et al. 2008).

A major challenge, therefore, is the fragmentation of knowledge, and the lack of structures that bring diverse knowledge systems into sustained, productive dialogue (Vázquez-Varela et al. 2022). Ecological research often remains weakly connected to the social relationships and institutional constraints that shape fire use in practice (Margules et al. 2020), while social science is seldom integrated into conservation planning and governance (Hopkinson et al. 2017). International policy arenas compound these limitations by promoting generalised solutions that seldom correspond to local realities (Boedhihartono et al. 2018). Meanwhile, protected-area managers accumulate extensive experiential knowledge through daily engagement with communities and landscapes, yet this knowledge often remains tacit because it is rarely documented, evaluated, or shared beyond immediate teams (Raymond et al. 2010; Fazey et al. 2006). Confronting this gap in knowledge mobilisation is essential for developing adaptive fire management that is ecologically and scientifically grounded, and socially legitimate.

Transdisciplinary approaches, which integrate knowledge across disciplines and with non-academic stakeholders, offer a promising pathway for managing complex fire-prone landscapes (Shackleton et al. 2023). By emphasising shared problem framing, collective interpretation of evidence and negotiated pathways for action between scientists, practitioners, and local communities, transdisciplinary approaches can align ecological understanding with social and institutional realities (Chambers et al. 2021; Margules et al. 2020). However, practical guidance on how to design and sequence such processes for fire management in biodiversity hotspots such as Madagascar remains limited.

In this Perspective, we document a practitioner-led, researcher-supported transdisciplinary process developed with protected-area managers across six sites in Madagascar that span diverse contexts and operate under severe resource constraints. We examine the mechanisms that practitioners identified as most valuable and reflect on the unresolved challenges that remain. Our aim is to communicate a collective journey and to distil emergent lessons that may inform similar efforts elsewhere.

A PRACTITIONER-LED TRANSDISCIPLINARY PROCESS

Process overview

Our transdisciplinary process brought together PA managers and fire officers from Madagascar (n = 13; hereafter ‘practitioners’), fire management specialists from South Africa (n = 2; hereafter ‘South African experts), and researchers from the United Kingdom (n = 4; hereafter ‘researchers’). The process was co-designed and

facilitated by the research team in collaboration with practitioners, and, unless stated otherwise, ‘we’ refers to the facilitation team comprising researchers, South African experts and practitioners.

Practitioners represented six IUCN Category V PAs: Menabe Antimena, Massif d'Itremo, Analabe-Betanantanana, Bemanevika, Makirovana-Ambatobiribiry Complex, and Ambondrobe. These sites encompass humid and dry forests, savannas, and grassland–forest mosaics, each operating under distinct ecological conditions, governance arrangements, and resource constraints (see Supporting Information Appendix 1 for site descriptions) (Ralimanana et al. 2022).

Three principles guided the process design. First, we approached capacity building as peer-to-peer exchange, recognising practitioners’ existing expertise and using active learning to support cross-site understanding (Waldrop 2015; Raymond et al. 2010). Second, we deliberately sequenced engagement, starting within a small practitioner group before expanding discussions to external stakeholders (Tengö et al. 2017). Third, we hosted residential workshops away from institutional settings to create enabling conditions for reflection and dialogue (McFayden et al. 2023).

Between November 2023 and October 2025, we staged a series of engagements, including a peer exchange in South Africa, field-based learning in Madagascar, a residential workshop focused on priority setting and spatial planning, and subsequent dialogue with national stakeholders. We present five interconnected activities that together aim to develop preliminary fire management plans, build

shared priorities among practitioners, and identify feasible implementation pathways across contrasting contexts (Fig. 1).

Figure 1. A practitioner-led, researcher-supported pipeline for developing context-specific fire management under institutional and resource constraints. Building upon existing practitioner and researcher knowledge, five sequential activities supported the formalisation of such knowledge by moving from shared learning, through articulation of priorities and governance constraints, to spatially grounded planning and institutional dialogue.

Activity One: Peer exchange and shared learning

Across Madagascar, fire management practitioners within NGOs often operate in relative isolation. Such isolation limits opportunities for shared reflection, cumulative learning, and can reinforce entrenched management approaches. Furthermore, responsibility for PA management is frequently devolved to international organisations whose institutional experience with fire may be limited,

or grounded in ecoregions where fire regimes, governance histories, and social relations differ markedly from those in Madagascar. Such challenges are compounded by Madagascar's relative external isolation from continental Africa where fire is commonly managed as an ecological process. Taken together, practitioner isolation, institutional discontinuities, and limited cross-regional exchange limits delivery of place-based, context-appropriate fire management.

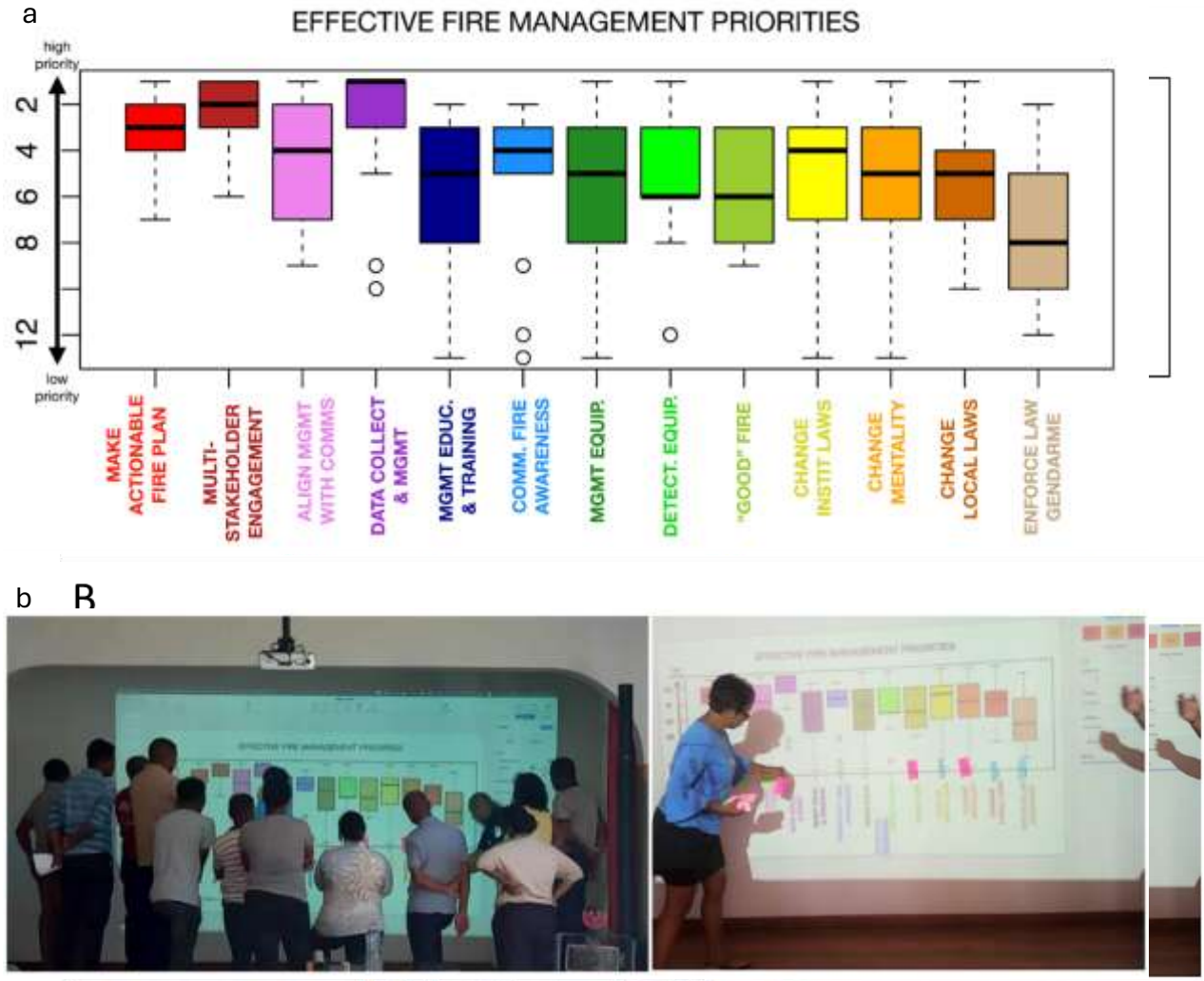
Activity One had two aims (Fig. 1). First, it sought to connect practitioners across organisations and sites in settings removed from day-to-day operational pressures, creating space for dialogue, reflection, and the emergence of a community of practice. Second, it aimed to link Malagasy practitioners with a wider fire management community drawing on long-standing experience from South Africa, enabling comparative learning

To expose practitioners to established approaches to proactive fire management the exchange focused on sites where fire is routinely planned, monitored, and legitimised but operate under diverse institutional arrangements. We visited Kruger National Park, Cathedral Peak, and Golden Gate Highlands National Park to observe prescribed fire, long-term fire research plots, and interventions balancing risk reduction with biodiversity objectives. Researchers facilitated daily reflection sessions to support comparative reasoning about transferability. A subsequent week of field-based learning in Madagascar grounded these reflections in the Madagascan context. We travelled to Menabe-Antimena to examine local fire management infrastructure and met fire management stakeholders.

Activity Two: Establishing fire management priorities

Practitioners routinely make trade-offs between ecological, social, and institutional pressures. However, these decisions are rarely documented in ways that allow comparison across sites or reflection over time. As a result, priorities often remain implicit and shaped by immediate constraints.

To move from shared learning to application, Activity Two focused on supporting practitioners to make their priorities explicit (Fig.1). Individually, practitioners documented the key actions required for effective fire management and the barriers that constrain progress. Researchers facilitated the synthesis of these reflections into thirteen shared themes (Fig. 2A). Practitioners then ranked these themes according to their perceived importance for their sites, and the ranking results were used to prompt collective discussion and move towards consensus through dialogue (Fig 2B). Ranking outcomes were subsequently presented to the group and practitioners refined the thirteen themes into four overarching priorities.



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216 **Figure 2. Articulating and consolidating practitioner priorities for fire**

217 **management across protected areas in Madagascar.** (a) Thirteen themes

218 identified by practitioners as important priorities to address for effective fire

219 management, synthesised from individual reflections (see Supporting Information

220 Appendix 2 for descriptions). (b) Participatory ranking and grouping exercise in which

221 practitioners collectively discussed and refined the thirteen themes into four

222 overarching priorities through facilitated dialogue. Photographs show protected-area

223 managers engaging in the consensus-building process.

Activity Three: Key stakeholders & their roles in PA management

Collaboration is central to effective fire management globally (Mistry et al. 2019). In resource-constrained contexts in which many Malagasy fire management practitioners operate, effective engagement with local stakeholders is especially important, often substituting for limited technical, financial, or enforcement capacity. However, while practitioners frequently navigate complex stakeholder environments, the roles, authority, and influence of different stakeholders are often unclear.

Building on the priorities identified in Activity Two, Activity Three aimed to articulate the landscape of key stakeholders shaping fire management at each site and to examine how different stakeholders influence, and are influenced by, fire-related decisions. Practitioners identified stakeholder groups involved in their PAs and assessed both their level of influence over fire management and the extent to which fire management outcomes affected them. These stakeholders were then positioned within a matrix defined by axes of influence and affectedness.

The exercise encouraged practitioners to reflect on where authority was constrained, where collaboration was essential, and where misalignments between formal mandates and on-the-ground practice limited effective action. Participants discussed stakeholder positions, the roles different stakeholders might play in supporting Activity Two's priorities, and pathways through which relationships could be strengthened or reconfigured.

Activity Four: Developing actionable fire plans

Many practitioners working within NGOs across Madagascar operate without clear operational plans to guide preparation for, and response to, the fire season. For several participants, this Activity represented the first opportunity to write such a plan.

Building on the priorities identified in Activity Two and the stakeholder landscapes articulated in Activity Three, Activity Four aimed to support the development of fire management plans that were both feasible to implement and grounded in local socio-ecological realities (Fig. 1). Researchers prepared poster-sized maps for each PA integrating high-resolution satellite imagery (Planet.com), nearby community locations, and seven years of fire frequency data derived from Sentinel-2 imagery (Roteta et al. 2019). Madagascar-wide reference maps provided broader context on fire patterns, vegetation, and environmental conditions (Phelps et al. 2022).

Practitioners used the spatial materials to identify priority areas for intervention, highlight zones presenting specific challenges, sketch feasible intervention and monitoring strategies, and integrate multi-year fire patterns with managers' experiential knowledge of seasonal dynamics and community fire use.

Activity Five: Sharing and refining priorities in multi-stakeholder settings

Fire governance in Madagascar is characterised by overlapping and sometimes ambiguous institutional mandates, particularly with respect to the legal status of fire use. In practice, the ambiguity and political sensitivity around fire use contributes to widespread risk aversion among practitioners. Such perceptions are reinforced

within hierarchical management structures, where junior staff may be reluctant to deviate from established norms or experiment with alternative approaches for fear of reprimand.

Building on the plans and priorities developed in Activities Two–Four, Activity Five aimed to create structured opportunities for dialogue with senior governmental and institutional stakeholders whose support is critical for implementation. Practitioners prepared materials to present their findings to representatives from key governmental and non-governmental institutions (see Supporting Information Appendix 3 for list of institutions).

Discussions focused how our priorities might align with existing legal and institutional frameworks, including provisions for authorising ecologically appropriate burning, and on the implications of shifting from a suppression-first model toward more adaptive and inclusive fire stewardship through community engagement. These exchanges also examined how fire is managed across different PAs and governance contexts.

Post-workshop validation and feedback

To clarify our process and its outcomes, we conducted a structured validation process following the workshop and stakeholder meeting. In facilitated group interviews and written reflections, practitioners, researchers, and South African experts provided feedback on emergent analysis and highlighted elements they regarded as most valuable for ongoing practice.

ILLUSTRATIVE PROCESS OUTPUTS

Reframing fire as an ecological management tool

Seeing fire as an active management tool, rather than an emergency to suppress, reshaped how practitioners understood their role in fire management. Observing fires lit by South African experts demonstrated how fire can be a carefully planned, relatively low-risk, evidence-informed intervention, and this challenged long-held assumptions about its inherent danger. For practitioners accustomed largely to suppression-first responses, the contrast proved striking. As one reflected, "*I was impressed that they were so confident in starting the fire…In Madagascar, using fire is scary.*" Another noted the coordination of fire crews and the organisation of operations.

These observations supported comparative reflection about how principles of preparation, safety, and evidence use might translate to Malagasy contexts, while acknowledging that techniques would need adaptation. As one practitioner explained, *"It's not about directly copying what's done here…if the place where I work is quite inaccessible, it requires more caution*."

The exchange established a shared conceptual foundation that informed all subsequent planning in Madagascar. Practitioners returned with a common vocabulary for discussing fire—e.g. prescribed fire, back burns, and fire regimes—and a clearer sense of how evidence, preparation, and coordination interact in effective management. A visit to Menabe-Antimena grounded our learning in a familiar landscape, helping them assess how South African practices might be

adapted to their local social and ecological conditions. The shared experience of visiting contrasting sites strengthened relationships within the practitioner group, building trust and a sense of collective purpose before the structured workshop activities began. These engagements provided the collaborative base on which the priority-setting and spatial planning exercises were built.

Establishing Shared Fire Management Priorities

Practitioners distilled their reflections into four shared priorities for strengthening fire management (Fig. 2b). These were: (1) improve stakeholder engagement, especially with local communities; (2) devise actionable fire plans that can feasibly be implemented with available resources; (3) influence perceptions around fire use as a management tool through education and awareness; and (4) modify fire laws and enforcement at institutional and local levels to support ecologically appropriate management (Fig. 3).

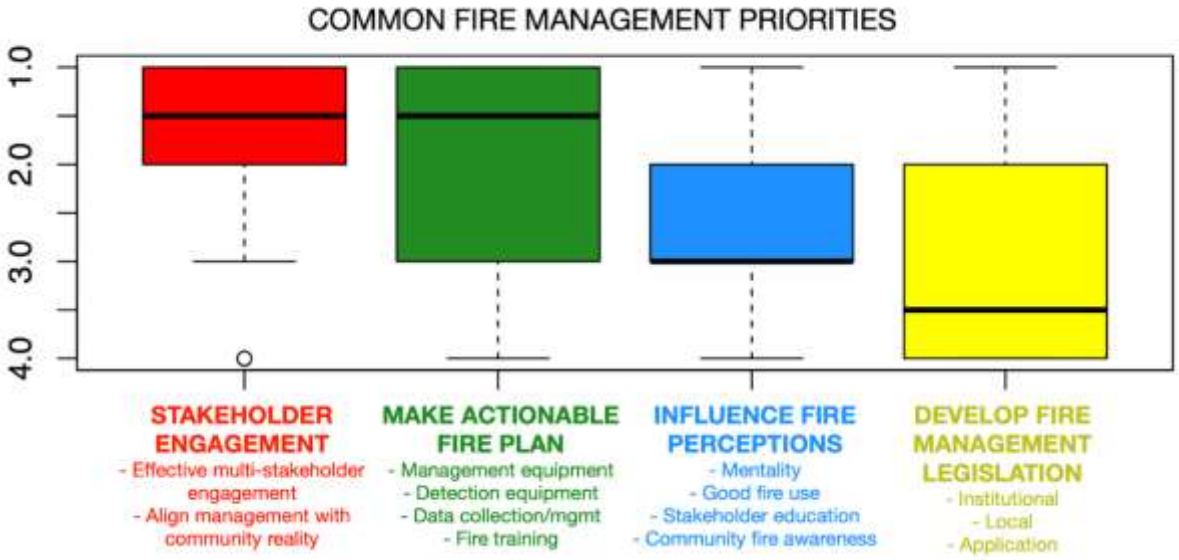

Figure 3: Four shared management priorities for improving the effectiveness of fire management in Madagascar.

Stakeholder engagement ranked consistently high, underscoring recognition that technical interventions cannot succeed without trust, coordination, and legitimacy. Practitioners described prioritisation as supporting clearer strategic thinking and more defensible decision-making under constraint. One practitioner explained: "*The prioritisation is useful because the results allow us to reflect on what we already have on the ground but also on what must be done in the future*." Another emphasised how the process strengthened their capacity to make strategic choices, noting that it "*allowed us both to justify the actions to undertake and to better use the limited resources we have”*.

Governance constraints and stakeholder relationships

Practitioners positioned neighbouring communities as the stakeholders most affected by fire yet frequently among the least influential in formal decision-making,

despite their central roles as fire users and participants in interventions. Government agencies held considerable legal mandate but varied influence depending on their proximity to fire-prone areas, operational capacity and relationships with practitioners. Conservation NGOs occupied heterogeneous positions, reflecting differences in resources, organisational mandates, and local legitimacy.

Making stakeholder relationships explicit supported discussion of feasible engagement pathways, including strengthened consultation, clearer inter-agency coordination, and recognition of community knowledge. They noted how fragmented government mandates diluted accountability, and inconsistent coordination between state and non-state agencies because of with overlapping responsibilities.

Developing actionable, context-specific fire management plans

All six protected areas produced draft fire management plans that integrated practitioner's understanding of spatial evidence with their knowledge of local fire use, access constraints, and community dynamics (Fig. 4). The plans demonstrated a shift from relying on isolated fire points (accessible hot spot data) toward a more strategic, landscape-scale understanding of risk and opportunity. As one practitioner reflected, *"Before, we just used fire points…Now, considering all GIS data and having many years of data helped us prioritise our actions and interventions*."

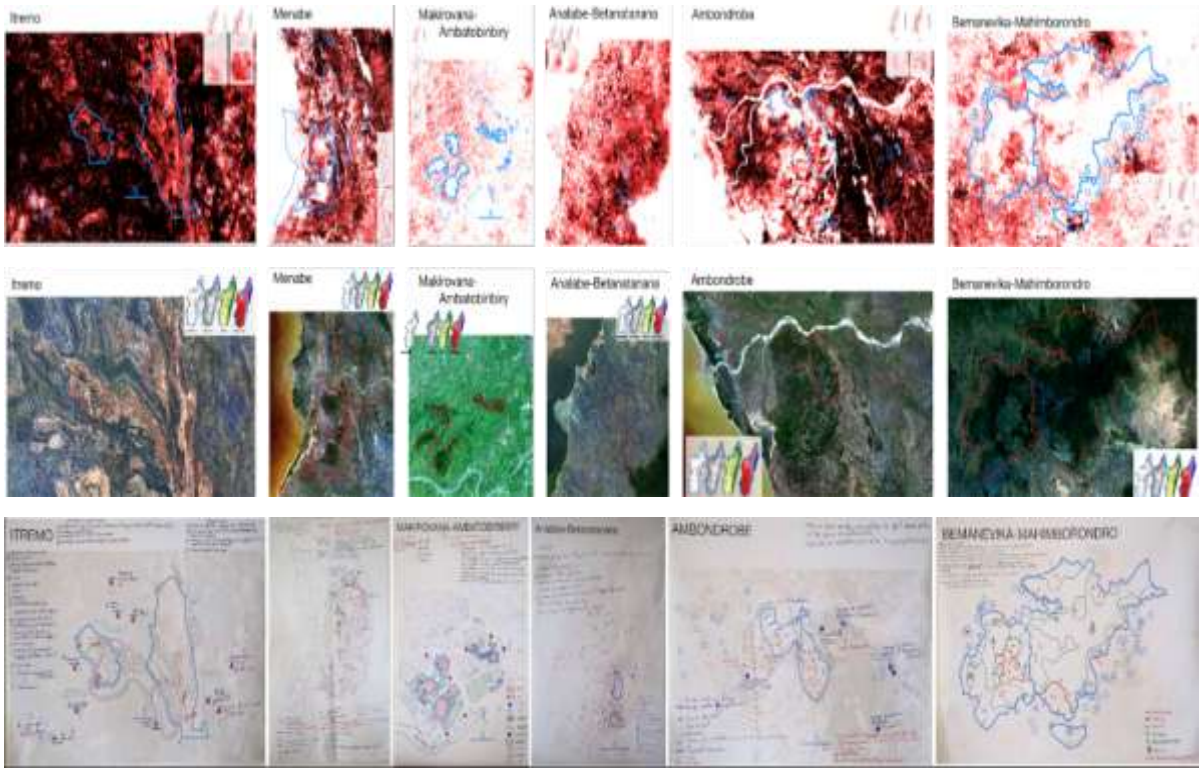

Figure 4: Developing spatially grounded fire management plans through integration of data and practitioner knowledge. Poster-sized maps combining multi-year fire history, high-resolution satellite imagery, community locations, and

environmental context were used by practitioners from six protected areas to develop draft, site-specific fire management plans.

Spatial mapping supported this shift by showing where unwanted fires originate and concentrate, where interventions were feasible, and where government or community engagement would be essential. Practitioners used these insights to identify sensitive ecological edges, sites that could constrain potential fire spread, and match proposed actions to the institutional and social conditions shaping each site. Together, plans reflected contextual expertise and showed how practitioners translated shared learning into strategies tailored to their own landscapes.

Practitioners emphasised that the plans were realistic within their constraints, yet difficult to implement without additional legal support. As one explained, "*we developed a plan adapted to the reality on the ground and feasible with the resources we have*," while another noted that "*the law remains the limiting factor between what we want to do and what we can do*."

National Engagement and Legal Clarification

Engagement with national authorities revealed that the challenges identified by practitioners were widely recognised across Madagascar's PAs. A key outcome was the clarification that some state-managed PAs took advantage of existing legislation which permits vegetation fires during certain times of year, when authorised by local state institutions, and incorporated into approved management plans. Although this provision has been in place for years, it was largely unknown to us because it

appears to contradict later legislation that prohibits all human-lit fires in conservation areas.

MECHANISMS, LESSONS, AND LIMITATIONS

Structured, practitioner-led and researcher-supported transdisciplinary processes can help address persistent fragmentation between scientific knowledge, practitioner experience, and institutional frameworks in fire management. Comparative learning, collective prioritisation, stakeholder analysis, and spatial planning supported fire management practitioners in Madagascar's protected areas to reshape how fire is interpreted, prioritised, and planned for. Our activities enabled the articulation of shared conceptual foundations for fire management and the development of context-specific planning approaches. As documented here and elsewhere, transdisciplinary approaches work to strengthen adaptive capacity in resource-constrained settings by creating peer networks, clarifying governance expectations, and providing decision-support tools that practitioners can readily use (Roux et al. 2006; Lang et al. 2012). This section reflects on how and to what extent these activities served their intended aims, examines the mechanisms through which they operated, and considers the implications for practice.

Practitioners already work as adaptive managers, navigating ecological pressures, community relationships, and institutional constraints (Fabricius and Cundill, 2014). However, ecological evidence, experiential understanding, and governance rules often circulate separately, shaped by different incentives and languages, and rarely meet through structured processes that allow shared interpretation. We saw a central barrier to implementation as the absence of mechanisms that enable practitioner knowledge to be documented, compared, and legitimised across sites (Fazey et al. 2005). This *formalisation gap* reflects limited tools, time, and

institutional spaces to turn experiential knowledge into accessible evidence that can guide planning. Without such structures, knowledge remains tacit, resists scrutiny, and cannot accumulate as organisational learning (Fazey et al. 2006).

How the transdisciplinary process helped bridge implementation gaps

Three elements of our process, peer exchange, boundary objects, and safe spaces worked together to address the formalisation gap. Collectively, these mechanisms enabled us to build shared legitimacy around fire as a management tool, made tacit knowledge visible and discussable, and supported the alignment required for collective planning across diverse PAs.

Building shared legitimacy through peer exchange

Lesson: *Carefully designed peer exchange can shift perceptions of what is legitimate and feasible in fire management, particularly where contested practices are constrained by risk aversion and institutional uncertainty.*

The peer exchange (Activity One) helped to reduce professional isolation and reshape how practitioners understood what was possible in fire management. Observing professional fire use by equivalent peers functioned as experiential social learning (Pahl-Wostl 2009), enabling practitioners to reconsider the legitimacy of contested practices such as prescribed burning. Seeing fire used confidently and safely dissolved assumptions that controlled burning was unrealistic or inherently dangerous in the Madagascar context.

The exchange also provided a shared vocabulary and operational reference points, enabling a more grounded sense of what might be possible. The value of cross-context learning often lies in enabling reflection on one's own practice (Wenger-Trayner 2008). Here, we returned asking where and how specific elements observed in South Africa could be adapted to Madagascar's ecological, social, and institutional conditions. The shift from seeing fire as inherently undesirable to seeing it as potentially governable when adapted to local conditions was the foundation for all other steps in our transdisciplinary process.

Making tacit knowledge explicit through boundary objects

Lesson: *Boundary objects such as maps, matrices, and prioritisation frameworks can help externalise tacit practitioner knowledge by making reasoning visible, comparable, and open to collective scrutiny*

Spatial maps, stakeholder matrices, and prioritisation frameworks acted as 'boundary objects' (Star and Griesemer 1989:p.387) that turned experiential and scientific knowledge into shared, negotiable representations. For example, actor matrices (Activity Three) clarified where institutional authority and political risk constrained decision-making. While multi-year fire maps (Activity Four) helped to shift planning from isolated fire incidents towards a landscape-scale understanding of risk. The physicality of the maps enabled us to look, layer and see where spatial data and practitioner knowledge of climate, access, and seasonal fire use could combine to deliver interventions. The value of 'boundary objects' lay in making knowledge visible, allowing interchange between different knowledge systems and openness to critique and re-negotiation in ways that verbal discussion alone may

not have achieved. Making tacit knowledge explicit in this way created the conditions for shared analysis and interrogation improving practitioners ability to justify management decisions to colleagues, communities and officials, all of which are essential to adaptive management across diverse socio-ecological contexts (Armitage et al. 2008).

Creating safe spaces for alignment and honest problem-sharing

Lesson: *Protected, non-hierarchical spaces are a prerequisite for honest reflection and internal alignment in politically sensitive management contexts*.

Working together in a residential setting created the trust and openness necessary for shared planning. Being away from our usual working spaces and their hierarchies, and spending extended time together while travelling and eating, allowed us to speak candidly about shared challenges and failures. Such conversations can be missing in formal institutional settings, yet they are essential for implementation (Pahl-Wostl 2009; Raymond et al. 2010). Our protected environment enabled us to express uncertainty, disagree constructively, and take the time needed to negotiate shared direction without organisational pressure.

Lesson: *Sequencing engagement to prioritise internal coherence can strengthen practitioner agency*....

The decision to sequence activities so that we aligned internally before engaging national stakeholders proved important. The approach reduced the risk of fragmented messages, built collective confidence, and supported the development of a unified position before entering more hierarchical policy spaces (Tengö et al.

2017). Such strategic sequencing foregrounded practitioner agency and knowledge in ways that parallel processes with all stakeholders present from the outset might not have achieved, particularly in contexts where discussions about legal fire use are discouraged and managers face political risks for engaging in them (Kull 2002).

Limitations and unresolved challenges

Not all elements of the process worked as intended, and several structural constraints limit how far such approaches can travel without broader institutional support.

Sequencing and the absence of direct community voices

Lesson:....*but involves trade-offs in early inclusivity.*

Community members did not participate in the workshop activities. This was a deliberate sequencing decision: practitioners wanted internal coherence before presenting to government authorities, to whom they are ultimately responsible, and there were concerns about tokenism and political risk for community representatives of fire users (Vázquez-Varela et al. 2022). However, this choice also reproduced a familiar pattern in conservation, where managerial perspectives are formalised first and community knowledge enters later (Copes-Gerbitz et al. 2024). While practitioners may require alignment to navigate institutional hierarchies, evidence from elsewhere suggests that durable and legitimate fire management depend on early and meaningful involvement of community fire users (Bilbao et al. 2019).

Practitioners themselves recognised this limitation and highlighted the need as one of our four priorities. At present, managers are taking draft plans back to their sites. Recognising that transdisciplinary processes can take many paths (Chambers et al. 2021), the absence of community perspectives at early stages remains a constraint. F Future processes could explore parallel pathways that support internal alignment while enabling earlier, safer community participation (Croker et al. 2024).

Language, access, and participation

Lesson: *Transdisciplinary processes must actively design for linguistic and institutional equity to avoid reproducing existing power asymmetries*.

As widely recognised, participation depends not only on who is invited, but on whether workshop formats, language arrangements, and timing create equitable conditions for contribution (Cash et al. 2003; Raymond et al. 2010). We found that the multilingual nature of our process resulted in uneven participation. Conversations shifted between Malagasy, French, and English, and despite translation support, those comfortable navigating multiple languages tended to speak more often and more confidently. This shaped which knowledge was foregrounded during discussions and whose remained peripheral, a dynamic which is widely recognised in transdisciplinary settings where linguistic hierarchies influence which voices gain legitimacy (Reed 2008).

Furthermore, participation was shaped by institutional hierarchies. Field technicians, who conduct day-today fire management and community engagement, were largely absent because workshops targeted managers. Their absence reduced

opportunities to incorporate operational insights and constrained the breadth of knowledge exchange (Cash et al. 2003).Future iterations could invest in stronger translation capacity, more inclusive participation of field-based staff, and workshop designs that support meaningful engagement across roles and linguistic backgrounds.

Differential reception and the limits of one-off approaches

Lesson: *Single engagement events are insufficient to secure institutional endorsement in risk-averse policy environments.*

Practical challenges too constrained our process. For example, travel disruptions, the disappearance of a tube of spatial maps, and a researcher falling down a mineshaft required improvisation and last-minute redesign. Despite prior planning, transdisciplinary processes rely on flexibility and improvisation, showing how fragile they can be when resources and contingencies are limited (Margules et al. 2020). Time pressures compounded these challenges. Practitioners and researchers are required to move through complex analytical exercises at a pace shaped by competing institutional responsibilities. For example, several participants noted that rushed discussions constrained their ability to interrogate assumptions or refine spatial plans. Transdisciplinary processes that rely on dense, multi-day agendas require temporal buffers and sustained organisational commitment. Without these, even well-designed methods can feel compressed or incomplete (Shackleton et al. 2023).

More significantly, the engagement session with national stakeholders fell flat. Whilst practitioners regarded the shared priorities and spatial plans as clear and actionable, government representatives responded with more caution and less enthusiasm than hoped. Policy stakeholders who had not been part of the co-production process encountered the outputs without experiencing the collaborative journey that made them meaningful to practitioners. Government stakeholders also operate within different incentive structures, face political risks in endorsing fire use, and often require evidence framed in bureaucratic or legal terms rather than experiential or landscape-level reasoning (Oliver et al. 2014). This uneven reception highlights that engagement with senior stakeholders needed to go beyond single events, and that endorsement depends on sustained involvement in the collaborative process to create outputs.

Next Steps and Resourcing

Lesson: *Intensive transdisciplinary processes depend on sustained resourcing, without which learning and coordination are difficult to maintain*.

Our proccess represents an initial phase in a longer trajectory of learning and development. Subsequent stages of our project, already underway, include supporting practitioners as they refine their plans with wider stakeholder groups, document emerging challenges and adaptations, and reflect adjust plans to ecological conditions, community engagement, and institutional feedback. Continued opportunities for cross-site exchange, international dialogue and structured reflection remain critical to our process to sustain a community of practice that can continue to function.

Resourcing, continuity, and implications beyond the project

The activities described here, including facilitated workshops, comparative exchange, and protected time away from day-to-day operational pressures, were enabled by sustained project funding. This project benefits from a relatively sustained funding (six years), rare in the context of conservation funding in Madagascar. Without dedicated financial support, opportunities for collective reflection, documentation, and peer exchange risk limiting the persistence of shared understanding and organisational learning (Eklund et al. 2025). Therefore, modest but sustained investment in facilitation, coordination, and cross-site exchange, rather than short-term funding driven by donor interest, is vital if practitioner knowledge is to embed within adaptive fire governance over the longer term.

SUMMARY

Our experience shows that transdisciplinary processes can provide the structure, relationships, and shared language needed to make fire management more adaptive and contextually grounded in Madagascar's protected areas. The value of the process lay in creating conditions under which practitioners could articulate their knowledge, interrogate assumptions, and develop strategies matched to their institutional and ecological realities. Peer exchange, boundary objects, and protected spaces for collective reflection enabled practitioners to formalise tacit expertise and navigate entrenched governance constraints.

These mechanisms are transferable to other conservation challenges where diverse stakeholders must coordinate under uncertainty. However, their effectiveness

depends on long-term institutional support, early and meaningful engagement with communities, and attention to language, power, and participation. When carefully designed and sustained, transdisciplinary approaches can build the foundations for more legitimate, feasible, and ecologically informed management.

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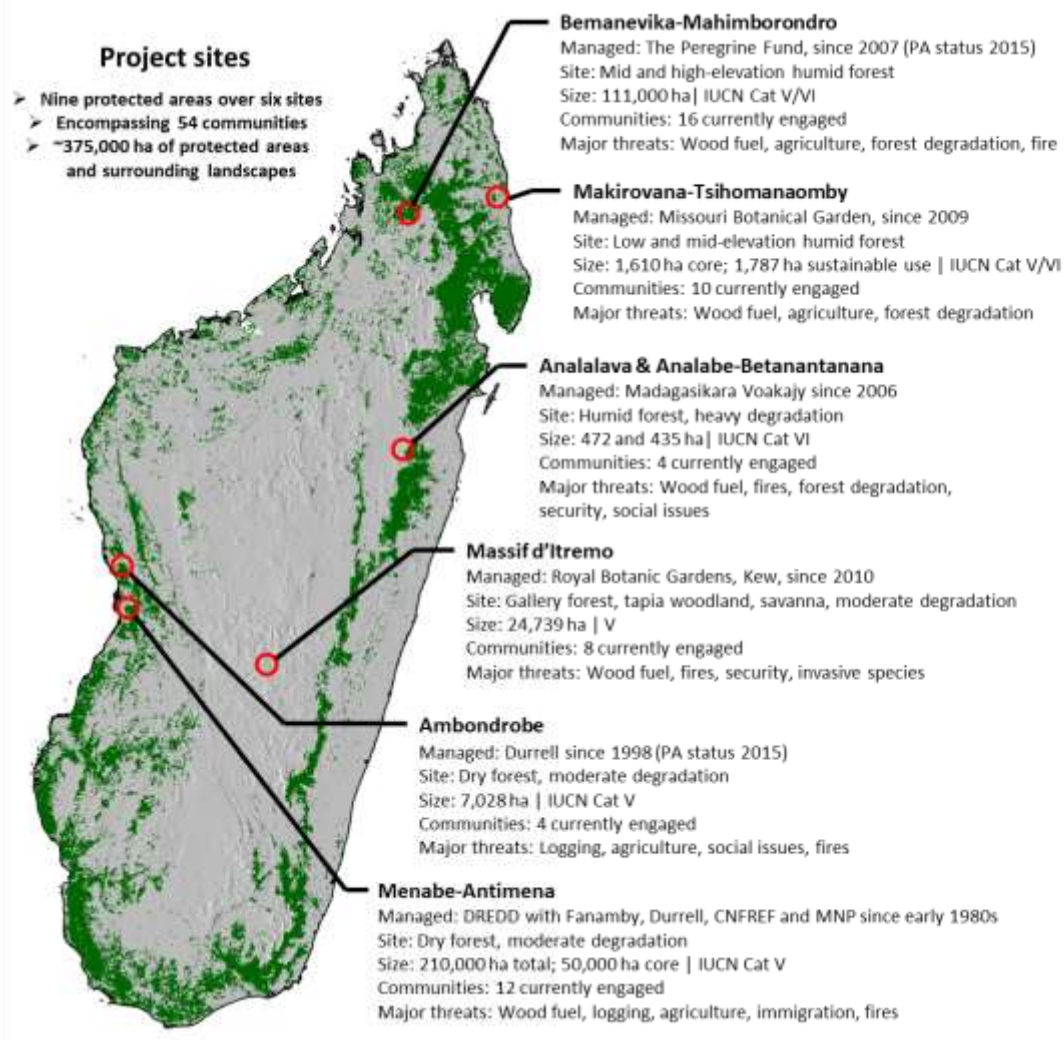
736 Supporting Information for A Practitioner-Led Transdisciplinary Process for Adaptive Fire

737 Management in Madagascar's Protected Areas

738 Appendix 1



739

740 **Figure S1. Locations and descriptions of the six protected areas involved in the**

741 **practitioner-led, transdisciplinary process.** Map highlights protected area governance

742 arrangements, vegetation type and status, protected area size, IUCN category, number

743 of communities who have access rights to the protected area, and major threats.

744 Appendix 2

Table S1. Descriptions of the thirteen themes identified by practitioners as important priorities to address for effective fire management

Priority	Description
Establish actionable fire plan	Meaning developing plans that can be implemented in practice rather than "sitting unused on a shelf", as one practitioner described
Multi-stakeholder engagement	Improving the working relationship with local, regional and national actors including communities and their leadership, Ministry of Environment and Sustainable Development (MEDD), Regional Directorates of Environment and Sustainable Development (DREDD), Madagascar National Parks etc.
Align fire management with community priorities	Co-develop fire management plans to include local community fire use needs within the plan
Fire data collection and management	Develop protocols and practice for collection of fire monitoring data including satellite and on-the-ground information both prior to and after the fire season.
Training and education for fire managers	Need for upskilling in facets of integrated fire management for fire managers within protected areas

Developing community fire awareness	Education programs which seek to raise awareness of fire risks and safe fire management techniques with local communities
Adequate fire management equipment	Possess well-maintained and ready to deploy fire management equipment for fighting fires such as fire bats and water pumps
Adequate fire detection equipment	Possess well-maintained and serviceable fire management equipment for detecting fires such as community patrols, watch towers and real-time satellite detection
Awareness and education around “good” fire (i.e. Controlled burning)	Raise national-level awareness of the role that fire plays in different contexts and how fire can be used to manage fire risk
Appropriate and adaptive institutional laws	Develop, possess and implement national and regional laws that allow for the use of fire as a conservation management tool within conservation areas in Madagascar.
Cultivate an adaptive multi-stakeholder mentality	Build the capacity of local, regional and national actors to work collaboratively in the management of fire.

Appropriate local laws	Develop, possess and implement regional and local laws, *DINA*, which regulate the local customs on fire use through the practical application of national law.
Law enforcement	Effectively implement the law on fire including the prosecution of arsonists.

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748

Appendix 3

Table S2. Governmental and non-governmental organisations who attended Activity Five

Organisation	Role
Ministry of Environment and Sustainable Development (MEDD)	Serves as Madagascar's primary authority for environmental governance, climate action, and the management of natural resources
Regional Directorates of Environment and Sustainable Development (DREDD)	The decentralized executive arms of Madagascar's Ministry of Environment and Sustainable Development (MEDD). There are 23 DREDD offices nationwide, each responsible for implementing national environmental policy at the regional level.
Bureau of National Risk and Disaster Management (BNGRC)	Operating under the Ministry of Interior, BNGRC is the central authority for managing and coordinating all disaster-related activities in Madagascar. Its primary goal is to shift the nation from reactive emergency response to a culture of prevention and resilience.
Corps de Sapeurs-Pompiers (CSP)	Professional fire brigades operating under the authority of local urban communes
Madagascar National Parks (MNP)	A private, para-statal body operating under the supervision of MEDD. MNP is the delegated manager of the majority of Madagascar’s flagship protected areas.

The Peregrine Fund	International NGO primarily focused on research and conservation of rare bird species. It manages four protected areas in Madagascar.
Missouri Botanical Garden	International NGO primarily focused on botanical research and the conservation of threatened plant species. It co-manages 13 protected areas across the island.
Madagascar Voakajy	Malagasy NGO focused on monitoring and protection of threatened animal species. It co-manages seven protected areas.
Durrell Wildlife Conservation Trust	International conservation NGO primarily focused on threatened animal species with a major focus on Madagascar. It co-manages seven protected areas.
Kew Conservation Centre Madagascar	International conservation NGO (Madagascar-based wing of the Royal Botanic Gardens, Kew) primarily focused researching and preserving rare plant species. It co-manages one protected area.
CARE International	International NGO with a dual focus on addressing the root causes of poverty and providing emergency humanitarian relief
LTS-NIRAS	Functions as an implementing partner for large-scale international donor projects, focusing on the intersection of climate resilience, sustainable landscapes, and economic development.

Appendix 4

Further photos documenting our process

764

765 **Figure S2. Topographic, fire regime and planning maps used in Activity Four during**

766 **the development of fire management plans**

Figure S3. Researcher and practitioner improvising to draw fire management plans in absence of maps, which were lost in transport

Figure S4. Practitioners sharing their design for fire management at the Ambondrobe site.

Figure S5. Group reflections on the stakeholder mapping activity

Figure S6. South African fire management expert sharing her experience during Activity Five, a structure dialogue with senior governmental and institutional actors.

Figure S7. All participants who attended the fire management workshop Activity Two.