

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

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56 ABSTRACT

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

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

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

77 INTRODUCTION

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

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

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

99 constraints of the people who depend on fire-shaped systems (Copes-Gerbitz et al.
100 2024; Govender et al. 2022). While there is often broad agreement on these
101 principles, conservation planning seldom turns knowledge into effective action
102 (Shuman et al. 2022). In Madagascar and elsewhere, scientific, practitioner, and
103 community perspectives frequently operate in parallel rather than through formal
104 processes that enable shared analysis, resulting in fire management strategies that
105 are neither grounded in local realities and nor workable in practice (Phelps et al.
106 2025; Knight et al. 2008).

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

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

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

137 A PRACTITIONER-LED TRANSDISCIPLINARY PROCESS

138 Process overview

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

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

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

152 Three principles guided the process design. First, we approached capacity building
153 as peer-to-peer exchange, recognising practitioners’ existing expertise and using
154 active learning to support cross-site understanding (Waldrop 2015; Raymond et al.
155 2010). Second, we deliberately sequenced engagement, starting within a small
156 practitioner group before expanding discussions to external stakeholders (Tengö et
157 al. 2017). Third, we hosted residential workshops away from institutional settings to
158 create enabling conditions for reflection and dialogue (McFayden et al. 2023).

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

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



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167 **Figure 1. A practitioner-led, researcher-supported pipeline for developing**
168 **context-specific fire management under institutional and resource constraints.**

169 Building upon existing practitioner and researcher knowledge, five sequential
170 activities supported the formalisation of such knowledge by moving from shared
171 learning, through articulation of priorities and governance constraints, to spatially
172 grounded planning and institutional dialogue.

173 Activity One: Peer exchange and shared learning

174 Across Madagascar, fire management practitioners within NGOs often operate in
175 relative isolation. Such isolation limits opportunities for shared reflection,
176 cumulative learning, and can reinforce entrenched management approaches.

177 Furthermore, responsibility for PA management is frequently devolved to

178 international organisations whose institutional experience with fire may be limited,

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

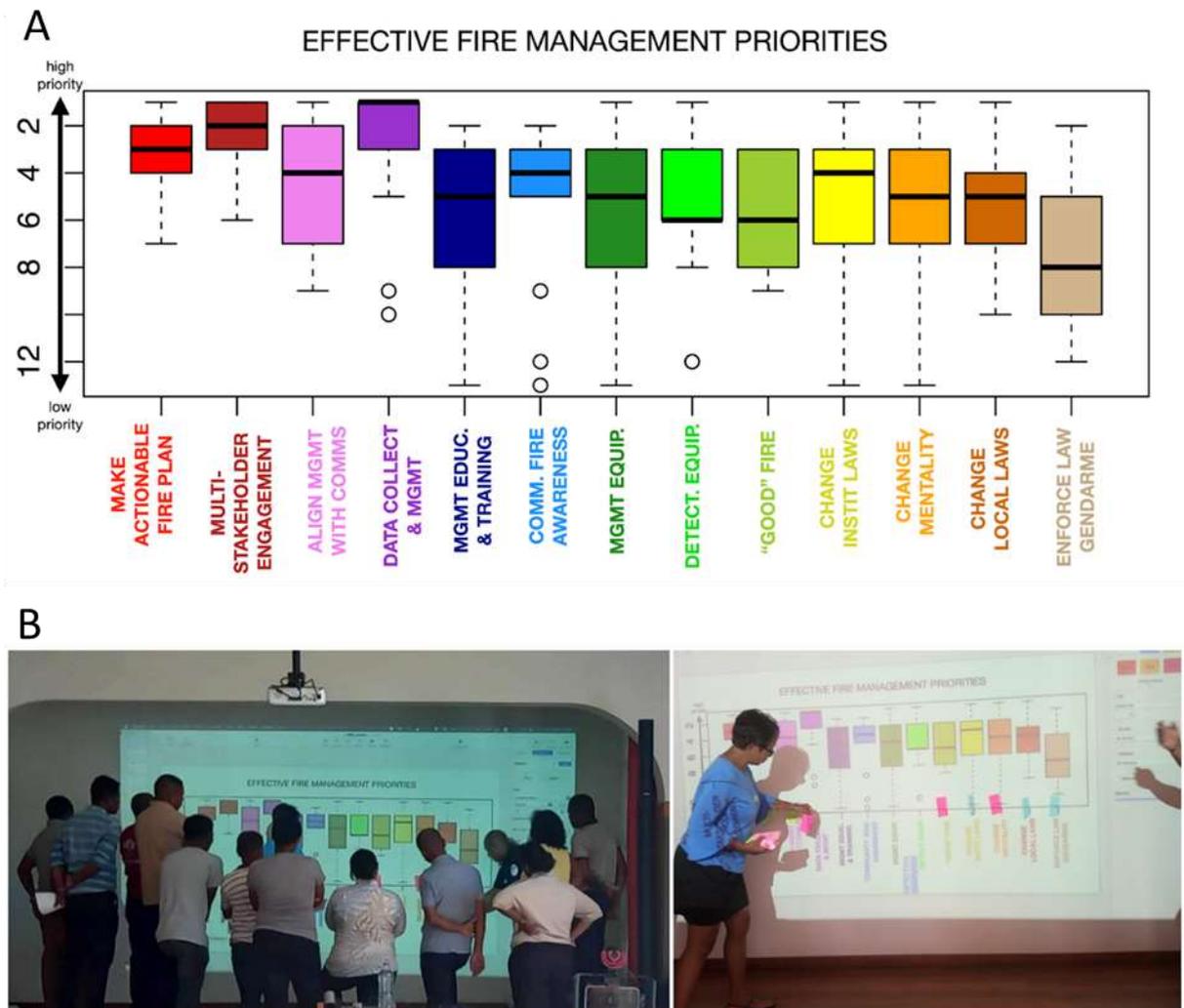
185 Activity One had two aims (Fig. 1). First, it sought to connect practitioners across
186 organisations and sites in settings removed from day-to-day operational pressures,
187 creating space for dialogue, reflection, and the emergence of a community of
188 practice. Second, it aimed to link Malagasy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

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

201 Activity Two: Establishing fire management priorities

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

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



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Figure 2. Articulating and consolidating practitioner priorities for fire

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

identified by practitioners as important priorities to address for effective fire

management, synthesised from individual reflections (see Supporting Information

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

practitioners collectively discussed and refined the thirteen themes into four

overarching priorities through facilitated dialogue. Photographs show protected-area

managers engaging in the consensus-building process.

224 Activity Three: Key stakeholders & their roles in PA management

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

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

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

245 Activity Four: Developing actionable fire plans

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

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

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

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

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

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

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

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

282 Post-workshop validation and feedback

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

288 ILLUSTRATIVE PROCESS OUTPUTS

289 Reframing fire as an ecological management tool

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

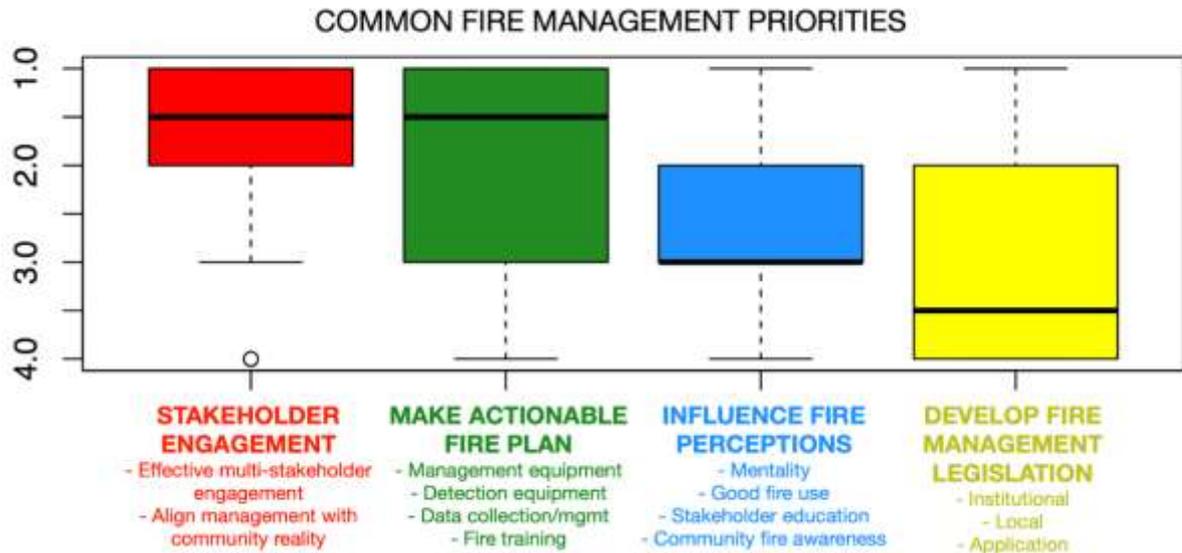
299 These observations supported comparative reflection about how principles of
300 preparation, safety, and evidence use might translate to Malagasy contexts, while
301 acknowledging that techniques would need adaptation. As one practitioner
302 explained, “*It’s not about directly copying what’s done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

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

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

315 Establishing Shared Fire Management Priorities

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



323

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

326 Stakeholder engagement ranked consistently high, underscoring recognition that
 327 technical interventions cannot succeed without trust, coordination, and legitimacy.

328 Practitioners described prioritisation as supporting clearer strategic thinking and
 329 more defensible decision-making under constraint. One practitioner explained: "

330 *The prioritisation is useful because the results allow us to reflect on what we already*
 331 *have on the ground but also on what must be done in the future."* Another

332 emphasised how the process strengthened their capacity to make strategic choices,
 333 noting that it "*allowed us both to justify the actions to undertake and to better use*
 334 *the limited resources we have*".

335 Governance constraints and stakeholder relationships

336 Practitioners positioned neighbouring communities as the stakeholders most

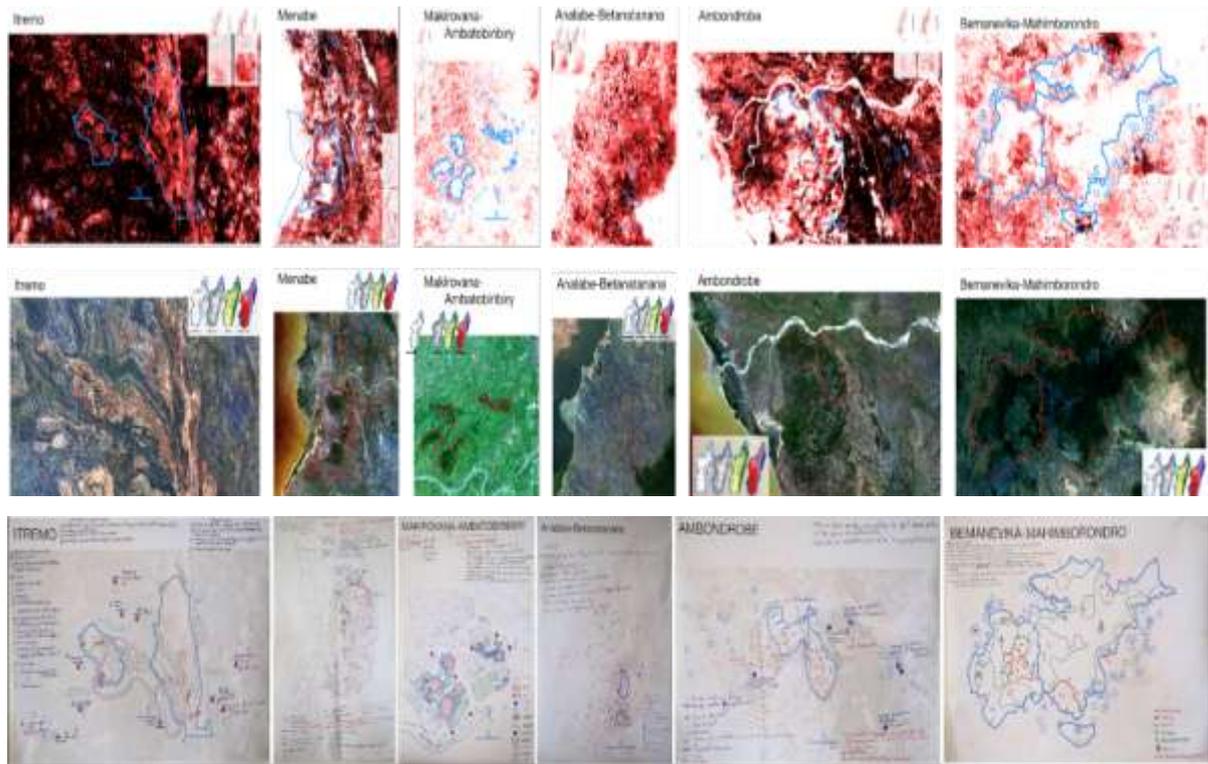
337 affected by fire yet frequently among the least influential in formal decision-making,

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

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

349 Developing actionable, context-specific fire management plans

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



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Figure 4: Developing spatially grounded fire management plans through

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integration of data and practitioner knowledge. Poster-sized maps combining

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multi-year fire history, high-resolution satellite imagery, community locations, and

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environmental context were used by practitioners from six protected areas to

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develop draft, site-specific fire management plans.

364

Spatial mapping supported this shift by showing where unwanted fires originate and

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concentrate, where interventions were feasible, and where government or

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community engagement would be essential. Practitioners used these insights to

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identify sensitive ecological edges, sites that could constrain potential fire spread,

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and match proposed actions to the institutional and social conditions shaping each

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site. Together, plans reflected contextual expertise and showed how practitioners

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translated shared learning into strategies tailored to their own landscapes.

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

376 National Engagement and Legal Clarification

377 Engagement with national authorities revealed that the challenges identified by
378 practitioners were widely recognised across Madagascar’s PAs. A key outcome was
379 the clarification that some state-managed PAs took advantage of existing legislation
380 which permits vegetation fires during certain times of year, when authorised by local
381 state institutions, and incorporated into approved management plans. Although this
382 provision has been in place for years, it was largely unknown to us because it
383 appears to contradict later legislation that prohibits all human-lit fires in
384 conservation areas.

385 MECHANISMS, LESSONS, AND LIMITATIONS

386 Structured, practitioner-led and researcher-supported transdisciplinary processes
387 can help address persistent fragmentation between scientific knowledge,
388 practitioner experience, and institutional frameworks in fire management.

389 Comparative learning, collective prioritisation, stakeholder analysis, and spatial
390 planning supported fire management practitioners in Madagascar’s protected areas
391 to reshape how fire is interpreted, prioritised, and planned for. Our activities enabled
392 the articulation of shared conceptual foundations for fire management and the

393 development of context-specific planning approaches. As documented here and
394 elsewhere, transdisciplinary approaches work to strengthen adaptive capacity in
395 resource-constrained settings by creating peer networks, clarifying governance
396 expectations, and providing decision-support tools that practitioners can readily use
397 (Roux et al. 2006; Lang et al. 2012). This section reflects on how and to what extent
398 these activities served their intended aims, examines the mechanisms through
399 which they operated, and considers the implications for practice.

400 Practitioners already work as adaptive managers, navigating ecological pressures,
401 community relationships, and institutional constraints (Fabricius and Cundill,
402 2014). However, ecological evidence, experiential understanding, and governance
403 rules often circulate separately, shaped by different incentives and languages, and
404 rarely meet through structured processes that allow shared interpretation. We saw a
405 central barrier to implementation as the absence of mechanisms that enable
406 practitioner knowledge to be documented, compared, and legitimised across sites
407 (Fazey et al. 2005). This *formalisation gap* reflects limited tools, time, and
408 institutional spaces to turn experiential knowledge into accessible evidence that
409 can guide planning. Without such structures, knowledge remains tacit, resists
410 scrutiny, and cannot accumulate as organisational learning (Fazey et al. 2006).

411 How the transdisciplinary process helped bridge implementation gaps

412 Three elements of our process, peer exchange, boundary objects, and safe spaces
413 worked together to address the formalisation gap. Collectively, these mechanisms
414 enabled us to build shared legitimacy around fire as a management tool, made tacit

415 knowledge visible and discussable, and supported the alignment required for
416 collective planning across diverse PAs.

417 Building shared legitimacy through peer exchange

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

421 The peer exchange (Activity One) helped to reduce professional isolation and
422 reshape how practitioners understood what was possible in fire management.

423 Observing professional fire use by equivalent peers functioned as experiential social
424 learning (Pahl-Wostl 2009), enabling practitioners to reconsider the legitimacy of
425 contested practices such as prescribed burning. Seeing fire used confidently and
426 safely dissolved assumptions that controlled burning was unrealistic or inherently
427 dangerous in the Madagascar context.

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

436

437 Making tacit knowledge explicit through boundary objects

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

441 Spatial maps, stakeholder matrices, and prioritisation frameworks acted as
442 ‘boundary objects’ (Star and Griesemer 1989:p.387) that turned experiential and
443 scientific knowledge into shared, negotiable representations. For example, actor
444 matrices (Activity Three) clarified where institutional authority and political risk
445 constrained decision-making. While multi-year fire maps (Activity Four) helped to
446 shift planning from isolated fire incidents towards a landscape-scale understanding
447 of risk. The physicality of the maps enabled us to look, layer and see where spatial
448 data and practitioner knowledge of climate, access, and seasonal fire use could
449 combine to deliver interventions. The value of ‘boundary objects’ lay in making
450 knowledge visible, allowing interchange between different knowledge systems and
451 openness to critique and re-negotiation in ways that verbal discussion alone may
452 not have achieved. Making tacit knowledge explicit in this way created the
453 conditions for shared analysis and interrogation improving practitioners ability to
454 justify management decisions to colleagues, communities and officials, all of which
455 are essential to adaptive management across diverse socio-ecological contexts
456 (Armitage et al. 2008).

457

458 Creating safe spaces for alignment and honest problem-sharing

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

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

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

471 The decision to sequence activities so that we aligned internally before engaging
472 national stakeholders proved important. The approach reduced the risk of
473 fragmented messages, built collective confidence, and supported the development
474 of a unified position before entering more hierarchical policy spaces (Tengö et al.
475 2017). Such strategic sequencing foregrounded practitioner agency and knowledge
476 in ways that parallel processes with all stakeholders present from the outset might
477 not have achieved, particularly in contexts where discussions about legal fire use
478 are discouraged and managers face political risks for engaging in them (Kull 2002).

479

480 Limitations and unresolved challenges

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

484 Sequencing and the absence of direct community voices

485 **Lesson:** *Prioritising internal alignment before wider engagement can improve*
486 *coherence but comes at the cost of early inclusivity.*

487 Community members did not participate in the workshop activities. This was a
488 deliberate sequencing decision: practitioners wanted internal coherence before
489 presenting to government authorities, to whom they are ultimately responsible, and
490 there were concerns about tokenism and political risk for community
491 representatives of fire users (Vázquez-Varela et al. 2022). However, this choice also
492 reproduced a familiar pattern in conservation, where managerial perspectives are
493 formalised first and community knowledge enters later (Copes-Gerbitz et al. 2024).
494 While practitioners may require alignment to navigate institutional hierarchies,
495 evidence from elsewhere suggests that durable and legitimate fire management
496 depend on early and meaningful involvement of community fire users (Bilbao et al.
497 2019).

498 Practitioners themselves recognised this limitation and highlighted the need as one
499 of our four priorities. At present, managers are taking draft plans back to their sites.
500 Recognising that transdisciplinary processes can take many paths (Chambers et al.
501 2021), the absence of community perspectives at early stages remains a constraint.

502 F Future processes could explore parallel pathways that support internal alignment
503 while enabling earlier, safer community participation (Croker et al. 2024).

504 Language, access, and participation

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

507 As widely recognised, participation depends not only on who is invited, but on
508 whether workshop formats, language arrangements, and timing create equitable
509 conditions for contribution (Cash et al. 2003; Raymond et al. 2010). We found that
510 the multilingual nature of our process resulted in uneven participation.

511 Conversations shifted between Malagasy, French, and English, and despite
512 translation support, those comfortable navigating multiple languages tended to
513 speak more often and more confidently. This shaped which knowledge was
514 foregrounded during discussions and whose remained peripheral, a dynamic which
515 is widely recognised in transdisciplinary settings where linguistic hierarchies
516 influence which voices gain legitimacy (Reed 2008).

517 Furthermore, participation was shaped by institutional hierarchies. Field
518 technicians, who conduct day-to-day fire management and community engagement,
519 were largely absent because workshops targeted managers. Their absence reduced
520 opportunities to incorporate operational insights and constrained the breadth of
521 knowledge exchange (Cash et al. 2003). Future iterations could invest in stronger
522 translation capacity, more inclusive participation of field-based staff, and workshop

523 designs that support meaningful engagement across roles and linguistic
524 backgrounds.

525 Differential reception and the limits of one-off approaches

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

528 Practical challenges too constrained our process. For example, travel disruptions,
529 the disappearance of a tube of spatial maps, and a researcher falling down a
530 mineshaft required improvisation and last-minute redesign. Despite prior planning,
531 transdisciplinary processes rely on flexibility and improvisation, showing how fragile
532 they can be when resources and contingencies are limited (Margules et al. 2020).
533 Time pressures compounded these challenges. Practitioners and researchers are
534 required to move through complex analytical exercises at a pace shaped by
535 competing institutional responsibilities. For example, several participants noted that
536 rushed discussions constrained their ability to interrogate assumptions or refine
537 spatial plans. Transdisciplinary processes that rely on dense, multi-day agendas
538 require temporal buffers and sustained organisational commitment. Without these,
539 even well-designed methods can feel compressed or incomplete (Shackleton et al.
540 2023).

541 More significantly, the engagement session with national stakeholders fell flat.
542 Whilst practitioners regarded the shared priorities and spatial plans as clear and
543 actionable, government representatives responded with more caution and less
544 enthusiasm than hoped. Policy stakeholders who had not been part of the co-

545 production process encountered the outputs without experiencing the collaborative
546 journey that made them meaningful to practitioners. Government stakeholders also
547 operate within different incentive structures, face political risks in endorsing fire use,
548 and often require evidence framed in bureaucratic or legal terms rather than
549 experiential or landscape-level reasoning (Oliver et al. 2014). This uneven reception
550 highlights that engagement with senior stakeholders needed to go beyond single
551 events, and that endorsement depends on sustained involvement in the
552 collaborative process to create outputs.

553 Next Steps and Resourcing

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

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

564 Resourcing, continuity, and implications beyond the project

565 The activities described here, including facilitated workshops, comparative
566 exchange, and protected time away from day-to-day operational pressures, were

567 enabled by sustained project funding. This project benefits from a relatively
568 sustained funding (six years), rare in the context of conservation funding in
569 Madagascar. Without dedicated financial support, opportunities for collective
570 reflection, documentation, and peer exchange risk limiting the persistence of shared
571 understanding and organisational learning (Eklund et al. 2025). Therefore, modest
572 but sustained investment in facilitation, coordination, and cross-site exchange,
573 rather than short-term funding driven by donor interest, is vital if practitioner
574 knowledge is to embed within adaptive fire governance over the longer term.

575 SUMMARY

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

584 These mechanisms are transferable to other conservation challenges where diverse
585 stakeholders must coordinate under uncertainty. However, their effectiveness
586 depends on long-term institutional support, early and meaningful engagement with
587 communities, and attention to language, power, and participation. When carefully

588 designed and sustained, transdisciplinary approaches can build the foundations for
589 more legitimate, feasible, and ecologically informed management.

590

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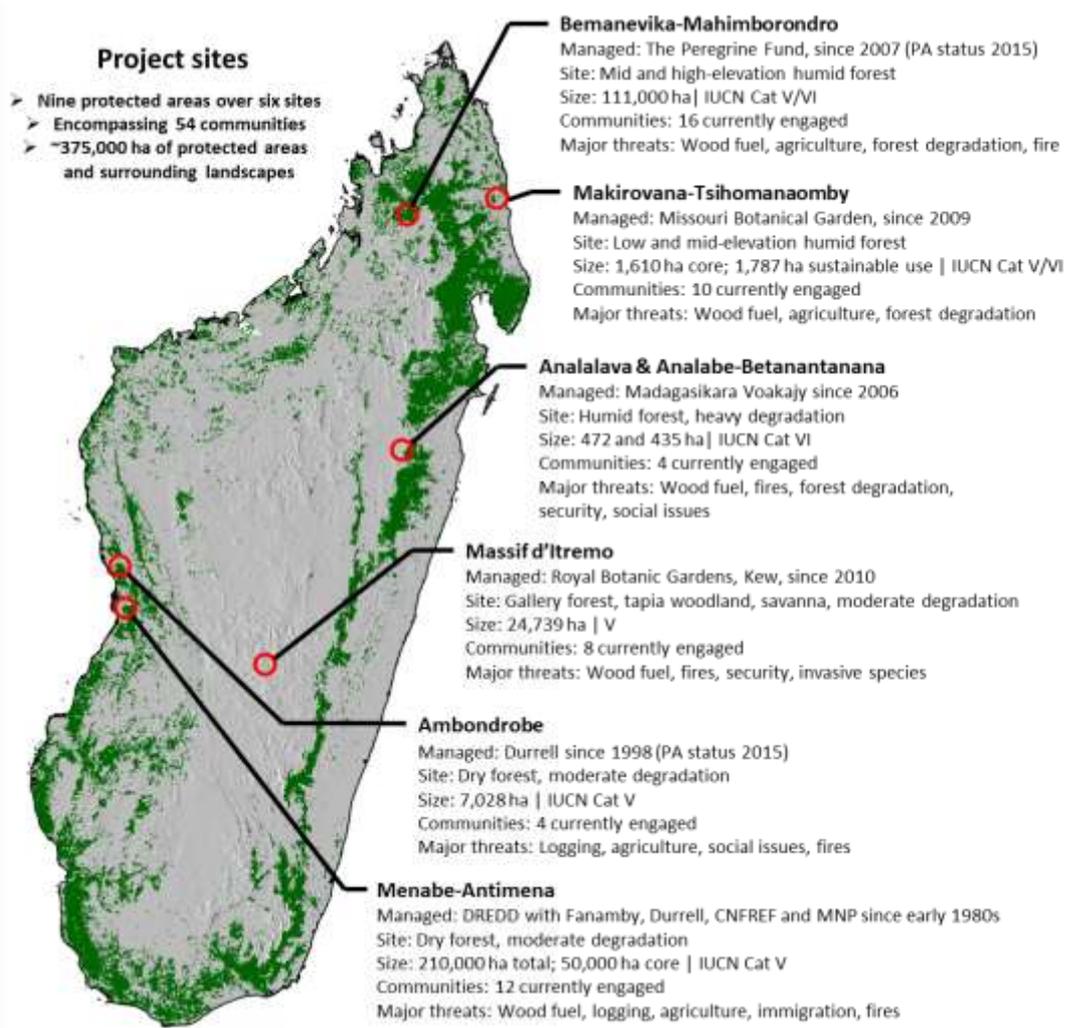
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740 Supporting Information for A Practitioner-Led Transdisciplinary Process for Adaptive Fire

741 Management in Madagascar's Protected Areas

742 Appendix 1



743

744 **Figure S1. Locations and descriptions of the six protected areas involved in the**
745 **practitioner-led, transdisciplinary process.** Map highlights protected area governance
746 arrangements, vegetation type and status, protected area size, IUCN category, number
747 of communities who have access rights to the protected area, and major threats.

748 Appendix 2

749 **Table S1. Descriptions of the thirteen themes identified by practitioners as**
 750 **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, <i>DINA</i> , 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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754 **Table S2. Governmental and non-governmental organisations who attended**755 **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.

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765 **Appendix 4**

766 Further photos documenting our process

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

770 **the development of fire management plans**



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

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

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780 **Figure S5. Group reflections on the stakeholder mapping activity**

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

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

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