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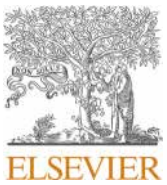

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Strategies to engage local communities in forest biodiversity conservation had limited effectiveness in Madagascar: Lessons from the literature

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ABSTRACT

To address the current biodiversity crisis, various conservation approaches have been implemented worldwide to engage local communities in biodiversity conservation. In Madagascar, a biodiversity hotspot, these approaches include protected areas, community-based conservation, and market-based conservation. However, their respective ecological, socio-economic, and socio-cultural effectiveness remains poorly understood. This study aimed to fill this knowledge gap through a systematic literature review. Out of 480 publications on forest conservation in Madagascar identified through standardized searches and screening, 156 were selected for in-depth full-text analysis. By combining quantitative and qualitative approaches, our results revealed generally positive ecological outcomes but negative socio-economic and cultural impacts. While the literature presents mixed findings on the effectiveness of conservation actions in reducing deforestation, protected forests have demonstrated improved biodiversity outcomes. However, these ecological gains come at a cost to local communities, especially the poorest households, who often receive inadequate compensation. Alternative livelihood activities proposed by conservation programs are often ill-suited to local contexts, and local elites tend to capture most conservation benefits, exacerbating inequalities and local conflicts. All three conservation approaches display similar trends, indicating recurring challenges regardless of the strategy employed. The literature highlights strategies to achieve more effective conservation while balancing ecological outcomes and human well-being. These include sustained investment in local conservation actions, genuine co-management frameworks, community empowerment, and stronger collaboration between researchers and local stakeholders. Although focused on Madagascar, the challenges and solutions identified in this study have broader global relevance for biodiversity conservation stakeholders.

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1. Introduction

As worldwide biodiversity decline continues, primarily due to anthropogenic factors and climate change (IPBES, 2019), its conservation has become an increasingly pressing challenge (Mace et al., 2018). Yet, biodiversity conservation often involves trade-offs with human development goals (Adams and Hutton, 2007; Meng et al., 2023; West et al., 2006), hence the necessity to systematically articulate challenges related to biodiversity conservation with challenges related to human well-being and development. Consequently, the central challenge in conservation sciences and practices concerns the (re)conciliation between human well-being and that of non-human living beings.

Protected areas (PAs) represent the cornerstone of the global strategy to address this challenge. From their inception, PAs were conceived as areas of land appropriated by the State while excluding local populations (Colchester, 2004; West et al., 2006). However, the often-violent evictions of residents and the injustices generated by this strategy, as well as the simultaneous expansion of both human-dominated areas and PAs (Blanco et al., 2020), have contributed to the emergence of more integrative approaches. These new approaches materialized in the 1980s through various conservation actions that aimed at promoting sustainable human-biodiversity coexistence within PAs and/or their buffer zones.

Madagascar, located in a global biodiversity hotspot (Myers et al., 2000), provides an excellent case study of the biodiversity conservation actions that evolved to incorporate human well-being concerns. The country has a long history of biodiversity conservation, from the establishment of nature reserves in the early 20th century to the development of market-based conservation strategies in the late 2010s (for details on this history, see Pollini, 2011; Demaze, 2014; Waeber et al., 2016). Between 1991 and 1996, the country's conservation strategy focused on expanding PAs, which were generally associated with Integrated Conservation and Development Projects (ICDPs) to compensate for the costs of biodiversity conservation for people living in the concerned areas (Bertrand et al., 2014; Ferraro and Kiss, 2002). From 1997 to 2003, Madagascar shifted emphasis to community-based conservation approaches through contractual management transfers, known as VOIs (the Malagasy acronym for *Vondron'Olona Ifotony*), which establish forest co-management schemes between both state and local communities (Rasolofoson et al., 2015). Subsequently, since 2003, the national conservation strategy targeted economic consolidation and diversification by developing market-based conservation approaches, including REDD/REDD+ and PES (Payment for Environmental Services) schemes. These successive conservation approaches demonstrate distinct strategies for engaging local populations in biodiversity conservation. Under PAs, people were typically not compensated for their loss of land access; with community-based approaches, they were acknowledged as legitimate land managers working alongside national and local authorities; with marked-based approaches, they were encouraged to adopt biodiversity-friendly behaviors through economic incentives. Despite this long Madagascar's conservation history, two critical research gaps prevent comprehensive conclusions. First, there is no integrated synthesis examining the multiple dimensions of conservation impacts, including ecological, socio-economic and socio-cultural. Rather, existing assessments have typically focused on only one type of outcomes, such as the economic costs of conservation actions for local populations (Neudert et al., 2017) or their effectiveness at reducing deforestation (Rasolofoson et al., 2015). Second, despite existing syntheses at national (Gardner et al., 2018; Waeber et al., 2016) and local levels (Gardner et al., 2013), comparative analysis of how the different conservation approaches perform in simultaneously preserving biodiversity and contributing to local people's well-being remains limited. Developing such syntheses is essential for designing future conservation strategies that build upon successes while addressing persistent challenges.

This study addresses these knowledge gaps by investigating the ecological, socio-economic and cultural effects of the diverse biodiversity conservation approaches implemented in Madagascar. To address this question, we conducted a standardized analysis of the peer-reviewed literature, focusing on tree and forest conservation across various ecosystems. In particular, the scope of the review included humid and dry forests, but also all areas covered with so-called trees outside forests (FAO, 2022), i.e. lands that are not classified as forests but contain trees, such as agroforestry areas and other wooded areas. On this basis, two key questions are examined in this study:

- What are the ecological, socio-economic, and cultural effects of biodiversity conservation actions in Madagascar?
- How do effects differ among the three main approaches (protected areas, community-based conservation, and market-based conservation)?

Our review identifies and discusses key barriers highlighted in the literature that hinder the effectiveness of biodiversity conservation in Madagascar, and summarize proposed solutions from the literature. Importantly, these barriers are not unique to Madagascar but reflect challenges common to conservation efforts worldwide, making the insights from this analysis relevant to improving biodiversity conservation globally.

2. Methods

The general workflow followed in this study involved four key stages and mixed quantitative and qualitative methods. First, we designed and implemented a systematic literature search protocol to gather a consistent "raw corpus" of peer-reviewed publications. From this raw corpus, a screening phase allowed us to focus on a "global corpus" of publications suited to address our research questions. Third, we conducted a global mapping of the corpus through bibliometric techniques and abstract-based data extraction. Building upon this mapping, we finally targeted a "final corpus" of 156 publications for a comprehensive full text analysis. This general workflow is further described in sections below and summarized in Fig. 1.

2.1. Literature search

Three academic, peer-reviewed publication sources were consulted to gather relevant literature on biodiversity conservation actions. Although we initially focused on the islands of the southwestern Indian Ocean, the predominance of publications from Madagascar ultimately led us to narrow our analysis and the scope of this study exclusively to this country (see Section 2.2). Our primary literature source was Web of Science (WOS), one of the most comprehensive scientific publication databases covering various fields, including conservation-related studies. Following an initial exploratory search and brainstorming among the study authors, we developed a set of keywords targeting three main elements: (i) forested and tree-covered landscapes (including forests and other lands containing trees), (ii) at least one island in the southwestern Indian Ocean, and (iii) biodiversity conservation actions. A standardized query (Table S1) yielded an initial corpus of 1439 publications published between 1977 and 2023. Our secondary literature source was the French-language OpenEdition database, which primarily indexes humanities and social science journals. Given this platform's more limited search functionality compared to WOS, we employed a series of queries combining one or two keywords, which identified 50 additional publications. Finally, we manually reviewed the table of contents of the bilingual journal *Madagascar Conservation & Development* (MCD), which yielded 66 additional publications. Even though this journal is not indexed in WOS or OpenEdition, we considered it as a relevant source of peer-reviewed publications due to its geographical and thematic scope. In total, these three bibliographic sources and search strategies resulted in a raw corpus of 1555 publications. All

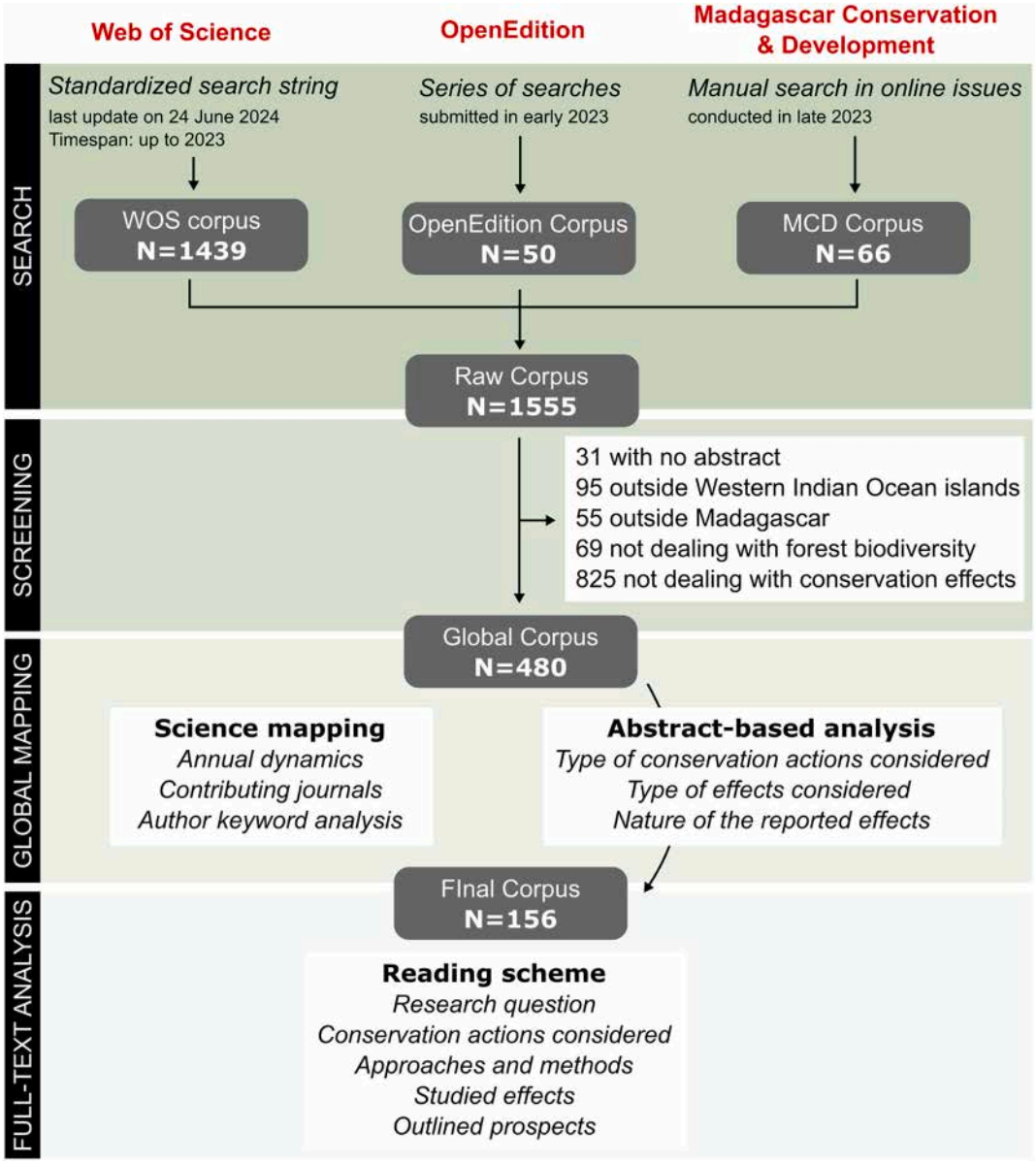

Fig. 1. Diagram summarizing the literature search, screening, and analytical procedures followed for this systematic and comprehensive literature review.

consulted bibliographic databases adhere to contemporary academic standards and contain only peer-reviewed publications. We deemed this a quality criterion essential for our synthesis, even though other databases could have offered relevant material (see Section 4.1).

2.2. Screening procedure

Publications collected from WOS and OpenEdition required a screening phase of titles and abstracts to solely focus on those addressing biodiversity conservation effects in the southwestern Indian Ocean. This screening procedure excluded several groups of publications: (i) those lacking abstracts and thus unsuitable for further analysis ($N = 31$; 2.0 % of the raw corpus); (ii) those unrelated to any Indian Ocean islands ($N = 95$; 6.1 %); (iii) those not concerning forests or forest biodiversity ($N = 69$; 4.4 %); and most significantly, (iv) those not examining conservation effects ($N = 825$; 53 %). The latter group — the largest group eliminated — included studies of species distributions, descriptions of areas emphasizing their conservation value, as well as ecological studies conducted within PAs but without examining their effects.

Upon reviewing the remaining publications, we found a marked disparity in geographical coverage. Publications focusing on islands other than Madagascar were notably limited ($N = 55$; 3.5 %), with insufficient material for each individual island to support a comprehensive review (Fig. S1, Geographical Scope). Consequently, we narrowed our analysis to Madagascar exclusively. Our global corpus then comprised 480 publications that directly or indirectly addressed the effects of biodiversity conservation actions in Madagascar's forested and tree-covered landscapes (see complete reference list in Supplementary Information).

2.3. Global mapping of the literature

Given the substantial size of the global corpus, we began with analyses based on publication metadata, including abstracts. First, we examined the temporal evolution of publication numbers within the corpus and the primary scientific journals by publications count using R software (R Core Team, 2023). We generated a co-occurrence cloud of keywords provided by authors to visualize dominant themes in the literature using VOSviewer (van Eck and Waltman, 2010). This keyword analysis was limited to the 379 WOS publications (79.0 % of the global

corpus) because VOSviewer could not process metadata from OpenEdition or MCD.

Next, we collaboratively developed a reading grid (Table S2) to extract information from publication abstracts. This grid allowed to record multiple dimensions of data for each abstract, specifically:

- The type of conservation action: PAs, community-based conservation actions, and/or market-based conservation actions. Since these actions coexist in some places, individual publication might address multiple actions simultaneously;
- Whether the publication empirically examined conservation effects rather than merely mentioning them in the introductory or perspectives sections;
- For relevant publications, the types of effects studied: ecological (impacts on ecosystems generally-speaking, including their ecological attributes and functions), socio-economic (material impacts on households, their economy, and livelihoods), and socio-cultural (more intangible impacts on social cohesion, stakeholder relationships, etc.); and
- For each type of studied effect, the direction of reported effect as indicated in the abstract: predominantly positive, predominantly negative, or complex/neutral when insufficient information was provided in the abstract for definitive assessment.

This initial global mapping based on bibliometric and abstract-based analysis yielded preliminary results regarding biodiversity conservation effects that are reported in Section 3.1. It enabled us to identify a final corpus of 156 publications that explicitly presented findings on the effects of the three conservation approaches of interest (PAs, community-based conservation, and market-based conservation).

2.4. Comprehensive analysis of full texts

To maximize insights from the scientific literature on biodiversity conservation actions, we developed a reading template for extracting relevant information from the full texts of the 156 selected publications (Table S3). This template was organized into five sections:

- Research objectives and questions: documenting the publication's general aim and research questions addressed;
- Conservation and/or development actions: detailing the actions studied, including their geographical area and scale (ranging from plot-level to regional analyses);
- Tools, methods, and approaches: providing an overview of the research methods, analytical approaches, and types of data collected or used;
- Studied effects: systematically listing all effects of biodiversity conservation actions reported in the Results sections and their associated underlying factors;
- Outlined perspectives: identifying reflections, interpretations, and recommendations presented in the Discussion sections.

Each co-author handled between 5 and 15 publications, resulting in one completed reading template per publication. The three first authors then summarized and analyzed the completed templates through a qualitative thematic approach, with a particular focus on the effects reported in each publication. During this analysis, individual effects were progressively regrouped together based on their nature, ultimately leading to six broad categories concerning: (i) forest land cover dynamics; (ii) biodiversity dynamics within forests; (iii) local residents' wealth; (iv) alternative livelihoods proposed to local residents; (v) the articulation between conservation and local people's interests; and (vi) local socio-economic asymmetries. Within these categories, we systematically identified the direction of each individual effect (positive, negative, or neither) found in the publications' results. Finally, we qualitatively assessed the level of confidence for each category of effect based on the quantity of evidence (i.e., number of publications that studied the category of effect) and the degree of consensus regarding that evidence (i.e., degree of consensus between publications on the direction of the effect). This assessment was done on the basis of the IPBES four-box classification system (IPBES, 2019; Moss and Schneider, 2000), which includes four descriptors of the "state of knowledge":

- Well established (supported by comprehensive meta-analysis, syntheses, or multiple concordant independent studies): we used this for categories of effects studied by >10 publications, of which >80 % found the same direction;
- Established but incomplete (reflecting general agreement despite limited studies, lack of comprehensive synthesis, and/or imprecise studies): we used this for categories of effects studied by <10 publications, of which >80 % found the same direction;
- Unresolved (multiple independent studies exist but reach divergent conclusions): we used this for categories of effects studied by >10 publications, of which >20 % reported contrasting directions; and
- Inconclusive (characterized by limited evidence and acknowledge significant knowledge gaps): we used this for categories of effects studied by <10 publications, of which >20 % reported contrasting directions.

We hereafter report the results of the full-text analysis through Sections 3.2 to 3.7, each one focusing on one of the six above-mentioned categories of effects.

3. Results

3.1. Overview of literature content and key conservation effects

Publications in the global corpus ($N = 480$ publications) spanned the period from 1990 to 2023, with a marked concentration in the last 15 years (Fig. 2a). As expected, conservation science journals dominated the corpus (Fig. 2b), led by *Madagascar Conservation & Development* ($N = 66$), *ORYX* ($N = 18$), *Biological Conservation* ($N = 17$), and *International Journal of Primatology* ($N = 16$). The corpus also featured significant contributions from broader-scope journals such as *PLOS ONE* ($N = 14$), *Les Cahiers d'Outre-mer* ($N = 9$), and *VertigO* ($N = 7$), alongside journals specialized on agriculture or forestry, such as *Agriculture, Ecosystems & Environment* ($N = 7$ publications) and *Bois et Forêts des Tropiques* ($N = 10$). The thematic diversity of this global corpus was also evident in the author keyword cloud analysis (Fig. S2). Several thematic clusters emerged around the two central issues of deforestation and biodiversity conservation, encompassing forest dynamics (degradation, fragmentation, habitat loss), shifting agriculture, agroforestry, wildlife utilization, ecosystem services, co-management initiatives, as well as political and governance dimensions.

Abstract analysis of the global corpus showed that one-third of the publications ($N = 160$) focused on PAs, while 64 examined community-based conservation, and 33 addressed market-based conservation approaches (Fig. 3a). A substantial portion of 268 publications did not focus on any of these three conservation approaches, either because they examined alternative frameworks (e.g., ecological restoration, red lists, environmental education) or discussed conservation in general terms without targeting a specific approach. Furthermore, we concluded that only 156 of the 480 publications (32.5 % of the corpus) contained substantive evaluations of conservation effects (Fig. 3b). In many publications, PAs served primarily as study sites rather than as conservation frameworks being evaluated. Of these 156 articles, most investigated the eastern part of Madagascar, where tropical rainforests are concentrated, as well as areas along major roads, particularly around the capital (Fig. 4). Notably, the abstract analysis revealed relatively balanced distribution of studies examining ecological ($N = 78$), socio-economic ($N = 79$), and socio-cultural ($N = 84$) effects. However, the direction of these effects was rarely discernible from the abstract alone (Fig. 3d),

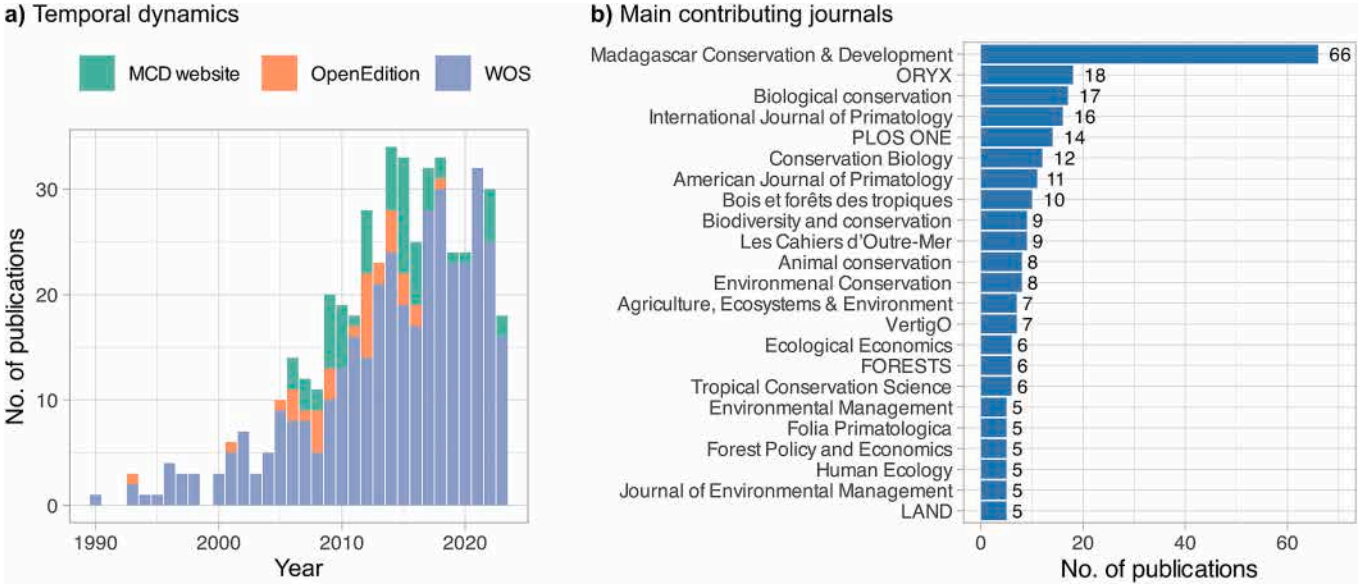

Fig. 2. Evolution in the annual number of publications and main contributing journals to the global corpus. a) Annual number of publications between 1990 and 2023 from the three literature sources used in this study. b) List of the 23 journals contributing most to the corpus (i.e., those with at least five publications).

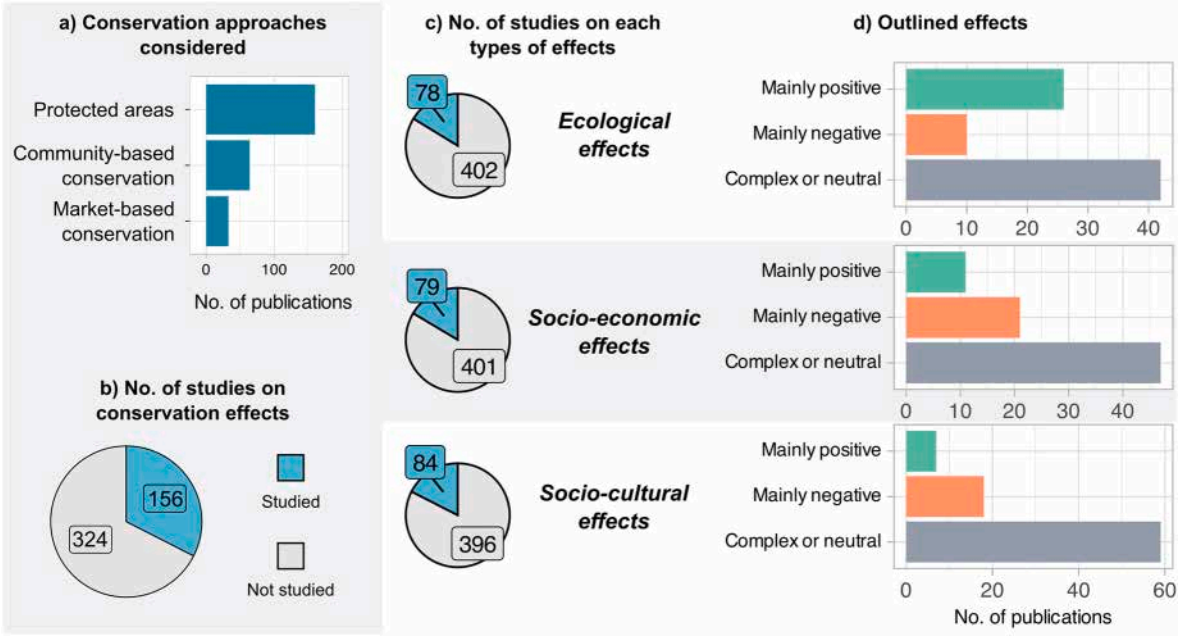

Fig. 3. Synthesis of the abstract-based analysis of the 480 publications in the global corpus. a) Number of studies dealing with one of the three conservation approaches of interest. b) Number of studies with effective assessments of conservation effects. c) Number of studies according to the three types of effects of interest. d) Nature of effects outlined in abstracts.

due to insufficient explicit information or the complexity of the effects (which could not be categorized simply as positive or negative). Nevertheless, the abstract analysis highlighted major trends, indicating predominantly positive effects from an ecological perspective contrasted with predominantly negative effects in socio-economic and socio-cultural dimensions (Fig. 3d). Although this finding warrants cautious interpretation, it was subsequently confirmed through our full text reading of the publications, as detailed in the following sections.

3.2. Conservation effectiveness at reducing deforestation and forest degradation: Unresolved

Out of the 156 publications in the final corpus, the full-text analysis identified 32 publications with results on biodiversity conservation action effects on forest dynamics, in particular deforestation. These studies presented mixed findings regarding the effectiveness of various conservation approaches in reducing deforestation, which highlights that deforestation metrics in Madagascar remain the subject of considerable debate at both the national and local levels.

On one side, several studies highlight that specific conservation actions have successfully reduced deforestation and anthropogenic

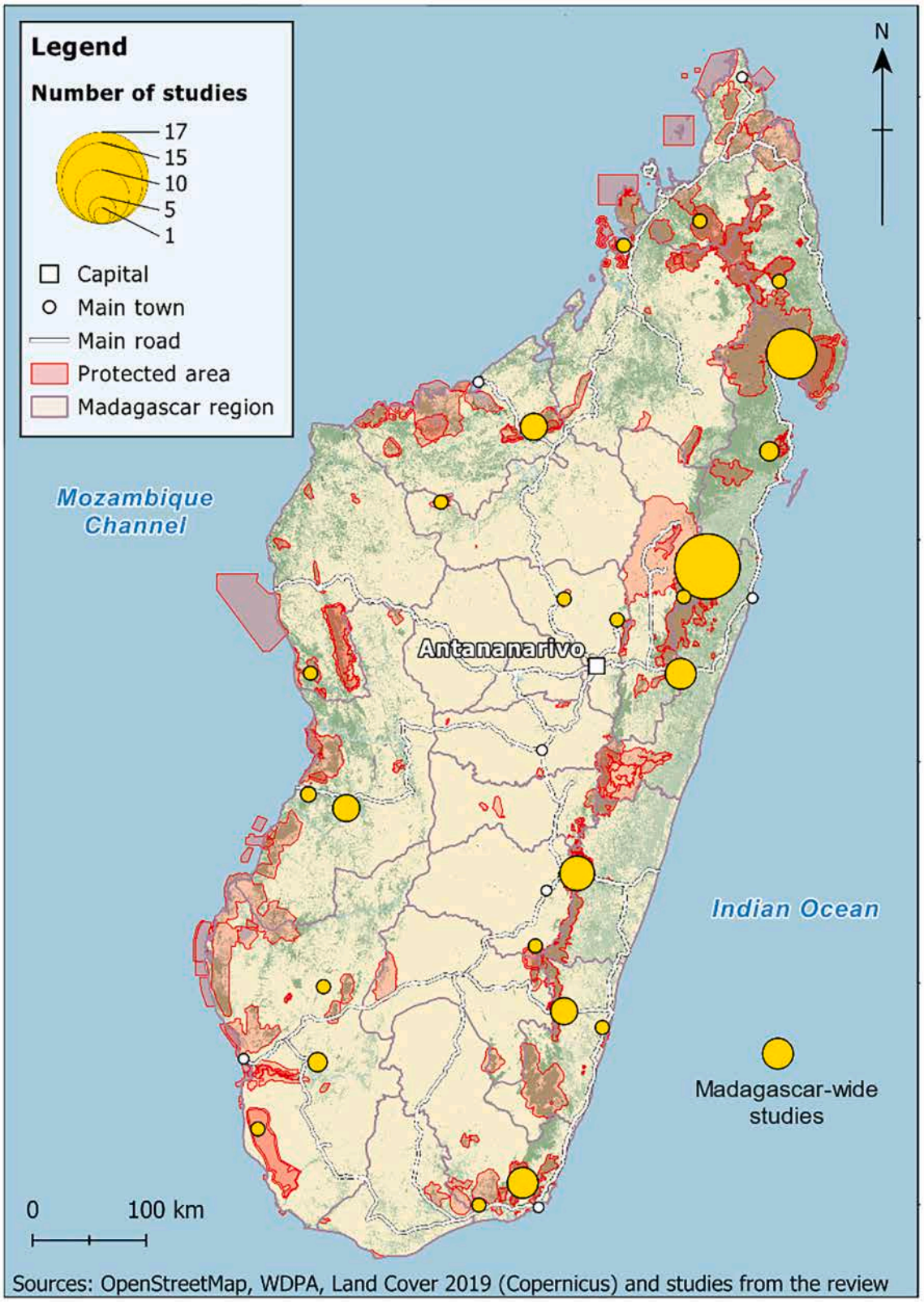

Fig. 4. Locations of study sites from the 156 publications included in the final corpus. Study sites are marked with yellow circles, whose size depends on the number of publications (study sites were clustered within a radius of 80 km). Protected areas are delimited by red polygons. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

pressures on forests (Cota et al., 2021; Desbureaux and Damania, 2018; Dewi et al., 2013; Eklund et al., 2016; Fan et al., 2023; Llopis et al., 2021; Long et al., 2021; Schüßler et al., 2020; Whitehurst et al., 2009). For example, Makira Natural Park experienced a notable slowdown in deforestation between 1990 and 2018 (Schüßler et al., 2020). Similarly, a comparative analysis of land cover maps from 2010 and 2019 revealed an increase in forested areas within the Betampona Reserve (Cota et al., 2021). The authors attributed this positive effect to multiple initiatives implemented within the reserve and its buffer zone, including reforestation programs, invasive species control, agroforestry promotion, reduction of *tavy* (slash-and-burn agriculture), and the distribution of fuel-efficient stoves. These findings align with other studies documenting reductions in forest-damaging activities (Bodonirina et al., 2018; Campera et al., 2019; Tabor et al., 2017).

On the other hand, numerous studies directly challenge or even refute these positive ecological impacts (Allnutt et al., 2013; Ingram and Dawson, 2005; Rafanoharana et al., 2021; Rakotondratsimba and Goodman, 2023; Schuurman and Lowry II, 2009). Allnutt et al. (2013) demonstrated that certain PAs exhibited deforestation rates exceeding the national average. In the Ankeniheny-Zahamena Corridor, deforestation reportedly increased following the temporary establishment of the PA, with annual rates rising from 0.45 % (2001–2005) to 0.51 % (2006–2012) (Brimont et al., 2015). These findings echo studies highlighting the persistent challenges in effectively curtailing forest-degrading human activities, even within PAs (Borgerson et al., 2022; Long et al., 2021; Merson et al., 2019; Rives et al., 2013; Schuurman and Lowry II, 2009). Notably, sectors supplying global markets for precious woods or minerals appear largely unaffected by restrictions on forest exploitation (Bertrand et al., 2014; Schuurman and Lowry II, 2009).

Studies specifically examining community-based conservation and market-based instruments remain scarce, with equally mixed results. The only study quantifying the effects of multiple community-based conservation actions on deforestation concluded there was no systematic impact (Rasolofoson et al., 2015), though certain actions proved effective (Schüßler et al., 2018). While no studies have directly addressed market-based approaches, Tabor et al. (2017) emphasized the critical importance of political stability and sustained investment in combating deforestation, while Seyller et al. (2016) cautioned against the reliability of baseline scenarios used to assess the effectiveness of these actions.

A significant challenge in evaluating conservation impact on deforestation lies in the influence of numerous confounding factors and their rapid evolution over time. Several studies indicated that the effectiveness of deforestation control primarily depends on forest accessibility — less accessible forests experience less vulnerability (Brooks et al., 2009; Allnutt et al., 2013; Eklund et al., 2016). Political stability represents another crucial factor, with pronounced spikes in deforestation observed during major political crises (Rafanoharana et al., 2021; Tabor et al., 2017). Additionally, though few studies have addressed the issue, evidence has emerged of leakage effects, i.e. the displacement of deforestation from PAs to other areas within or outside PA buffer zones (Dewi et al., 2013).

3.3. Conservation effectiveness at protecting biodiversity within forests: well-established

Conservation efforts in Madagascar have demonstrated positive impacts on biodiversity and the ecosystem services provided by preserved forests (Axel and Maurer, 2011; Brown et al., 2009; Campera et al., 2019; Kari and Korhonen-Kurki, 2013; Llopis et al., 2021; Rainio and Niemela, 2006; Randriamady et al., 2021; Ratsirarson et al., 1996; Wasimuddin et al., 2022). This effect was investigated in 16 publications of the final corpus, of which 12 reported a positive direction and four emphasized more nuanced impacts (e.g. Schüßler et al., 2018).

In Ranomafana National Park, for example, sites within the park exhibit higher biodiversity levels compared to areas outside and near villages, with fewer exotic species and a forest structure characterized by larger trees (Brown et al., 2009). Wildlife health improvements have also been documented. In the same park, Bublitz et al. (2015) evidenced that feces of six lemur species contained pathogenic intestinal bacteria of human origin, but only in areas frequented by humans. Similarly, in the Bezà Mahafaly PA, researchers recorded higher lemur abundances in protected forests compared to unprotected ones, highlighting the effectiveness of conservation measures targeting this taxonomic group (Axel and Maurer, 2011). Despite these successes, some studies reported more nuanced outcomes. For example, Schüßler et al. (2018) examined a community-based management transfer in the Analanjirofo region and found that while the intervention effectively preserved forest cover, it did not yield significant improvements in lemur populations.

3.4. Costs are higher than benefits for local residents: Well-established

We identified 30 publications in the final corpus with consistent analysis of the cost-benefit balance of biodiversity conservation actions for local residents. Twenty-three of them reported a negative balance, emphasizing that communities most affected by biodiversity conservation actions bear substantial material costs that remain inadequately compensated (Aubert et al., 2013; Blanc-Pamard and Rakoto Ramiarantsoa, 2008; Brimont et al., 2015, 2017; Brimont and Karsenty, 2015; Casse and Milhøj, 2012; Corson, 2012; Cullman, 2015; Ferraro, 2002; Kari and Korhonen-Kurki, 2013; Llopis et al., 2021; Mackinnon et al., 2018; Marcus, 2001; Marie et al., 2009; McConnell, 2002; Munasinghe, 1993; Neudert et al., 2017; Poudyal et al., 2018b; Racevska et al., 2022; Rakotondratsimba and Goodman, 2023; Rakoto Ramiarantsoa et al., 2014; Samisoa, 2012; Ward et al., 2018).

In proximity to PAs, socio-economic consequences for local populations ranged from mixed (Llopis et al., 2023; Ward et al., 2018) to predominantly negative (Marcus, 2001; Marie et al., 2009). For example, a comparative assessment of communities surrounding Makira and Masoala National Parks documented both positive (improved housing quality, enhanced electricity access, better child education, increase in cash crop value) and negative outcomes for local populations (decline in rice self-sufficiency, decreased water availability and quality, diminished security, reduced village cooperation, and restricted forest access) (Llopis et al., 2023). Similarly, community-based management transfers struggled to generate tangible benefits for populations experiencing access restrictions (Cullman, 2015), while financial support provided through REDD/REDD+ initiatives consistently proved insufficient to offset household-level economic losses (Brimont et al., 2017; Poudyal et al., 2018a).

Regardless of the conservation approach, similar processes and explanatory factors underlie these observed outcomes. On the one hand, local communities incur significant costs through restrictions imposed on agricultural (particularly shifting cultivation) and forestry activities (Kari and Korhonen-Kurki, 2013), as well as constrained land access (occasionally extending to expropriation). The widespread absence of formal land tenure documentation prevents proper compensation for residents affected by conservation policies. On the other hand, although financial compensation mechanisms are theoretically established, they frequently fail to materialize (Peña Valderrama, 2023; Rakotondrabe et al., 2014) or provide remuneration incommensurate with actual losses (Brimont et al., 2017). Poudyal et al. (2018a) quantified that merely 5 % of opportunity costs were compensated adjacent to the Ankeniheny-Zahamena Corridor, with numerous eligible households receiving no compensation whatsoever. These shortcomings stem from insufficient budgetary allocations but can also be attributed to high transaction costs, which constitute 30 to 40 % of the total costs in certain conservation actions (Brimont et al., 2017; Mackinnon et al., 2018). As a result, activities intended to benefit local populations demonstrated no significant influence on household economies (Marcus, 2001), with the most geographically isolated households receiving minimal assistance, primarily due to prohibitive transaction costs associated with reaching

remote villages (Mackinnon et al., 2018).

Beyond these predominant findings, several studies showed that, under specific conditions, populations can derive benefits from conservation actions. For example, research examining a PES water project in the Andapa district of the Antsiranana province demonstrated that abandoning shifting cultivation resulted in increased internal rate of return for participating households and enhanced agricultural income (Rakotondrabe et al., 2014). Similarly, in Mantadia PA, reduced flooding attributable to conservation actions contributed to agricultural surpluses (Kramer et al., 1997). Generally positive perceptions of benefits were documented among participants in a PES initiative in the Menabe region (Sommerville et al., 2010), while fragile but demonstrable advantages were observed in the Fandriana-Vondrozo Corridor (Rakoto Ramiarantsoa et al., 2014).

These findings suggest that initiatives investing sufficient effort and implementing appropriate approaches can generate concrete benefits for households, as shown theoretically through modelling approaches for REDD/REDD+ projects (Neudert et al., 2018; Rakotomahazo et al., 2021). However, as elaborated in Section 3.7, these potential benefits frequently confront pre-existing asymmetries in power distribution and capabilities within local communities.

3.5. Alternative activities contribute to people's well-being: inconclusive

A fundamental strategy employed by conservation actions to redirect populations from forest utilization while generating socio-economic benefits is the development of Income-Generating Activities (IGAs). Yet, evaluations of the socio-economic effectiveness of IGAs in the peer-reviewed literature are scarce: we identified seven publications in the final corpus. More importantly, these few studies present contrasting results, illustrating the considerable variability in implementation contexts and collaboration modes between project leaders and local populations.

Some of these studies have determined that IGAs frequently experience limited adoption rates due to their insufficient relevance to local contexts and incompatibility with specific population constraints. For example, in villages surrounding Andasibe-Mantadia park, McConnell (2002) showed that fundamental misunderstanding of the local agro-ecological and institutional landscape, combined with inadequate consideration of social hierarchies, resulted in the promotion of agricultural techniques incompatible with existing land tenure systems, ultimately leading to their rejection by farmers. Near Ranomafana National Park, novel techniques promoted by NGOs — often generic such as rice-fish farming, new crop varieties, and improved rice cultivation — experienced minimal adoption among farmers, who instead developed their own adaptation strategies in response to conservation measures, including sugarcane cultivation and strategic acquisition of lowland areas (Toillier and Serpantié, 2007).

Conversely, several studies reported more positive outcomes for populations, or at least for part of them (Rakotondrabe et al., 2014; Rakoto Ramiarantsoa et al., 2014; Toillier, 2008). Within communities participating in PES project in the Andapa district of Antsiranana province, households that abandoned shifting cultivation demonstrated increased agricultural income (Rakotondrabe et al., 2014). Additionally, skills development and empowerment processes have been observed among some village members, particularly those involved in local associations or IGA initiatives (Fritz-Vietta et al., 2009; Rakoto Ramiarantsoa et al., 2014; Ward et al., 2018).

3.6. Conservation priorities take precedence over local people interests: Well-established

We identified a total of 28 publications that focused on the gaps and tensions between biodiversity conservation actions and local residents in terms of priorities and visions. The large majority of these studies documented the systematic prioritization of conservation NGO and donor views and interests over those of local populations in Madagascar (Corson, 2012, 2020; Ganomanana, 2011; Long et al., 2021; Marcus, 2001; Razafindrabe, 2015; Waeber et al., 2016).

This phenomenon manifests conspicuously during the PA boundaries establishment. Although consultation with local communities is nominally conducted, the urgency of NGOs and donors to implement conservation measures expeditiously frequently result in hastily delineated boundaries that inadequately accommodate local interests and practices. Engagement with local stakeholders is often reduced to mere awareness campaigns rather than meaningful participatory processes. This procedural shortcoming was notably observed during the establishment of the Ankeniheny-Zahamena and Fandriana-Vondrozo forest corridors (Corson, 2012). Furthermore, international organizations largely determine Madagascar's conservation policy, consistently prioritizing global biodiversity conservation objectives over local territorial development imperatives (Corson, 2020; Long et al., 2021; Razafindrabe, 2015; Waeber et al., 2016). Locally, this results in the systematic exclusion of communities and local authorities from decision-making processes. At the national level, several researchers have identified a progressive weakening of the Malagasy State's influence over environmental policy formulation and implementation, coinciding with the increasing dominance of international institutions and NGOs (Demaze, 2014).

Consequently, while rural populations in Madagascar primarily focus on securing their livelihoods, conservation NGOs and affiliated stakeholders prioritize biodiversity preservation, conceptualized as a global public good rather than a common local resource. This divergence in priorities creates a persistent asymmetry between locally incurred costs and globally accrued benefits (Marcus, 2001; Neudert et al., 2017). It also contributes to negative attitudes of local residents towards biodiversity conservation actions, which are seen as illegitimate and unfair external commands.

3.7. Local elites benefit more from conservation: Well-established

We found a remarkable consensus regarding the tendency of conservation actions to reinforce pre-existing social and economic inequalities within local territories, particularly through the capture of benefits by local elites. Our full-text analysis identified 26 publications containing data on this effect, all of which reaching similar conclusions. The first dimension of this phenomenon relates to distributive injustices — meaning the inequitable distribution of conservation benefits relative to the differential costs borne by various households. As mentioned earlier, the poorest households, typically those most dependent on forest resources, disproportionately bear conservation costs while benefiting the least from compensation measures or IGAs (Brimont et al., 2017, 2015; Brimont and Karsenty, 2015; Poudyal et al., 2016; Sommerville et al., 2010). Conversely, individuals involved in community-based management transfers — generally those already occupying socially or economically privileged positions — derived the greatest the economic advantages from conservation (Long et al., 2021; Poudyal et al., 2016; Rakoto Ramiarantsoa et al., 2014; Sommerville et al., 2010; Ward et al., 2018). The processes underlying these distributive injustices are multifaceted (Poudyal et al., 2016):

- Limited accessibility and geographical remoteness: Rural populations in isolated areas, often representing the poorest and most vulnerable, remain difficult to engage due to prohibitive transaction costs associated with reaching remote communities (Brimont et al., 2017; Mackinnon et al., 2018);
- Incomplete or false declarations: Some individuals deliberately omit reporting involvement in illegal activities (such as charcoal production or unauthorized land clearing) during surveys conducted to identify populations affected by conservation restrictions;
- Reliance on existing institutions: The local implementation of conservation projects often operates through institutions such as

management transfer structures, which tends to reproduce pre-existing social hierarchies and often inadequately represent the broader population (Brimont and Karsenty, 2015; Kraemer, 2012; Rakoto Ramiarantsoa et al., 2014); and
- Lack of adaptive capacity: Poorer households demonstrate limited capacity to adapt to the constraints imposed by conservation initiatives, whereas wealthier households transition more readily to cash crop production or intensive agricultural practices (Rakotondrabe et al., 2014; Rakoto Ramiarantsoa et al., 2014; Toillier, 2008).

The inequitable distribution of conservation costs and benefits partly derives from procedural injustices, characterized by imbalanced and unfair stakeholder participation in decision-making processes, or governance structures of conservation initiatives. Given these phenomena, it is unsurprising that prospective studies (conducted prior to project implementation) frequently highlight local concerns about insufficient transparency in project management (Rakotomahazo et al., 2021). Consequently, numerous studies report increased conflicts and exacerbated power asymmetries following conservation actions. These included interpersonal and inter-village conflicts, as well as tensions within *fokontany* (local administrative units) (Long et al., 2021; Sodikoff, 2009; Thielsen, 2016). For example, in the Ambositra-Vondrozo forest corridor, Blanc-Pamard and Ramiarantsoa (2007) illustrated how dominant lineage groups strategically leverage conservation initiatives to consolidate their territorial control over valuable agricultural areas.

4. Discussion

This literature review, combining a systematic approach with an in-depth analysis of the most relevant publications, provides a comprehensive assessment of the ecological, socio-economic, and socio-cultural effects of conservation approaches implemented in Madagascar over the past three decades. Although focused on a specific country, our findings echo those of numerous studies conducted globally, as discussed below. Thus, beyond identifying the current challenges for biodiversity conservation in Madagascar, this work contributes to understanding the more generic challenges underpinning biodiversity conservation actions worldwide (see Section 4.3).

4.1. The challenge of robust assessments of conservation effects

One of the key insights from this work concerns the difficulty of assessing 30 years of environmental policies and actions in Madagascar based solely on peer-reviewed scientific literature. Out of >1500 references identified through our literature search phase as addressing forest conservation, only 10 % (156 articles) actually provided data-based analysis informing the assessment of ecological, socio-economic, or socio-cultural effects of the three major conservation approaches. Furthermore, we experienced abstracts frequently lacked clarity about whether biodiversity conservation effects were assessed or not, and about the direction of studied effects. While complex effects cannot be easily classified as positive or negative, our observation also originated from how abstracts themselves were structured and written. We therefore suggest that areas of improvement exist in how key results are highlighted in publications abstracts. More concerning, our initial research ambition encompassed the entire Southwest Indian Ocean region, which proved unfeasible do due to insufficient literature beyond Madagascar. Similarly, within Madagascar, research on conservation effects is unevenly distributed geographically, with a predominance of research taking place in humid forests. Most studies were concentrated along major road networks, introducing a bias regarding the populations and areas surveyed. This lack of information on the most isolated forests and their associated communities skewed the general findings on both deforestation and socio-economic impacts. This geographic bias may partially reflect the historical implementation of PAs in Madagascar, which prioritized humid and accessible forests before expanding to dry forests and more remote areas.

The inclusion of gray literature, such as studies and reports from conservation NGOs, and non-indexed literature, such as books, could help address gaps in peer-reviewed scientific studies. However, this would necessitate a dedicated procedure for evaluating the quality of these sources (as outlined in ROSES or PRISMA approaches, e.g., Haddaway et al., 2018), given that the absence of peer review increases the risk that some studies may not meet scientific validity criteria (e.g., unbiased sampling plans, appropriate statistical methods, etc.). For example, the evaluation frameworks developed by conservation actors have sometimes proven inadequate as they insufficiently account for social indicators (Fromont et al., 2024; Knight et al., 2008).

In Madagascar, as elsewhere, monitoring and evaluating conservation actions emerges as a significant deficiency, partly attributable to limited data sharing between international research teams and local conservation stakeholders (Gardner et al., 2013; Pyhälä et al., 2019). Consequently, there is a relative scarcity of long-term monitoring studies in the scientific literature, which are essential for resolving uncertainties about the multifaceted effects of conservation actions. This review also highlighted that the different conservation approaches are not evaluated with the same magnitude, with protected areas being assessed more frequently than community-based or market-based approaches, likely due to the longer history of protected areas. The formation of interdisciplinary research teams in collaboration with conservation practitioners offers a promising avenue for overcoming these methodological challenges (Fromont et al., 2024).

4.2. The limited effectiveness of conservation actions in Madagascar

The results of this literature review, which indicate mixed results of conservation actions from an ecological standpoint and predominantly negative impacts from a socio-economic and socio-cultural perspective, particularly align with similar research findings on Madagascar and elsewhere. For example, our study corroborates Neudert et al. (2017), which showed that conservation actions in Madagascar generated more local costs than benefits. Their analysis relies on the assumption that conservation actions are effective at reducing deforestation and biodiversity decline, which would be at the basis of global benefits despite local costs. Yet, our results on the mixed ecological effectiveness of conservation actions suggest that some of these global benefits may not be achieved. In particular, while we found evidence that conservation actions benefited biodiversity within protected forests, we also showed that the current literature remains too divided to conclude any definitive benefit in terms of deforestation reduction. Further research is required to resolve this question and to be able to produce robust assessments of conservation actions based on their effective costs and benefits. One of the key challenges towards this end being the integration of leakage effects at the national level and beyond.

Our study also supports the findings of Waeber et al. (2016) regarding the difficulty faced by Malagasy authorities, despite continuously expanding PAs, to effectively combat harmful practices that negatively impact forests and their biodiversity. This raises questions about the political commitment of policymakers to genuinely work in favor of forest biodiversity conservation when considering the economic benefits and growth generated through natural resource exploitation, especially when contrasted this with the financial resources invested in conservation actions (Burt et al., 2022). Another identified reason for this mixed result is Madagascar's pervasive corruption across all levels (Waeber et al., 2016), which certainly facilitate the elite capture of benefits documented in numerous studies. By adding some nuance into this assessment, our synthesis demonstrated that protected forests constitute significantly more favorable habitats for diverse animal and plant species compared to unprotected forests. Thus, conservation actions are not in vain, and increased investment would likely help consolidate these ecological benefits.

Finally, when comparing our results to similar evaluations conducted in other regions or at a global scale, the outcomes for Madagascar appear less positive than elsewhere. Studies conducted at broader geographic scales have generally concluded that biodiversity conservation efforts produce overall positive ecological effects (Blanco et al., 2020; Godet and Devictor, 2018; Gray et al., 2016), although exceptions exist. Our results indicate highly context-dependent effects, making it difficult to attribute outcomes directly to conservation actions. Similarly, from a socio-economic perspective, our findings suggest more consistently negative effects than reported in other regions (Blanco et al., 2020). One can reasonably assume that these less favorable results stem from conditions unique to Madagascar, which faces particularly challenging socio-economic circumstances (high food insecurity, rapid population growth, extremely low rural electrification rates, etc.). This situation likely explains the low prioritization of environmental concerns in public and private decision-making processes. An additional explanation may lie in the role of national and local elites, who potentially capture a disproportionate share of benefits generated by development and conservation actions (Razafindrakoto et al., 2017).

4.3. The lack of effective people's engagement in conservation actions

While our study examined three distinct conservation approaches involving varying levels of local people engagement, our conclusions remain consistent regardless of the approach considered. PAs, community-based and market-based conservation all struggle to translate into demonstrable ecological benefits and to generate sufficient economic returns for affected populations. More concerning, our analysis revealed that local residents are not genuinely engaged in the implemented conservation actions and tend to consider them illegitimate.

This observation echoes already expressed concerns regarding the Durban Vision: "*Careful consideration is needed as to whether these new Durban Vision PAs in Madagascar can truly be defined as co-managed when there are certain rules and regulations which local communities and NGOs are not involved in designing. The IUCN governance typology may need greater flexibility in its descriptions of how co-management partners may be involved in PA governance and management*" (Ward et al., 2018, p. 10). Our results certainly demonstrate that, despite evolving discourses, on-ground practices have changed little (Fromont et al., 2024). First and foremost, research on biodiversity conservation issues remains dominated by European and North American authors and collaboration networks, which was also documented in numerous literature reviews (Blanco et al., 2020; Mabele et al., 2023). This unequal structuration of the knowledge coproduction process does certainly not contribute to moving away from ethnocentricity and colonial structures. Second, in a more practical perspective, conservation projects continue to limit 'participation' to mere consultations or awareness-raising activities, often conducted hastily (Carrière-Buchsenschutz, 2006; Marie et al., 2009). These projects then struggle to truly adapt to local realities and expectations, producing what some have called a 'participatory illusion' (Blanc-Pamard and Fauroux, 2004).

This situation can be explained through two primary considerations: one paradigmatic and the other operational. At the paradigmatic level, it is necessary to recognize that community-based and participatory conservation is far from consensual within the global conservation community (Büscher and Fletcher, 2020). Conversely, following the shortcomings of participatory approaches, movements advocating a return to 'fortress conservation' have emerged in recent decades (Hutton et al., 2005). Thus, multiple conservation paradigms currently coexist, which exhibit fundamental disagreements regarding the necessity of involving local populations in conservation actions (Büscher and Fletcher, 2020). These differences in paradigms undoubtedly contributes to heterogeneous practices in conservation implementation and the consideration (or not) of the affected populations' expectations. Since not all conservation practitioners pursue the objective of a genuine involvement of local populations, it seems normal that these are generally not included as co-managers of PAs and other conservation actions.

At the operational level, establishing effective co-management regimes involving local populations is a key challenge for conservation project leaders. First, as observed in numerous studies, establishing such regimes requires time and financial resources (Fromont et al., 2024). Preliminary work necessitates comprehensive stakeholder analysis, including identification of the interests and expectations of all parties, including the most marginalized populations, which demands significant investment in surveys and workshops. Second, based on such analyses, co-designing management plans with stakeholders would obviously take more time than less inclusive processes. Furthermore, supporting such efforts requires expertise in the humanities and social sciences, management sciences, and contextual socio-cultural knowledge that conservation managers may not necessarily possess (Bennett et al., 2017; Gardner et al., 2013). Finally, it is also crucial to have sufficiently flexible operational frameworks to enable substantive adaptation of planned conservation actions (Ward et al., 2018).

4.4. Levers for more just and effective conservation actions

Our literature analysis enabled identification of key challenges for biodiversity conservation in Madagascar and potential strategies to address them (Table 1). This identification derives the publications reviewed for this study, but remains of course subject to our interpretations of the literature. Many identified challenges and strategies are not context-specific and are relevant to biodiversity conservation globally.

First, Table 1 emphasizes key structural constraints for biodiversity conservation that remain largely beyond the influence of conservation practitioners. These constrains are mainly linked to national situations and parallel observations in other countries (Fromont et al., 2024). For example, the political instability threatens the long-term success of conservation and development actions in Madagascar (Ganomanana, 2011; Llopis et al., 2019), while the lack of infrastructures (road, electricity, etc.) leads most projects to concentrate on the same accessible regions (as illustrated in Fig. 4). In addition, centralized governance favors top-down approaches, while resource limitations for local authorities render local enforcement of laws and regulations difficult (Corson, 2012; Rakoto Ramiarantsoa, 2012). These constraints must be acknowledged and accommodated by conservation practitioners, as addressing them surely requires lager and deeper socio-political transformations than what a conservation project could do.

Beyond these structural constraints, we identified key challenges and envisioned solutions for biodiversity conservation (Table 1). The recommendations emerging from this analysis encompass four fundamental needs:

(i) more sustained investment in local conservation actions

Researchers frequently identify a lack of funding and their ephemeral nature impede long-term engagement of local people, who come to realize that the costs they bear are not properly compensated and that their efforts are not sustained over time. Efforts should therefore focus on either reinforcing funding (a strategy Madagascar pursued when developing PES projects) or adjusting conservation ambitions to available funding, for example, by concentrating on smaller areas. Transitioning from short-term projects to embrace long-term approaches should also be considered by funding agencies. Similarly, diversifying conservation funding sources represents a frequently-mentioned challenge in a context where Madagascar's conservation relies primarily on international, North American aid, making it particularly vulnerable to geopolitical changes.

(ii) a real coproduction of conservation strategies and actions

Table 1
Key constraints, challenges and identified strategies for more effective and inclusive conservation actions.

Key constraints to conservation actions in Madagascar (independent from conservation practitioners)	Examples of references
Political instability Lack of infrastructures in rural areas (road, electricity, etc.) Centralized governance Lack of resources in local authorities (communes, fokontany, etc.)	(Corson, 2020; Ganomanana, 2011; Llopis et al., 2019; Long et al., 2021)

Key challenges and strategies for conservation actions			
Challenges and consequences		Envisioned solution	
Insufficient funding	- People losses are not compensated enough - Only a few benefits from conservation	- Reinforcing funding - Diversifying funding sources	(Brimont et al., 2015; Fritz-Vietta et al., 2009)
Short-term approach	- No real long-term change - Low trust between stakeholders	- Implementing long-term fundings - Moving beyond project timescale	(McConnell, 2002; Thielsen, 2016)
Elite capture	- Benefits do not reach the most isolated households - Marginalized people such as migrants are not involved in participatory processes - Politically powerful people capture most benefit	- Reinforcing efforts to reach remote and marginalized populations - Biasing conservation benefits towards disadvantaged households	(Long et al., 2021; Rasolofoson et al., 2017; Ward et al., 2018)
Gap between stakeholders	- Villagers' priorities not addressed - Villagers not aware of conservation boundaries and agenda - Low villager adherence and participation to conservation goals and activities - Gaps between local rules and conservation rules - Actions considered as non-legitimate and neocolonial by villagers	- Reinforcing participation by investing more time and efforts - Making flexible conservation actions - Co-designing conservation activities with concerned people - Co-designing conservation rules with concerned people - Reinforcing local public information campaigns on conservation actions	(Aubert et al., 2013; Campera et al., 2019; Corson, 2012; Ingram and Dawson, 2005; Marie et al., 2009)
Weak local governance	- Local conservation associations (VOIs) are dysfunctional - Poor empowerment and local capabilities	- Reinforcing training on required areas (administrative management, accounting, meeting facilitation, etc.)	(Bodonirina et al., 2018; Cullman, 2015; Fritz-Vietta et al., 2009)
Knowledge gap	- Context-specific dynamics hinder generalizing conclusions - Long-term assessments not available in the scientific literature	- Reinforcing social, economic and environmental monitoring - Reinforcing the interface between conservation researchers and practitioners	(Eklund et al., 2019; Ingram and Dawson, 2005)

Conservation actors willing to engage local populations in biodiversity conservation must demonstrate authentic commitment, moving beyond 'passive participation' approaches to establish genuine co-management frameworks. This would first require more time and investment in workshops with populations to achieve coproduced management plans. In the meantime, this would require more flexible frameworks allowing fine-tuned adjustments of conservation actions to context-specific requirements.

(iii) reinforcing the capacity and legitimacy of local stakeholders to make them uncontested land stewards

A key barrier to genuine co-management regimes is the limited capacity of local populations to handle administrative procedures, collective management and leadership challenges, and to gain recognition as legitimate biodiversity stewards by local authorities. Training and empowering actions appears central to addressing this barrier and reducing asymmetries between local populations and other conservation actors, especially considering that the majority of rural populations in Madagascar have limited literacy skills.

(iv) bridging the gap between researchers, practitioners and stakeholders

Finally, more transdisciplinary approaches involving scholars, conservation managers and other relevant actors are vital to jointly advancing conservation efforts. This effort is not specific to conservation biology but concerns all scholars and practitioners working towards contemporary challenges of the Anthropocene. In this regard, significant theoretical, methodological and ethical advances have been made to foster such a transdisciplinary agenda (Blanco et al., 2025).

5. Conclusion

This systematic literature review provides a comprehensive synthesis of the ecological, socio-economic and socio-cultural effects produced by the various conservation approaches implemented in Madagascar. Although some conservation actions have contributed to biodiversity preservation and deforestation reduction in specific areas, their overall outcomes remain mixed. Moreover, the burden of costs borne by local populations and the absence of tangible benefits for the most vulnerable people raise fundamental questions about the sustainability and legitimacy of the existing conservation actions.

To move towards more equitable and effective conservation approaches, the literature stresses the need to invest substantially in genuinely participatory systems, empower local actors, and promote project co-design with all relevant stakeholders. This would require not only sustained funding and flexible institutional frameworks but also political commitment and concrete dedication to transcend superficial participation and establish genuine co-management regimes. At a time when the global biodiversity crisis is more critical than ever, many lessons learned from Madagascar are likely relevant in other regions worldwide and can contribute to broader reflection on the effectiveness of local population engagement methods into the local-to-global biodiversity conservation agenda.

CRediT authorship contribution statement

Julien Blanco: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Norotiana Rasambo:** Writing – review & editing, Investigation, Data curation. **Clémentine Durand-Bessart:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation.

Josoa R. Randriamalala: Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jérôme Queste:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Nathalie Becker:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Julien Sarron:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Harizoly Razafimandimby:** Writing – review & editing, Investigation, Conceptualization. **Conscient Zafitody:** Writing – review & editing, Investigation, Conceptualization. **Stéphanie M. Carrière:** Writing – review & editing, Investigation, Conceptualization. **Verohanitra M. Rafidison:** Writing – review & editing, Investigation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the content of the published article.

Declaration of competing interest

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Appendix A. Supplementary data

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Data availability

The authors do not have permission to share data.

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