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RESEARCH ARTICLE

The impact of tropical forests on local climate: Comparing recent research with conservation practitioner information priorities

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Abstract

1. The local-scale climate impacts of tropical forests (LCIF), such as reducing temperatures and increasing rainfall, are directly relevant to climate change adaptation and mitigation. Strengthening understanding of these local climate benefits can encourage actions to conserve natural forests, with positive implications for climate resilience, economic development, public health and biodiversity. Non-governmental organisations (NGOs) play a central role in conveying climate research to policymakers and other stakeholders, yet there is limited empirical evidence regarding their knowledge of the local climate impacts of forests, or how this knowledge informs their work.
2. Using the research-integration-utilisation model of scientific knowledge transfer, we compared the knowledge needs of environmental NGOs with recent research on the LCIF, with insights into research integration. A semi-systematic literature review identified 69 publications, mostly multinational studies focussed on tropical South America and Asia.
3. Most publications examine the effects of deforestation, rather than of forest expansion or stable forest cover, on temperature and/or rainfall. Sixteen studies additionally assess outcomes related to biodiversity, human health, economic conditions and agricultural productivity. Knowledge utilisation was evaluated through questionnaire surveys and focus group discussions involving 44 environmental NGOs operating across 24 tropical and subtropical countries. These organisations already engage with research on the local climate impacts of forests, drawing primarily on peer-reviewed literature and academic conferences. Their principal knowledge priorities concern the local influences of forests on rainfall, temperature and biodiversity.

4. We found strong alignment between climate research outputs and NGO knowledge priorities around the effects of forests and deforestation on local temperature and rainfall. In contrast, NGOs' need for evidence on biodiversity, economic, health and agricultural outcomes is only partially addressed. The decision-support tools most valued by NGOs are online, map-based applications offering locally specific information.
5. *Policy implications*: Improved understanding of forests' local climate impacts can enhance the policy relevance of forest conservation, yet NGOs require more detailed, context-specific information to apply this science effectively. Developing decision-support tools that synthesise evidence on the local climate effects of forests, alongside involving NGOs in research, would strengthen local to global efforts to protect tropical forests.

KEYWORDS
decision-support tools, environmental NGOs, implementation science, knowledge transfer, local climate, rainfall, research-integration-utilisation model, tropical forests

1 | INTRODUCTION

Protecting and restoring natural forests are international priorities reflected in the Paris Climate Accords (UNFCCC, 2015), the Convention on Biological Diversity (UNEP, 1992) and the United Nations Sustainable Development Goals (United Nations, 2015). Despite pro-forest policies, net tropical forest loss continues (Chen et al., 2025; Song et al., 2018) contributing to increases in global atmospheric carbon (Baccini et al., 2017). In contrast to the global climate benefits of forests, national and international policies are less concerned with the local climate benefits of forests. However, evidence of the role of tropical forests in moderating local climates is growing, with implications for climate change mitigation and adaptation (Ellison et al., 2017; Lawrence et al., 2022; Lawrence & Vandecar, 2015; Seymour et al., 2022; Smith, Robertson, et al., 2023; Staal et al., 2024). For example, Reddington et al. (2025) show that deforestation over the past two decades has already exposed around 8 million people to local warming of over 2°C. Economic productivity is also affected as deforestation-induced increases in heat exposure reduce the number of safe working hours for outdoor workers (Parsons et al., 2021; Wolff et al., 2021).

The local-scale climate impacts of tropical forests (LCIF) arise largely due to biophysical processes that include evapotranspiration-induced cooling, air turbulence due to the surface roughness of a forest canopy and increased moisture availability from evapotranspiration, increasing rainfall (Lawrence et al., 2022; Smith, Baker, & Spracklen, 2023; Spracklen et al., 2018). The cooling effect of forests is strongest in the tropics (Lawrence et al., 2022). These processes work in tandem with deforestation-induced biogeochemical changes detectable on the global scale, including carbon dioxide and methane release (Anderson-Teixeira et al., 2012).

The protection of climate and other ecosystem services is a motivation for communities to conserve their forests (Isyaku, 2021). The local climate benefits of tropical forests are often recognised by people living within tropical forest landscapes. For example, Wolff et al. (2018) conducted extensive surveys across nearly 500 villages in Kalimantan, Indonesia, and found maintenance of cool local temperatures was the most commonly identified health benefit of forests. People are more likely to act on climate change, including reducing deforestation, when development co-benefits, such as the positive agricultural, economic and health outcomes from the LCIF, are understood (Bain et al., 2016). Similarly, people are more likely to adopt climate change adaptation measures if they have confidence in the adaptive measures available to them (Blennow & Persson, 2009). Therefore, emerging knowledge on the LCIF has relevance for conservation practitioners in tropical forest countries. However, the knowledge priorities and constraints of conservation practitioners are poorly understood. This risks a mis-alignment between research on the LCIF and conservation practitioners' research needs, which can limit research impact (Nago & Krott, 2022), and weaken the evidence base for environment-related decision-making (Cook et al., 2010). In the health sector, implementation science has helped bridge researcher-practitioner gaps. For example, implementation science highlighted that disconnects between clinician research needs and clinical research resulted in billions of dollars in research funding being spent on research unusable by clinicians (Ioannidis, 2016). Since then, implementation science has contributed to increased adoption and implementation of clinical research (Ashcraft et al., 2024). By examining the alignment between research production and the research needs of environmental non-governmental organisations (NGOs), the study aimed to generate greater interest in adapting implementation science to environmental research, including through evidence-based decision-support tools.

NGOs are influential forest conservation practitioners. NGOs can also be influential 'allies of science' in both promoting and implementing evidence-based decision-making (Böcher, 2016) and contributing directly to research and monitoring. However, information priorities for practitioners have received less attention than those of policy-makers (Howarth et al., 2017, 2022). The United Nations defines NGOs as '*any non-profit, voluntary citizens' group which is organized on a local, national or international level*' (United Nations, 2026). Environmental NGOs are a diverse grouping with influence on environmental discourse, management and governance (Partelow et al., 2020). As biodiversity conservation practitioners, NGOs have influenced the expansion and management of protected areas, including 67 Mha of new and expanded protected areas supported by the Critical Ecosystem Partnership Fund and The Nature Conservancy (TNC), since 1951 (CEPF, 2024; TNC, 2024). NGOs also provide training and awareness raising to local communities and can facilitate the flow of climate information to end-users such as small-scale farmers (Gouroubera et al., 2023).

Decision-support tools have been widely used in nature conservation and environmental management (Adem Esmail & Geneletti, 2018; Huang et al., 2011), including for coastal (Barzehkar et al., 2021), wetland (Oliveira et al., 2026), water (Wardropper & Brookfield, 2022) and wildlife (Griesberger et al., 2024) management and restoration. In an ecological context, decision-support tools can help decision-makers to balance outcomes for people and nature in a systematic way using methodologies such as multi-criteria decision analysis (Huang et al., 2011) and scenario analysis (Fajardo et al., 2026). Decision-support tools connect research with practitioner or policy-maker decision-making. Decision-support tools '*aid in structuring and resolving contested problems, while also increasing the transparency of decision-making*' (Walling & Vaneeckhaute, 2020). They range in form and complexity from simple toolkits to artificial intelligence systems. The most effective decision-support tools are those that have been developed with the close participation of their intended users (Ibid). This requires an understanding of user knowledge needs and gaps.

There is a significant gap in our understanding of how emerging science around the LCIF can better support environmental NGOs to conserve tropical forests. While climate researchers have demonstrated that local warming induced by deforestation can exceed warming induced by global-scale climate change (Lawrence et al., 2022), the degree to which this information is known and is being applied is poorly understood. Given that potential negative outcomes of local deforestation-induced warming include increased human mortality (Reddington et al., 2025), hotter and less safe working conditions for agricultural workers (Wolff et al., 2021), and reduced agricultural productivity (Flach et al., 2021; Lawrence & Vandecar, 2015), achieving broader understanding of these dynamics has relevance across multiple sectors.

Using the research-integration-utilisation (RIU) model of scientific knowledge transfer (Böcher, 2016), this paper explores the nonlinear process of research, integration and utilisation of LCIF knowledge by environmental NGOs. In the RIU model, integration is a '*bi-directional step in the process of interaction between practical utilisation and research*', (Böcher, 2016) while utilisation refers to '*the delivery of a finalized utilization product of scientific policy advice and the active use of scientific advice by…citizens*' (Böcher, 2016).

This study addresses the question 'Does current research on LCIF align with the knowledge needs of environmental NGOs operating in tropical regions and, if not, how can research better align with these needs?' The study addresses significant gaps in our understanding of how environmental NGOs engage with research on the LCIF and how such research can be more effectively integrated into practice.

Focussing on the influence of tropical forests on local climate, this study has two objectives. First, it seeks to document the knowledge needs of environmental NGOs and compare these with recent research on the LCIF. By comparing the 'demand' for knowledge with the existing 'supply' from recent publications, the study highlights critical research gaps limiting evidence-based action. Second, the study documents the perspectives of conservation practitioners regarding mechanisms to enhance research integration and utilisation. These insights provide empirically grounded evidence for: climate researchers seeking to enhance the practical relevance of their research; funding bodies seeking to support research that is both policy-relevant and practice-oriented; and environmental NGOs seeking to participate more actively in the co-production and integration of scientific knowledge. The methodological approach is applicable to other disciplines and contributes to the development of environment-related implementation science by deepening understanding of the processes through which scientific evidence is translated into effective practice.

2 | MATERIALS AND METHODS

This study applies the RIU model to explore the transfer of knowledge on the LCIF from research to practice (Böcher, 2016). Connecting with environmental science, the RIU model has been used variously to assess research-to-practice dynamics in biodiversity conservation and protected area management (Do et al., 2017, 2018; Krott & Zavodja, 2023). The RIU model provides one approach to examine the under-use of science in practice, the 'knowledge-action' gap (Räsänen et al., 2024). Although knowledge transfer and implementation science related to environmental issues are an emerging research area, implementation science has been widely applied in the health sector (Chambers & Emmons, 2024; Huntington et al., 2024) and, to a lesser extent, in the agricultural sector (Gagnon et al., 2015).

The study uses a semi-systematic literature review to characterise recent research and a questionnaire survey to identify the knowledge needs and evidence-utilisation behaviours of conservation practitioners. Integration barriers and opportunities, and research-utilisation preferences were discussed in focus groups. The study's methods are summarised in Figure 1.

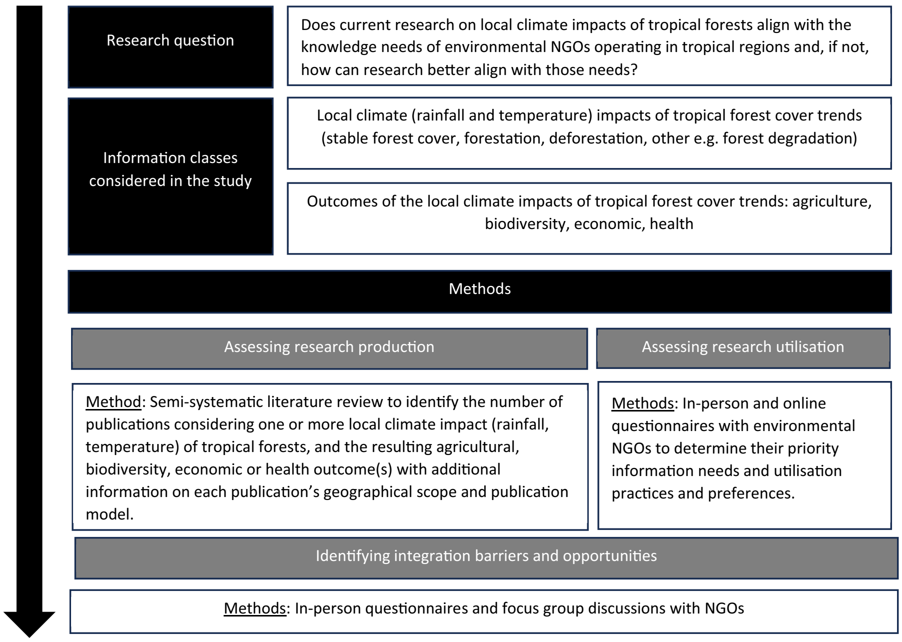

FIGURE 1 Overview of the research question and methodology used in the study.

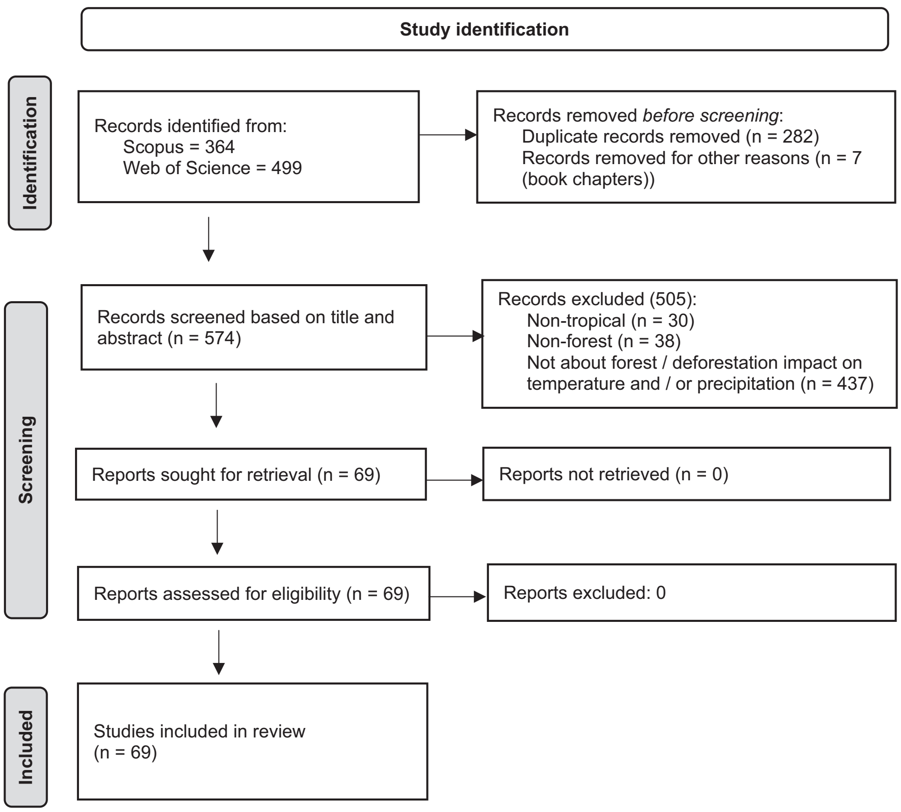

FIGURE 2 Summary of the process used to select publications on the local-scale climate impacts of tropical forests for inclusion in the literature review, including the number of studies included or excluded at each step of the study identification process. Diagram based on Page, McKenzie et al. (2021).

2.1 | Literature review

A semi-systematic literature review was conducted to characterise recent research related to LCIF (Figure 2). Semi-systematic literature reviews involve a systematic element and a qualitative or narrative element (Snyder, 2019). They are well-suited to research efforts, such as this study, that require systematic assessment of trends and the identification of knowledge gaps. They contrast with systematic literature reviews that synthesise knowledge from multiple studies, often used in medical research (Page, McKenzie, et al., 2021). In this study, the qualitative element is the thematic analysis of the eligible publications and discussion of knowledge gaps. For transparency and replicability, the study follows the guidance of the 2020 Preferred Reporting Items for Systematic Review and Meta-Analysis Statement specifying information sources, eligibility criteria, search strategy, selection process, data collection processes and data items (Page, Moher, et al., 2021). Since the purpose of the study was to characterise recent research rather than synthesise the empirical results reported in the literature, methodological steps essential to a fully systematic review, including risk-of-bias assessment and extraction of effect measures, were not conducted.

2.1.1 | Information sources

The study considers articles in scientific journals and conference proceedings. Book chapters are excluded as so few academic books are freely available online, only 5% according to one study (Taylor, 2020). Therefore, it is assumed that new knowledge published in academic books is unlikely to be available to NGOs in tropical countries, the knowledge users central to this study. Grey literature was included to the extent that it was included in Scopus or Web of Science Core Collection. Grey literature includes conference proceedings and technical reports produced by organisations such as NGOs, not by publishing companies (Corlett, 2011). Eligible publication dates should be 'recent', defined as 01/01/2019 to 31/12/2023, the 5-year period preceding the start of the review. No limit was set on the temporal scope of a study since the objective is to characterise recent research developments, not to evaluate recent trends in forest–climate interactions.

2.1.2 | Eligibility criteria

In deciding which studies to review, the study adopted eligibility criteria related to the scope, climate impact and outcome considered in a publication as described below and summarised in Figure 2.

Scope: the grouping of interest, in this case, are publications on tropical forests. For inclusion, a publication needed to meet two initial criteria related to the focus of the study:

(i) Geographically, studies must include tropical areas. This reflects the study's focus on tropical forests. Publications that also covered other geographical zones, such as global studies, are included.
(ii) Publications must focus on forests, defined as, '*land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use*' (FAO, 2018). This definition includes dry forests.

Forest cover trend: Publications must specify whether they are assessing the impact on local climate of a stable forest cover, deforestation, degradation and/or forestation scenario.

Climate impact: the study should describe the impact(s) of forest/forest cover change on precipitation and/or on temperature. This could include the impact of forests on processes that affect precipitation and temperature, such as changes in atmospheric chemistry, so long as the implications for temperature or rainfall are considered. Papers solely considering fire impacts, evapotranspiration and/or the carbon cycle, for example Pillai et al. (2019) were excluded. Papers considering only the impact of changes in precipitation or temperature on forests were also excluded, for example Arenas-Wong et al. (2023).

2.1.3 | Search strategy

The study used two databases of scientific publications: Scopus and the Web of Science Core Collection. The following search terms were used:

Scopus

TITLE-ABS-KEY (("tropical") AND ("forest" OR "deforestation") AND ("precipitation" OR "temperature") AND ("local")) AND PUBYEAR >2018 AND PUBYEAR <2024 AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA, "EART") OR LIMIT-TO (SUBJAREA, "MULT"))

Web of Science Core Collection

ALL= (("tropical") AND ("forest" OR "deforestation") AND ("precipitation" OR "temperature") AND ("local"))
PUBLICATION DATE=01/01/2019 to 31/12/2023

2.1.4 | Selection process

As a first step, duplicates (publications listed twice having been identified by both Scopus and the Web of Science Core Collection) were removed. The titles and abstracts of 574 publications were then screened according to the eligibility criteria. Eligibility was independently assessed by two reviewers. Where there was a difference between the two reviewers, as occurred for 34 of the 574 publications, the reviewers discussed each to reach consensus. This resulted in 13 publications changing status (10 shifted from being excluded to being included; 3 shifted from being included to being excluded). None of the publications was authored or coauthored by either of the two reviewers. To assess the degree to which the exclusion of book chapters could have biased the results, the number of eligible book chapters was calculated. While seven book chapters were identified during the preliminary stage of the literature review, of which five were behind paywalls, none of the chapters met the eligibility criteria for inclusion in the detailed review.

2.1.5 | Data collection process

For all eligible publications, the full text was reviewed by one reviewer. The data were recorded systematically in Excel for each of the data items described below. The dataset is publicly available (Doggart et al., 2026).

2.1.6 | Data items

Data were collected on the geographic scope and scale of the study, the forest cover trend(s), climate impact (precipitation and/or temperature), and outcome (agriculture, biodiversity, economy, health or other) (Table 1). Outcomes refer to the environmental, social and economic results of the forest cover trend-induced climate impacts. For example, it could include the impact on human health from increased local temperatures caused by deforestation. These data were collected because of their relevance to NGOs and their work on environmental and livelihood issues. As it was anticipated that publication paywalls could prove a barrier for NGOs to access research, the publishing model (open access (gold/green or bronze), hybrid or not open access) for each publication was documented. To assess the participation of environmental NGOs in the research, data were collected on any authors who listed their institutional affiliation as an NGO.

TABLE 1 Data items collected for each publication included in the literature review.

Type of information	Classes
Geographical scope The broad location for the study area.	Global Pan-tropical Africa Asia and the Indo-Pacific South America Central America and the Caribbean
Scale	Multi-national National Sub-national
Intervention The forest-related dynamic considered by the study. One or more interventions could be selected.	Stable forest Deforestation Forestation Other
Climate impact The climate impact considered by the study as a response to the intervention(s). One or more impacts could be selected.	Precipitation Temperature Other
Outcome The implications of the climate impact triggered by the forest/forest change-related intervention. Zero, one or more outcome could be selected.	Agriculture Biodiversity Economy Health Other Number of considered outcomes
Publication model	Gold Green Bronze only Not open access Hybrid
NGO affiliation of any author or co-author	Author affiliations include an environmental NGO. Yes/No

2.2 | Questionnaires and focus group discussions

NGO LCIF knowledge utilisation practices and priorities, and integration barriers and opportunities were identified through questionnaires and Focus Group Discussions (FGDs) (Figure 1).

The research involved NGOs who attended the World Land Trust (WLT) Partner Symposium in July 2023. WLT is a UK-based NGO with the mission of '*helping people across the world protect and restore their land to safeguard biodiversity and the climate*'. WLT works with a network of local NGO conservation partners located primarily in the Global South. All participating NGOs are involved in land-based conservation initiatives, including establishing new protected areas and private conservancies. Most work in tropical forests ranging from rainforests to semi-arid dry forests such as the Gran Chaco biome in South America.

Focussing on knowledge around LCIF, two questionnaires were administered followed by FGDs. The first questionnaire was administered online using Google Forms to all participants prior to the symposium. The survey included questions on current knowledge, perceived relevance to the work of their NGO and potential uses. During the symposium, one author (DVS) gave a 15-min presentation on key findings from recent research, including how deforestation can cause local and regional warming of 1°C–2°C and 3°C respectively with 8%–10% reductions in rainfall (Butt et al., 2023; Smith, Baker, & Spracklen, 2023; Smith, Robertson, et al., 2023). The mechanisms by which tropical forests impact local temperature and rainfall were explained in simple terms with examples of potential outcomes (crop failure, heat stress, wildfires).

A second questionnaire survey was administered in person to all participants during the symposium (Supporting Information S2). The questionnaire included questions on respondents' sources of climate science, and associated challenges; knowledge level and, potential and actual knowledge uses; priority knowledge classes (e.g. impacts of forests/deforestation on temperature or rainfall, or on health, economic, biodiversity or agricultural outcomes) and geographical scale. The questions also covered the preferred ways to access scientific information. For these questions, common examples of sources of scientific information were included in the ranking with a follow-up question to record other preferred information sources.

FIGURE 3 Location of the areas of operation for the World Land Trust partner NGOs represented in this study.

Descriptions of the different options were provided verbally during the introduction to the questionnaires. Translation support was provided for participants who were not fluent in English. Some questions were open-ended, while six questions required respondents to rank options in order of priority or relevance. In these ranking exercises, some participants gave equal ranking to two or more choices, rather than giving a unique ranking to each choice. For example, they ranked all choices A, B and C as 'most relevant' instead of indicating a relevance hierarchy, as intended. Similarly, some respondents excluded some options from their rankings. To resolve this and ensure that each participant's rankings contributed equally to calculating the mean rankings (see Figures 5–7), unranked options were allocated a zero score, and the scores were adjusted, using ordinary least squares so that the sum of the scores of each participant was equal while retaining their choice ranking (see Doggart et al. (2026) for details). Average scores were calculated from these values. Other questions asked participants to provide additional information, such as ways in which they could use information on the LCIF beyond the options included in the ranking exercise. During data analysis, responses to the open-ended questions were thematically grouped to present the results. The consent of the participants was sought and granted by all respondents.

Thirty-eight senior officials from NGOs operating in 21 tropical and sub-tropical countries completed the online questionnaire, while 51 senior officials representing 44 environmental NGOs operating in 24 tropical and sub-tropical countries completed the in-person questionnaire (Figure 3). Cumulatively, the NGOs contribute to the conservation of more than 1 million hectares of forest and other ecosystems. All respondents who completed the online survey also completed the in-person questionnaire.

FGDs are a qualitative social science method appropriate for exploring issues, such as research–integration–utilisation dynamics, in greater depth (Gill et al., 2008). Through FGDs involving 51 people, four topics were explored in greater depth: (i) experiences of forest-climate benefits; (ii) conservation—science linkages; (iii) different ways to frame forest-climate benefits; and (iv) design recommendations for a decision-support tool on forest-climate benefits, with key points documented on flip charts. The topics were selected first to add depth to the results of the questionnaires (topic i); second to explore issues relevant to research integration (topics ii and iii); and finally, to inform the design of a planned decision-support tool (topic iv). Participants were divided into three roughly equal-sized groups, one each for NGOs from Central America, South America, and Africa and Asia. Due to time limitations, two groups only addressed three of the four topics, skipping topics (i) or (iv). Key points were recorded on flip charts, and illustrative quotes were documented by facilitators. The number of participants supporting or opposing specific points was not recorded, as the discussions were intended to complement and contextualise the quantitative questionnaire findings.

Ethics approval for the research was granted by the Faculty Research Ethics Committee for Business, Environment, Social Sciences at the University of Leeds, UK. Reference 2266. All participants in the questionnaires and FGDs gave their written consent.

3 | RESULTS AND DISCUSSION

3.1 | Research production and NGO knowledge on the local-scale climate impacts of tropical forests: An overview

Overall, the study shows that a growing body of research on the LCIF is being produced, and that at least some of this knowledge is filtering through to environmental NGOs who are using it in their work. Sixty-nine recent publications on the LCIF were identified through the literature review (Doggart et al., 2026). Most are multi-national studies; they consider the impact of deforestation on temperature; and are focussed on South America and Asia (Table 2). The transfer of this scientific knowledge to NGOs is ongoing, as evidenced by the questionnaire results in which participants self-assessed their current knowledge on the LCIF and utilisation of LCIF research. Most respondents indicated a moderate level of knowledge, with 47% (online, $N=38$; in-person, $N=51$) of respondents on both

TABLE 2 Results of the literature review including number of publications in each data class (geographical scope, scale, forest cover trend, climate impact, outcome).

Geographical scope	Number (percentage) of publications Global	Pan-tropical	Africa	Asia and the Indo-Pacific	South America	Central America and the Caribbean	Total	% of publications
Total	11 (16%)	8 (12%)	4 (6%)	20 (29%)	26 (38%)	4 (6%)	69	100%
Scale								
Multi-national	11	8	3	8	11	1	38	55%
National	N/A	N/A	0	0	0	0	0	0%
Sub-national	N/A	N/A	1	12	15	3	31	45%
Forest cover trend assessed								
Stable forest	4	3	1	1	4	2	14	20%
Deforestation	7	6	1	17	20	2	50	74%
Forestation	3	0	2	2	1	0	7	10%
Climate impact assessed								
Rainfall	3	4	3	9	15	1	34	49%
Temperature	9	5	3	16	18	4	51	74%
Outcome assessed								
Health	0	2	0	4	1	0	7	10%
Economy	0	1	0	1	1	0	3	4%
Biodiversity	0	1	0	1	4	2	8	12%
Agriculture	0	1	1	0	2	0	3	4%

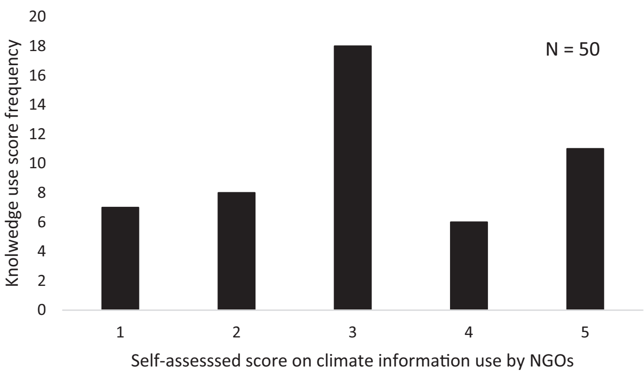

FIGURE 4 Scoring by environmental conservation practitioners on the extent to which they agree with the statement 'My NGO already considers local climate impacts of forests in our work' where 1 = disagrees and 5 = strongly agrees (N = 50).
Source: Results of the study's in-person questionnaire.

questionnaires scoring 3 out of 5, where 5 = a lot of knowledge and 1 = very little knowledge. 16% (online, N = 38) and 22% (in-person, N = 51) of respondents considered that they had little knowledge (scores of 1 or 2), while 8% (online, N = 38) and 6% (in-person, N = 51) of respondents considered that they had a lot of knowledge. Although recent LCIF research was presented to participants between completing the online and in-person questionnaires, the similarities in the online and in-person questionnaire responses suggest that this did not significantly impact their self-assessed knowledge.

Most respondents (70%, N = 50) indicated that they already consider LCIF in their work, to some extent (scores of 3–5) (Figure 4), and 90% (N = 51) stated that information on forest-climate benefits would be helpful to their NGO (scores of 4–5 on a scale from 1 = not useful to 5 = very useful). Excluding respondents who self-assessed as having little knowledge of the subject made no difference to the percentage of respondents who considered the research useful for their work (90%, N = 51 for all respondents, compared to 90%, N = 40 only including those scoring highly (scores of 3–5) on the knowledge self-assessment). Unless stated otherwise, N = 38 for online surveys and N = 51 for in-person surveys. Some respondents did not respond to some questions on the in-person questionnaire; hence differences in the reported sample size. See Doggart et al. (2026) for the full results of the questionnaires and FGDs.

3.2 | Research integration: Assessing alignment between recent research on the local-scale climate impacts of tropical forests and NGO knowledge priorities

Integration occurs when NGOs draw on scientific research, while researchers pursue questions relevant to NGOs. This creates a dynamic interplay between the producers and users of scientific knowledge (Böcher, 2016). This section examines the alignment between recent research and NGOs' priority knowledge needs on the LCIF across five areas: geographical scope, forest-cover trend, climate impact, environmental and livelihood-related outcomes and scale.

3.2.1 | Geographical scope

The participating NGOs included NGOs from across the tropics including NGOs operating in Africa and Madagascar (25%), Asia (14%), Latin America (59%) and globally (2%). Similarly, the literature review reported publications from across the tropics (Table 2). However, both Africa and Central America and the Caribbean are significantly under studied, with just four publications each. For Africa, this may reflect the scarcity of meteorological stations across the continent (except South Africa), limiting the availability of observational datasets (Faniriantsoa & Dinku, 2022; Zhan et al., 2023), a general scarcity of research in tropical dry forests, as are common in sub-Saharan Africa (Siyum, 2020), and a relative lack of research on the Congo Basin compared to other tropical forest regions (White et al., 2021). Historically, African deforestation has been comparatively under-researched relative to other tropical regions (Deikumah et al., 2014; Masolele et al., 2024). In contrast, the focus on South America largely reflects research interest in the Amazon (15 [58%] out of 26 publications on South America), assisted by Brazil's well-developed meteorological monitoring network facilitating high-impact climate research (Zhan et al., 2023).

3.2.2 | Forest-cover trends

Framing reflects the way in which an issue is approached and presented in research. The efficacy of different framings for climate research varies between research-users operating in different socio-political contexts (Badullovich et al., 2020). This study shows that most research uses a 'deforestation' framing, while many NGOs prefer a 'stable forest cover' framing.

The literature review demonstrated a strong emphasis on deforestation, with 74% ($N=69$) of studies adopting this framing, compared with only 14% and 9% addressing stable forest cover and/or forestation, respectively. That researchers more often consider deforestation than stable cover likely reflects researchers' response to global concern around the impacts of deforestation, particularly tropical deforestation, and the relative ease of modelling deforestation to detect climate feedbacks, compared with modelling no- or incremental forest cover changes (Lawrence et al., 2022). te Wierik et al. (2021) also noted a significant gap in research on how reforestation affects local climate, particularly rainfall. They highlight the methodological and conceptual challenges posed by the multi-scale trade-offs underlying these processes.

A greater proportion of survey respondents (51%, $N=51$) preferred local climate impacts to be presented using a 'stable forest cover' framing. Reasons included: the importance of hope, particularly from positive, local, solutions-oriented stories and messages. In the FGDs, reasons for preferring messages on the benefits of forests were elaborated with statements such as: '*People are overwhelmed → solutions are needed*'. The framing of recognising the benefits of maintaining tropical forest cover aligns with more recent policy mechanisms such as the Tropical Forest Forever Facility and the High Integrity Forest Investment Initiative (HIFOR). Participants also mentioned that, often, people do not respond well to negative messaging. This is consistent with research indicating that positive environmental messaging can empower audiences and promote behaviour change, so long as the influence of cognitive biases is managed. Cognitive biases, understood as '*systematic patterns of deviation from rationality in judgment*', encompass tendencies such as spatial and temporal discounting (De Vries, 2020).

While less common, 45% ($N=51$) of respondents considered that it is most useful to frame messaging around the risks of deforestation to local climate, aligning with research demonstrating that high-threat messages trigger a greater sense of collective efficacy while more hopeful messages can lower motivation to act (Hornsey & Fielding, 2020). The variation in respondents' views reflects the broader literature, in which studies differ on whether positive or negative framings are more effective in influencing attitudes and behaviour (De Vries, 2020).

3.2.3 | Climate impact

In assessing the integration of research on the LCIF, two climate variables were considered: rainfall and temperature. The study identified a degree of misalignment between the research, which predominantly examines temperature effects, and the expressed priorities of NGOs, which place greater emphasis on rainfall-related research. This misalignment is illustrated in Figure 5, which compares the number of publications with NGOs' average relevance scores across each class of climate impact and outcome.

The literature review recorded significantly more research on temperature (74% of publications) than rainfall (49% of publications), although 16 (23%) publications consider both (Figure 5). This may reflect the greater complexity of the relationship between local rainfall and forest cover including issues relating to scale, tipping points and nonlinearity (Smith, Baker, & Spracklen, 2023), contrasting with the more consistent relationship between forest cover and local temperature (Reddington et al., 2025). In contrast, NGOs gave a higher relevance score (mean rank $=4.5/6$, $N=51$) to rainfall than temperature (mean rank $=3.8/6$, $N=51$) (Figure 5). The importance of rainfall was reinforced during the FGDs with comments including: '*water is a universal concern*' and '*forest is seen as the protector of water sources*'.

3.2.4 | Environmental and livelihood-related outcomes

The study considered four 'outcomes' affected by the LCIF: agriculture, biodiversity, economic development and health. Only 16 (23%) publications considered these outcomes of forest-climate dynamics, including biodiversity (12%), health (10%), economy (4%) and agriculture (4%). Although there is a plethora of research on a

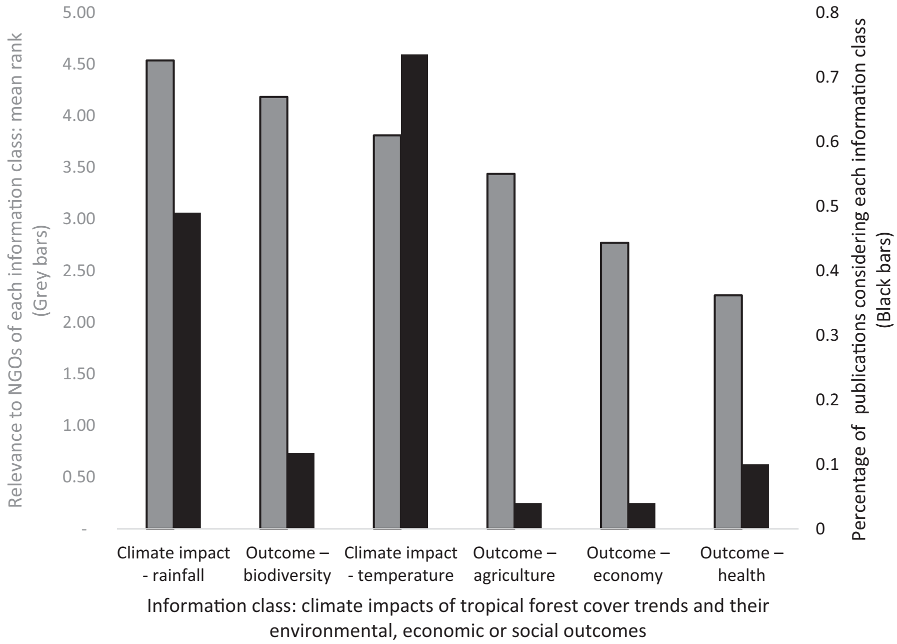

FIGURE 5 Conservation practitioners' mean relevance ranking ($N=51$, grey/left-hand y axis) for each information class compared with the percentage of publications ($N=68$, black/right-hand y axis) considering each information class. The information classes include two climate impacts of forest cover trends: Rainfall and temperature; and four environmental, economic and social outcomes of those climate impacts: Agriculture, biodiversity, economy and health. The relevance ranking ranges from 5 = most relevant to 1 = least relevant.

global scale on the impacts of deforestation and climate change on health (Baker et al., 2022), economy (Byrne & Vitenu-Sackey, 2024) and agriculture (Challinor et al., 2014; Malhi et al., 2021), local impacts of deforestation-induced climate change have received less research attention, a finding also noted by Lawrence et al. (2022).

When ranking the relevance of research on these four outcomes to their NGO's work, respondents prioritised biodiversity and agricultural outcomes over economic ones, consistently placing health outcomes as least relevant (Figure 5). Biodiversity outcomes were of greater interest than even temperature-related impacts. The higher relevance ranking given to biodiversity likely stems from the participants' professional backgrounds; as employees of nature conservation NGOs, their work is inherently centred on biodiversity issues. In contrast, the focus groups elaborated on the low relevance score given to research on health-related outcomes of forest–climate dynamics. Participants explained that poverty is often so extreme, and healthcare is so poor that there is already an expectation of poor health in many of the communities where they work. Instead, research relevant to the basic needs of food, water and agriculture is considered to be more relevant.

In the surveys and FGDs, respondents also identified additional outcomes of interest, including changes in water supply and impacts of deforestation on local wind, extreme weather events and wildfires, with the latter two outcomes being mentioned by 8% and 4% of in-person questionnaire respondents respectively. Although the literature review revealed that each of these additional outcomes had been addressed by at least one publication, the findings nonetheless indicate broader and additional NGO research priorities.

Taken together, the results highlight a significant misalignment between NGO priorities and the current research landscape. Despite NGO interest in the biodiversity, agricultural and economic outcomes of LCIF, these areas remain only partially integrated into ongoing research.

3.2.5 | Scale

Scale is a complex and contested concept in environmental science (Padt & Arts, 2014) with frequent mis-matches between the scale of environmental processes, management and policy (Brumberg, 2025; Falco et al., 2022). While the study was focussed on 'local' climate impacts, most publications (55%) had a multi-national scope (Table 2). This means that the publications were looking at 'local' forest-climate dynamics while drawing conclusions relevant at a multi-national scale. The other 45% of papers described research conducted at a sub-national scale. Between papers, the definition of 'local' varied, ranging from 5 km (Prevedello et al., 2019) to 200 km (Smith, Baker, & Spracklen, 2023). This spread reflects the scale of the principal biophysical mechanisms linking forest cover to local climate including albedo, evapotranspiration and turbulence (Lawrence et al., 2022). Beyond this range, biogeochemical processes become the dominant drivers of forest-related climate effects.

When asked about the spatial scale most relevant for information on forest–climate benefits, questionnaire respondents expressed a clear preference for subnational and local data with average scores of 2.35 and 2.23 ($N=51$) respectively (on a 0–3 scale where 1 = least relevant, 3 = most relevant). These compare with a low relevance ranking (1.42) for national-level information (see Doggart et al. (2026)). This preference for subnational and local scale information likely reflects the operational scale of the respondents' NGOs, all of which manage subnational, land-based conservation projects. As one FGD participant noted, '*the community/landscape scale is the most important*', while another added that '*local data is needed for local activity*'. Local framing was described as offering more hope, as people feel they can actively contribute to change at that level. Two groups emphasised that spatial scale mattered more to them than the choice between positive framing (highlighting forest benefits) and negative framing (highlighting deforestation risks).

This scarcity of local, and even national, data were the most frequently cited challenge in accessing climate science: 25% ($N = 51$) of respondents identified it as their main challenge. Furthermore, 60% ($N = 50$) disagreed with the statement '*I have access to information on local climate impacts of forests for the area where my NGO operates*', while only 4% ($N = 50$) strongly agreed. FGD participants further emphasised persistent mismatches between the geographical scale of scientific research and their practical information needs. Within climate research, as in other research, global or multi-country studies may attract more citations than local or national studies (Aksnes et al., 2019), thereby incentivising global or pantropical studies, supported by the growing accessibility of global climate models and remote sensing data, over studies conducted at local scales.

This mismatch is counter-intuitive given the alignment between the scale of the biophysical processes that underpin the local climate impacts of forests (<1–200 km) and the scale of most participating NGOs' projects, which extend in area up to approximately 500 km^2. Nonetheless, striking a balance between researcher and practitioner priorities around scale to produce research usable at the scale of NGO projects would enhance research integration.

Relatedly, FGD participants also highlighted challenges in determining the applicability of research findings across different locations and scales. Uncertainty about where and under what conditions results remain valid can lead to misinterpretation or dismissal of research. This need for contextualisation mirrors a well-documented barrier in public health implementation research (Ramani-Chander et al., 2024). Clearer guidance from scientists on how their findings can inform decision-making beyond the immediate study area or at different scales would considerably enhance usability.

Participants also discussed the temporal scale of information needs. Practitioners require real-time data and short to medium-term projections, such as advice for farmers on planting schedules. Although research has increasingly quantified the local climate impacts of forests with high accuracy, these effects unfold within broader weather and climate variability that operates over days, weeks and months, timescales directly relevant to NGO planning. FGD insights suggest that providing local-scale and near real-time information may help mitigate risks of inaction driven by cognitive discounting of non-immediate information.

3.3 | Integration

3.3.1 | Research co-production

Integration comprises the '*interaction between scientific research and utilization in politics and practice*' (Böcher, 2016). Research co-production represents a key pathway for achieving Böcher's concept of 'integration' as it brings together diverse knowledge systems to generate new and contextually grounded understanding (Nehring et al., 2025). In the health sector, research co-production, including partnerships between researchers and private-sector actors, is recognised as an effective mechanism for knowledge transfer and has been associated with improved public health outcomes (Cope et al., 2025). Across sectors, co-production approaches involving NGOs can be particularly effective in generating actionable, community-focused solutions and enhancing real-world research impact (Bravo & Elliott, 2025). Research co-production has also been shown to strengthen NGO advocacy and awareness raising efforts, as well as improve the overall quality of research (Ziervogel et al., 2022).

To evaluate the extent of research integration occurring through co-production, we calculated the proportion of publications with at least one NGO-affiliated author. Only 6% of papers met this criterion. The six NGO-affiliated authors, contributing to four of the 69 papers, were all affiliated with TNC, a large international environmental NGO based in the United States. These results indicate that environmental NGO participation in climate research is relatively uncommon, representing a likely barrier to research integration, with opportunities to learn from TNC. Among the NGOs participating in this study, there was strong interest in deeper engagement with research. Notably, 74% of participants expressed interest in contributing to the development of a toolkit on the LCIF. This interest in co-producing research on forest-climate benefits echoes findings in other areas of climate science (Howarth et al., 2022). These findings suggest that NGOs exhibit a substantial, yet largely unrealised, willingness to engage actively in research on the LCIF, and that research co-production may offer an effective strategy for strengthening research integration.

3.3.2 | Barriers to integration

NGOs' access to LCIF research is a fundamental prerequisite for effective integration. However, most participants (67%, $N = 51$) reported encountering barriers when trying to access climate science, and only 10% indicated that they experienced no challenges. Barriers discussed in the FGDs included: limited funding for NGOs to support or engage in research; misalignment between academic and practitioner research priorities where publications were perceived to be researchers' priority while practitioners wanted practical information to support planning and decision-making; a disconnect between researchers' emphasis on global or multinational analyses and the local-scale information most valued by conservation practitioners; and paywalls restricting access to scientific publications. Differences in epistemologies between academia and traditional

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knowledge were also cited as a barrier to integration including the exclusion of local people from data collection. '*Some climate data is local knowledge. It is not only about academic knowledge. Local people can also collect data*'. Practitioners also mentioned the value of partnerships. '*We can't be good at everything. We need to link with universities*'. Other challenges mentioned by respondents to the in-person questionnaires include: interpretation of data (15%) and identifying reliable data sources (13%). Relatedly, FGD participants described difficulties in distinguishing the effects of global climate change from deforestation-driven local climate impacts, highlighting the complexity of disentangling global and local climate dynamics (Lawrence et al., 2022).

To assess the extent to which paywalls restrict access to LCIF research, we calculated the proportion of papers that were/were not open access. Most publications (68%) were freely available online either as gold open access made freely available by the publisher (51%), or through a freely accessible online repository (green open access) (17%). However, 25% of studies were behind paywalls, including some highly cited papers, for example Zeng et al. (2021). A further 7% had access limitations with bronze (4%) or hybrid (3%) access. The high proportion of freely available papers reflects a global shift toward open access publishing, supported by evidence that open access articles attract more, and more diverse, citations (Bautista-Puig et al., 2020; Huang et al., 2024).

3.4 | Utilisation

3.4.1 | Potential uses of information on local climate impacts of forests by conservation practitioners

Utilisation encompasses the direct use of scientific advice by society (Böcher, 2016). Understanding the utilisation of climate research can help climate researchers in framing their research questions and findings to enhance usability (Dilling & Lemos, 2011). To gain a deeper understanding of research utilisation, respondents were asked to rank seven potential uses for research on the LCIF, according to their likelihood of use. Awareness-raising had the highest average score (5.4/7), followed by protected area management (4.4/7), policy/advocacy (4.05/7), fund-raising (4.0/7), livelihoods (3.96/7) and behaviour change (3.45/7) for the in-person questionnaire ($N=51$). Research received the lowest score in the in-person questionnaire (2.7/7), while research (2.7/6) and REDD+ (a form of forest-related climate finance) (2.2/6) were ranked lowest in the online survey. Other responses included: working with farmers and communities for climate change mitigation and adaptation; wildland fire prevention and management; training of community trainers such as agricultural extension workers; habitat restoration; biodiversity monitoring; general project design and implementation; and disaster preparedness and resilience building. That awareness raising emerges as the highest-ranked use is consistent with evidence from implementation science that the provision of educational materials and delivery of educational meetings are the most impactful strategies for practitioners' research utilisation (Ashcraft et al., 2024). Overall, the results indicate that NGOs recognise a diverse range of potential uses for research on the LCIF.

3.4.2 | Utilisation products

'*Utilisation involves the delivery of a finalised utilisation product*' (Böcher, 2016). In the RIU model, these utilisation products play a key role in research dissemination. To assess the relevance of different products in the research integration process, participants were asked to rank various climate science product types according to their perceived importance. The term 'importance' was not defined allowing participants to interpret it in the context of their specific needs. The product types, or sources of information, included in the ranking were initially identified based on authors' experience of working with NGOs. To allow for other product types to be included, an open-ended question about 'other sources of information' was included. Peer-reviewed scientific papers, seminars and conferences, and in-depth scientific reports were the most important sources of climate science for the in-person questionnaire respondents (Figure 6). Social media was the least important source. Other product types mentioned by respondents included climate websites such as online databases, government reports and data, and data collected directly by the NGO and/or their partners, mentioned by six, five and four respondents respectively.

During the FGD, practitioners shared examples of scientific products that they currently use. These included the Global Forest Watch interactive map showing forest cover dynamics (World Resources Institute, 2014), NASA's Open Data Portal (NASA, 2026) with access to several different datasets, and BirdLife's DataZone (BirdLife International, 2026) including species-specific information on the conservation status and threats to more than 11,000 bird species. These three products all combine reliable science, user-friendly interfaces, including map-based tools that enable the user to focus on their specific area of interest.

Environmental decision-support tools, such as climate toolkits, can be a useful way to integrate research with knowledge utilisation. Such tools are effective if users' priorities, motivations and agency are reflected in their design (Roelich & Giesekam, 2019). However, many decision-support tools have failed to gain traction due to challenges including aligning with stakeholder priorities and dealing with uncertainty (Walling & Vaneeckhaute, 2020). As an objective of the study was to consult on the development of a decision-support tool, respondents were asked to preference-rank four different types of decision-support tool, of which an online map-based application had the highest mean rank and was ranked as the favourite choice by 67% of respondents (Figure 7). Although the map-based application was the most popular, the other options were also relevant with 25%, 24% and 16% of respondents selecting research summaries, decision-making frameworks and information exchange networks as their preferred decision-support tools. The categories

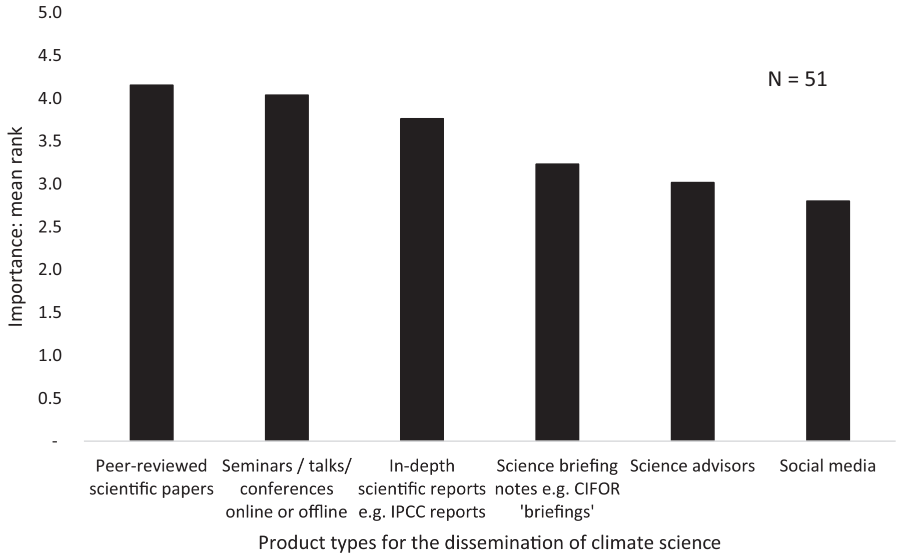

FIGURE 6 Conservation practitioners' average importance ranking of different product types for the dissemination of research on the local-scale climate impacts of tropical forests where 5 = most important and 1 = least important (*N* = 51).
Source: Results of the study's in-person questionnaire.

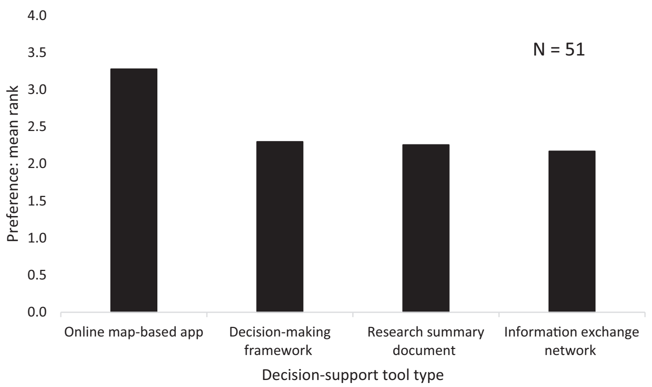

FIGURE 7 Conservation practitioner preference ranking for different types of decision-support tools (*N* = 51).
Source: Results of the study's in-person questionnaire.

of decision-support used for this exercise were deliberately broad to allow respondents to select options beyond model-based systems given their well-documented challenges (Bagstad et al., 2013; Walling & Vaneeckhaute, 2020).

Two of the three focus groups discussed the design of the decision-support tool. Both emphasised that different audiences will have different interests and needs. Environmental NGO knowledge needs that were mentioned included: information to use internally with NGO staff; material that can be used for advocacy and communicating with government; infographics for social media; and material that can easily be translated to local languages. Again, the issue of scale was raised. Participants expressed interest in products that could be tailored to local contexts and information that could link local and global issues for different ecosystems. Flexibility of products to suit diverse needs was emphasised.

4 | LIMITATIONS

The study has three key limitations. First, the study equated research 'supply' with recent research outputs (2019–2023), thereby assuming that earlier work does not fulfil NGOs' priority knowledge needs. This could result in research gaps being exaggerated as NGOs may be using pre-2019 literature.

Second, the in-person questionnaire relied on simplified 5-point Likert items to assess respondents' agreement with statements regarding their access to, interest in, and use of information on the LCIF. While the endpoints were defined ('1 = disagree' and '5 = strongly agree'), the intermediate categories (2, 3, and 4) were not. This may have reduced consistency, thereby affecting the robustness of the mean rankings. Providing clear definitions for each step in the ranking process would have enhanced consistency in respondents' interpretations of the scale.

Third, respondents interpreted the ranking exercises inconsistently, with some assigning equal ranks to multiple options. In addition, one response option was inadvertently omitted from the in-person questionnaire section on preferred sources of climate science. To address these issues, rankings were adjusted using an ordinary least squares approach so that each respondent contributed equally to the overall averages. While the use of a digital data collection tool with fixed ranking rules could have standardised responses and prevented duplicate rankings, logistical constraints necessitated the use of a paper-based survey.

5 | RESEARCH RECOMMENDATIONS

The study underscores the need for further research into how climate research is integrated into practice. Although implementation science is a mature field within the health sector, it is still in its early stages in environmental research. Adapting and applying implementation science frameworks to the environmental sector could enhance research uptake and impact, ultimately improving environmental and livelihood outcomes.

Further research on the LCIF is also recommended, particularly around the gaps identified earlier in the study including research on: the LCIF in Africa, including dry forests; the impact of (re)forestation on local climates; contextualising research on the LCIF, particularly to local scales; local forest–rainfall dynamics; and research on the biodiversity, agricultural, economic and health outcomes arising from the LCIF.

6 | CONCLUSIONS

The study set out to examine how well recent research aligns with the knowledge use needs of environmental conservation practitioners seeking to understand the LCIF. Encouragingly, most practitioners are already aware of this research and are actively applying relevant science in their work. Overall, there is good alignment between research and practitioners' knowledge needs on the LCIF. However, several important gaps and mismatches remain. Many NGOs favour a positive framing that emphasises the benefits of forests for local climate, whereas most published research adopts a negative framing focused on the risks posed by deforestation. Moreover, while practitioners need information at local to national scales, much of the existing research is conducted at multinational scales, creating a mismatch between the spatial scale of available evidence and the scale at which practitioners operate. The study also identified a shortage of recent studies addressing the biodiversity, health, economic and agricultural outcomes of the LCIF; areas that are central to NGOs' activities.

Practitioners showed strong interest in co-producing new research. Yet they also described several barriers to research utilisation. These barriers underscore the need for improved NGO access to research and for investment in researcher–practitioner integration, including through research co-production.

Overall, the findings highlight a key opportunity: closer collaboration between NGOs and researchers, supported by more locally relevant research on forest-climate impacts, could enhance NGOs' capacity to assist communities, protected area managers, and other stakeholders in protecting forests and the ecosystem services they provide. Achieving this will require researchers, NGOs and funders to adopt deliberate strategies that more effectively integrate knowledge users and producers.

AUTHOR CONTRIBUTIONS

Nike H. Doggart, Dominick V. Spracklen, Carly L. Reddington, Richard J. Cuthbert and Mary McEvoy conceived the ideas and designed the methodology. Nike H. Doggart and Carly L. Reddington carried out the semi-systematic literature review. Nike H. Doggart, Carly L. Reddington and Dominick V. Spracklen collected the data. Nike H. Doggart analysed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

DATA AVAILABILITY STATEMENT

The dataset generated for this study is available in the Research Data Leeds Repository at https://doi.org/10.5518/1607. This includes two Excel files, one containing the results of the semi-systematic literature review, and one containing the results of the questionnaires and focus group discussions. The questionnaires are also provided as Supporting Information S1 and S2.

STATEMENT ON INCLUSION

Our study brings together authors from four different countries, Nepal, Qatar, United Republic of Tanzania, and the United Kingdom. All questionnaire and focus group discussion participants were invited to participate in the publication of the paper. All those who responded to this invitation and provided substantive comments on the paper drafts are included as authors.

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SUPPORTING INFORMATION

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

Data S1. The online questionnaire used for this research which was distributed digitally to participants.

Data S2. The in-person questionnaire used for this research which was distributed in-person to participants during the WLT symposium.

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