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Overlaps of indigenous knowledge and climate change mitigation: evidence from a systematic review

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There is now increasing acknowledgement of the role of indigenous and local people (ILP) in climate change, particularly in impact assessment, mitigation and adaptation. However, the methods and ways on how exactly indigenous and local knowledge (ILK) can be used in climate change action largely remain fragmented. While a growing share of scholarship has addressed the overlaps between ILK and adaptation, limited attention has been given on practical ways of working with indigenous communities to enhance knowledge of implementing mitigation actions. Without clearly articulated indigenous-sensitive methods for ILK integration in mitigation science, holders and users of this knowledge may remain at the boundaries of climate change action. Their knowledge and experiences may not be used to guide effective greenhouse gas (GHG) emission reduction activities. There are also fears that hurriedly and poorly developed mitigation projects that ignore indigenous and local communities may infringe their customary rights and livelihoods. To contribute to improved guidance on meaningful involvement of ILP in climate change mitigation, this study used the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) to systematically review literature that links ILK and climate mitigation. We do this by (a) Identifying case studies that examine the overlaps of ILK and climate change mitigation from Scopus and Web of Science databases ($n = 43$); (b) analysing the methods used for engaging indigenous people in these studies; (c) determining the knowledge, ways, practices and experiences of ILP that show mitigation benefits; and (d) highlighting the direction for participatory engagement of ILP in mitigation research and practice. We have added to the emerging but fast growing knowledge on the overlaps of ILK and climate change mitigation. This intersection is evident in three ways: (a) Validation and application of concepts used to understand carbon sequestration; (b) GHG emission reduction mainly from natural resource dependent livelihoods involving ILP; and (c) the application of participatory methodologies in research and the practice of climate change mitigation. We conclude that studies that focus on the intersection of ILK and climate mitigation need to use indigenous-sensitive methodologies to give more benefits for climate mitigation objectives while recognising the rights of ILP.

KEYWORDS

climate change, GHG emissions, indigenous and local knowledge, mitigation, participatory research, PRISMA

1 Introduction

The treatment of indigenous and local knowledge (ILK) in climate research has emerged in all fields of impact and vulnerability assessment, mitigation, and adaptation – the key topics that are considered in climate change studies. While more attention has been given on the intersections of ILK and impact assessment (Boillat and Berkes, 2013; Panda, 2016; Savo et al., 2016; Weber and Schmidt, 2016; Whitney et al., 2020) and ILK and adaptation (Reid, 2016; Makondo and Thomas, 2018; Nalau et al., 2018; Taylor et al., 2023), few studies have examined the topics of ILK and climate change mitigation. This limitation emerges against a backdrop of increasing need to mitigate greenhouse gas (GHG) emissions to avoid dangerous climate change (IPCC, 2022). To avoid global warming of 1,5°C or higher above pre-industrial levels, a scenario feared to result in disruptive climate change, the climate change community urges urgent and ambitious mitigation actions (Altieri and Nicholls, 2017; Giannakidis et al., 2018; IPCC, 2022). Mitigation is understood as an approach to cut GHG emissions or to enhance their sinks (Nyong et al., 2007). Mitigation is required to stabilise global warming and slow down climate change to reduce pressure on adaptation, which hitherto has proven to be challenging (Panda, 2016; IPCC, 2022). The climate mitigation community is increasingly acknowledging the role of indigenous and local people (ILP) in efforts to enhance carbon sinks and mitigate climate change. In this study, we use the term ILK to refer to detailed knowledge encompassing indigenous knowledge and local knowledge held by indigenous and local people and developed from their many years of interacting with the environment, the knowledge of which is useful for mitigating climate change. This joint treatment of indigenous knowledge and local knowledge has been preferred to deal with the overlaps that exist in the use of these knowledge forms. Indigenous knowledge is culturally unique, context specific, mainly transmitted intergenerationally and developed after many years of experiencing environmental phenomena. Local knowledge refers to knowledge developed from constant experiences and learning about changes happening in people's environment and may not necessarily have the long span characteristic of indigenous knowledge (Boillat and Berkes, 2013; Makondo and Thomas, 2018). Collectively, the knowledge, experiences and practices can be used to provide ways of limiting carbon emissions or enhance their sinks.

However, compared to studies on ILK and adaptation, studies that look at the overlaps of ILK and climate change mitigation are still fewer. There has been more attention on ILK-adaptation relationships perhaps owing to the ethical question about not putting the burden of mitigation on indigenous people. Our point of departure is to deploy a systematic review of literature that examines the overlap of ILK and climate change mitigation to give nuances on how this connection has been studied. We go beyond identifying case studies of this overlap to identifying the knowledge, ways, practices and experiences of ILP that show mitigation benefits; and mapping the location of these cases.

Several reasons have been provided to explain why indigenous and local communities matter in climate mitigation. First, ILP are closely connected to forests and ecosystems (Kuh, 2012; Vergara-Asenjo and Potvin, 2014; Alejo et al., 2021) that have the potential to sequester significant amounts of carbon dioxide given that they occupy up to 65% of the world's land [Rights and Resources Initiative (RRI), 2015] and manage approximately 28% of the global land surface (Clay and Cooper, 2022) and directly manage about 11% of the world's forests [Rights and Resources Initiative (RRI), 2015]. It is estimated that about 20% of carbon is stored in the regions with indigenous people influence (Brack, 2019). Second, indigenous peoples and local communities are disproportionately affected by climate change impacts, yet they have contributed the least to global warming (Nyong et al., 2007). Third, indigenous communities inhabit areas that are prone to the effects of climate change, such as small islands, mountain regions, coastal regions and drylands and are among the poorest and most marginalized people globally (Ramos-Castillo et al., 2017; Jones, 2019). Fourth, they have predominantly natural resource dependent livelihoods that are sensitive to climatic disruptions (Chanza and Musakwa, 2021a). Fifth, and vitally important, many communities of indigenous people are long-time observers of changes in their local environments, many hold religious beliefs about such changes and their knowledge is useful in environmental monitoring (Brattland et al., 2019). Sixth, climate change interventions such as afforestation projects may also interfere with the rights and livelihoods of ILP (Jones, 2019). Seventh, the success of mitigation projects may only be realised with the full participation of indigenous communities (Robinson et al., 2014; Ramos-Castillo et al., 2017).

Systematic reviews involve replicable and robust reviews of literature as they specify procedures and protocols to guide a scientific field of enquiry (Hallinger, 2013; Linnenluecke et al., 2020; Kraus et al., 2022). Hallinger (2013) stressed that a systematic research synthesis adheres to transparent methods involving a standard set of stages that are accountable, replicable and updateable to ensure reports are relevant and useful. Our study sets to locate and analyse cases that show the engagement of indigenous and local people in climate mitigation research and practice. This contribution is against a background of growing acknowledgement of the role of ILP in mitigation action (Ramos-Castillo et al., 2017; Jones, 2019; Maru et al., 2023). However, very few studies have used a systematic review to collate the evidence of overlaps between ILK and climate change mitigation. The synthesis of this evidence is timely to enhance understanding of opportunities that exist when indigenous and local people are incorporated in mitigation research and action. As this interest grows, there is fear that hurried approaches of prescribing mitigation projects that are not appropriate to indigenous communities may end up jeopardising the objectives of climate change mitigation (Ramos-Castillo et al., 2017; Jones, 2019).

We have set our research objectives as: (a) To identify case studies that examine the overlaps of ILK and climate change mitigation; (b) to analyse the methods used for engaging ILP in mitigation studies; (c) to document the mitigation benefits that emerge from indigenous and local people's knowledge, experiences and practices; (d) to characterise concepts that connect ILK and climate change mitigation; and (e) to show the direction of ILK and climate change mitigation research. In the next section, we examine the intersection of ILK and climate mitigation. Later on, we show how we conducted the systematic review of available studies before presenting and discussing the results.

Conceptualising indigenous knowledge and climate change mitigation

Participation of indigenous people in knowledge development and planning for environmental management, under which the topic of climate change falls, is particularly governed by the United Nations

Declaration on the Rights of Indigenous Peoples (UNDRIP), the Convention on Biological Diversity (CBD), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the International Indigenous' Peoples Forum on Climate Change (IIPFCC). The UNDRIP acknowledges that, 'indigenous knowledge, cultures and traditional practices contribute to sustainable and equitable development and proper management of the environment' (UN, 2007). Article 8(j) of the CBD specifies the need to '…respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities … relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge…' (UN, 1992). The IPBES recognises and works with ILP in ecosystem and biodiversity assessment studies (IPBES, 2019). Mitigation and adaptation practices of indigenous people are emphasised by IIPFCC (2012). Within these frameworks, concepts that highlight the intersection of ILP and climate change are nature's contribution to people (NCP) and nature-based solutions (NbS). As a concept, nature's contribution to people recognises the diversity of knowledge and worldviews in enhancing understanding of nature-people interactions (Ellis et al., 2019; Hill et al., 2021). In the context of climate mitigation, the knowledge and worldviews of ILP can be used to understand ecosystem status, manage ecosystems and monitor their quality. Similarly, NbS encompasses a broad approach of enhancing nature to solve challenges such as climate change and integrates approaches such as ecosystem-based adaptation (EbA), ecosystem-based mitigation (EbM) and nature climate solutions whose objectives are to reduce GHG emissions from ecosystems and harness their potential to store carbon dioxide (Cohen-Shacham et al., 2019; Seddon et al., 2021).

Mitigation efforts at the national level are now widely framed in the form of Nationally Determined Contributions (NDCs) following the 2015 Paris Agreement that sets to stabilise GHG emissions under the United Nations Framework Convention on Climate Change (UNFCCC). The NDCs are climate action plans to cut emissions and adapt to climate change. In its latest report, the Intergovernmental Panel on Climate Change (IPCC) states that up to 21% of global anthropogenic emissions comes from Agriculture, Forestry and Other Land Use (AFOLU) sector, with deforestation being responsible for 45% of total AFOLU emissions. However, this sector offers significant potential for sequestrating carbon to achieve the required GHG emission reduction targets. To reach these targets, actions would be required by all players, including indigenous and local communities. For example, ILP can participate through reducing deforestation and engaging in afforestation and reforestation projects. The UNFCCC has developed a carbon financing scheme known as Reducing Emissions from Deforestation and Forest Degradation (REDD+) whose implementation and success rely mainly on indigenous and local communities (Brugnach et al., 2017).

So far, studies examining the overlaps of ILK and climate change mitigation have not advanced with the pace and urgency required to articulate the climate crisis. Available studies largely focused on the role of indigenous and local communities in mitigation (Martello, 2008; Salick et al., 2014; Chanza and Musakwa, 2021b; Kunz et al., 2022; Maru et al., 2023), including mitigation of climatic impacts (Ifejika Speranza et al., 2010; Hiwasaki et al., 2014; Schlingmann et al., 2021). In this study, however, we made a distinction between mitigation of climate change and mitigation of climatic impacts. We concentrated on the former that looks at measures to prevent or limit the occurrence of climate change and not the latter that can also be called adaptation, but not the focus of this paper. The studies identified here exist as isolated empirical contribution to the knowledge of what indigenous and local people can do to mitigate climate change in their unique contexts. Apparently, very few studies have made a systematic review of literature that show how these topics have evolved. Nair et al. (2009) reviewed 42 studies to understand the carbon sequestration potential of agroforestry but did not focus on indigenous communities. Von Seggern (2020) used a meta-ethnographic approach to synthesise empirical results of local and indigenous climate change adaptation and mitigation strategies. However, the review was only limited to selected South Pacific Island states and integrated both mitigation and adaptation. A collection of eight articles published as a special issue in *Climatic Change* in 2017 attempted to address the relationship between climate change mitigation and indigenous peoples. However, the focus of this collection was to identify policy measures that can be used to pursue the dual goals of indigenous sovereignty and climate change mitigation (Ramos-Castillo et al., 2017). To advance knowledge on the intersection of indigenous knowledge and climate change mitigation, it is timely to examine this connection and how ILK has been applied in mitigation studies.

Methodology

Drawing on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach, we structured the data and analysis process into four main stages: database search, primary screening, secondary screening and tertiary screening (Figure 1). Database search sets the systematic review process by identifying keywords for use in the literature search based on what we aimed to achieve, that is, to understand how local and indigenous knowledge has been incorporated into climate change mitigation research. Conscious of the heterogenous deployment of indigenous knowledge terminology in literature, we included the following terms in our searches: 'indigenous knowledge'; 'indigenous knowledge systems'; 'indigenous climate knowledge'; 'traditional knowledge'; 'traditional ecological knowledge'; 'cultural knowledge'; 'local knowledge'; and 'local ecological knowledge'. For climate change mitigation, we used the terms 'climate mitigation'; 'climate change mitigation'; 'mitigation of climate change'. We excluded studies on mitigation of climate change impacts since we were mainly interested in those that covered measures that contribute to GHG emission reduction or contribute to carbon sequestration. We then generated a search query that combines these words in Scopus and Web of Science (WoS) electronic databases as follows: ('indigenous knowledge' OR 'indigenous knowledge system*' OR 'indigenous climate knowledge' OR 'traditional knowledge' OR 'cultural knowledge' OR 'traditional ecological knowledge' OR 'local knowledge' OR 'local ecological knowledge' AND 'climate mitigation' OR 'climate change mitigation' OR 'mitigation of climate change'). Scopus and WoS are the commonly used databases in systematic research (Hallinger, 2013; Nalau et al., 2018; Garcia-del-Amo et al., 2020). The search was conducted on 24 April 2023 and yielded a total of 162 publications from Scopus ($n = 104$) and WoS ($n = 58$) prior to screening (Figure 1).

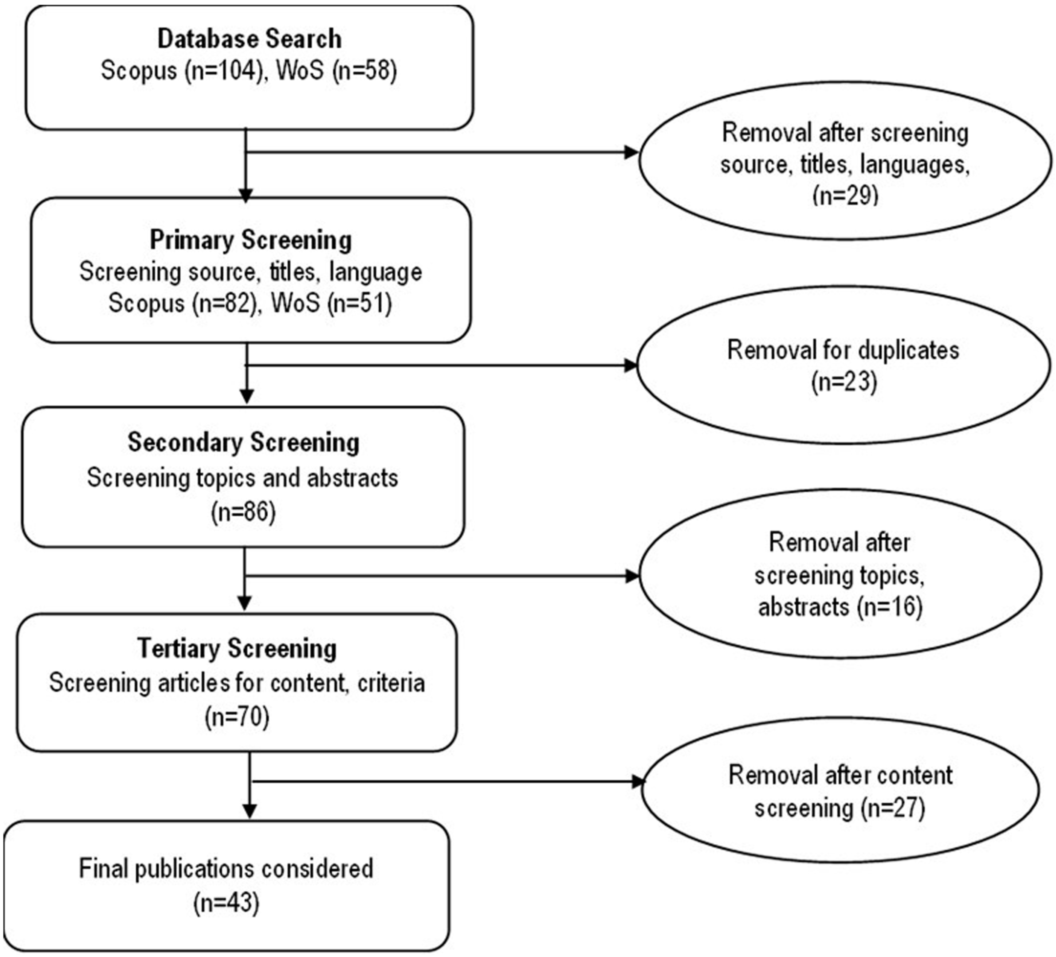

FIGURE 1
Process flow diagram for article search and identification.

The screening stages involved analysis of the search results for screening according to the inclusion criteria that we developed. The criteria consisted of the following: (1) an empirical study that focuses on local or indigenous knowledge and practices relevant in mitigating climate change; (2) use of the terms ILP or ILK or associated terminology; and (3) the research process involved participation of ILP. For the second stage, the identified total records ($n=162$) were sorted according to source type (journal articles and book chapters) and language (English), leaving only relevant sources sought from Scopus ($n=82$) and WoS ($n=51$). We then removed duplicates ($n=23$) to remain with only clean results ($n=96$). At the third stage, we conducted further screening involving topic and abstract screening and removed articles that did not meet our set criteria ($n=16$). Finally, the remaining articles ($n=70$) were further subjected to content screening. The excluded publications ($n=27$) were outside the scope of this review. These studies related to adaptation studies, studies covering mitigation of climate change impacts or mitigation of climatic risks, literature reviews or studies based on theoretical investigations rather than empirical cases. A total of 43 publications were finally considered for detailed content analysis.

In line with the set objectives of the study, we read through each of the 43 reports and structured the results as follows: (a) Place where the studies were conducted; (b) year of publication; (c) methods used for study and how the indigenous and local people were engaged; (d) the concepts that emerged from the joint treatment of ILK and climate change mitigation; and (d) the activities or practices that show the evidence of mitigation contribution. We summarised these results in a table for easy reference. For showing how these studies evolve over time, we plotted the results in a graph generated in Microsoft Excel. A map was also generated to show the location of these cases. Given the fewer cases considered in this study ($n=43$), we preferred a qualitative analysis of the results to depict more content on the engagement of ILP in climate change mitigation research and projects and to better understand the practices that contribute to climate change mitigation. We continued to read through the result summaries as we synthesise the findings according to the identified themes. The results were largely qualitatively presented and analysed. We used tables to summarise some of the findings for easy inferences.

Results

Studies on ILK and climate change mitigation

Studies examining the overlaps of ILK and climate mitigation emerged in the 2000s but continue to evolve over time (Figure 2). The first study identified was that of 2007 and the number steadily rose till 2012, then rose exponentially to 43 in 2023. The highest number of contributions was found in 2022 where our study identified 10 cases that focused on the intersection of ILK and mitigation of climate change.

There is also a widespread spatial distribution of the studies across all regions of the world (Figure 3). Most of the case studies are located in areas where indigenous people occupy areas with abundant forest resources such as the boreal forest of northern Sweden (Hallberg-Sramek et al., 2023), the Madya Pradesh of India (Mahalwal and Kabra, 2023) and the Himalayan region of India and Nepal (Kumar and Brewster, 2022), Tagbanua and Palawan of Philippines (Dressler et al., 2012), Aotearoa of New Zealand (Buckley et al., 2023) and nation states of Canada (Lewis et al., 2020). The spread of these studies shows that the agenda to work with ILP is receiving some attention at the scholarship front. India has the highest number of studies (7), followed by Canada, Norway, Sweden, New Zealand, Nepal, and Philippines which had 3 case studies each. The rest of the countries had either 1 or 2 cases. However, there are other studies conducted in more than one country, such as cases studied by Salick et al. (2014) (Nepal and Bhutan), Solomon et al. (2016) (Liberia and Ghana), Lewis et al. (2020) (Canada and New Zealand), and Clay and Cooper (2022) (Canada, United States and South Africa). Only a few studies draws from regional cases involving the Arctic (Martello, 2008) and the Sahel (Nyong et al., 2007) regions. One study used cases drawn from Asia, Africa and Latin America (Chhatre and Agrawal, 2009).

Conceptual approaches for studying ILK and climate change mitigation

The topics of ILK and climate change mitigation are given heterogenous framings in literature. We found a total of 26 terminologies that were used in the 43 cases studied. We classified these concepts according to the main topics, ending up with five categories (ecosystem management and monitoring, ecosystem services, agroforestry and agroecology, mitigation, and vulnerability assessment). The remaining terminologies, that is, ‘indigenous knowledge-science integration’, ‘indigenous representations’ and ‘indigenous health promotion’ were classified as other (Table 1). Based on the number of case studies in which the themes appeared, the largest category is agroforestry and agroecology where terminologies identified covered ‘climate smart agriculture’, ‘climate resilient agriculture’, ‘agroforestry’, ‘agroecology’, ‘field margin vegetation’, ‘climate smart forestry’, ‘agroecosystems’ and ‘homestead forests’. This is followed by the ecosystem services category that consists of ‘ecosystem health’, ‘nature-based solutions’, ‘sacred forests’, ‘ecosystem-based adaptation’ and ‘forests livelihoods’. Ranking third is the ecosystem management and monitoring group consisting of ‘ecosystem management’, ‘forestry management’, ‘environmental management’, ‘ecosystem monitoring’ and ‘community-based forestry monitoring’. Mitigation group comes fourth consisting of ‘mitigation-adaptation’, ‘REDD+’ and indigenous carbon economy. The fifth group, vulnerability assessment, is made up of ‘socio-ecological assessment’ and ‘vulnerability assessment’. The use of multiple terminologies suggests the broad range of application in which ILK has been used in climate mitigation studies and the many knowledge fields that this knowledge can be applied (Brook and McLachlan, 2008).

Methods for engaging ILP in mitigation studies

We found a diverse mix of methods used to interact with the ILP in studying the convergence of ILK and climate change mitigation. These methods and tools range from simple interactions through questionnaire-based surveys to participatory and collaborative research with indigenous people (Figure 4). Participant observation, survey questionnaires, focus group discussions (FGDs) and open interviews were the main methods used. In many cases, these methods were not deployed in isolation but triangulated. For example, Solomon et al. (2016) used environmental anthropology with villagers in Ghana

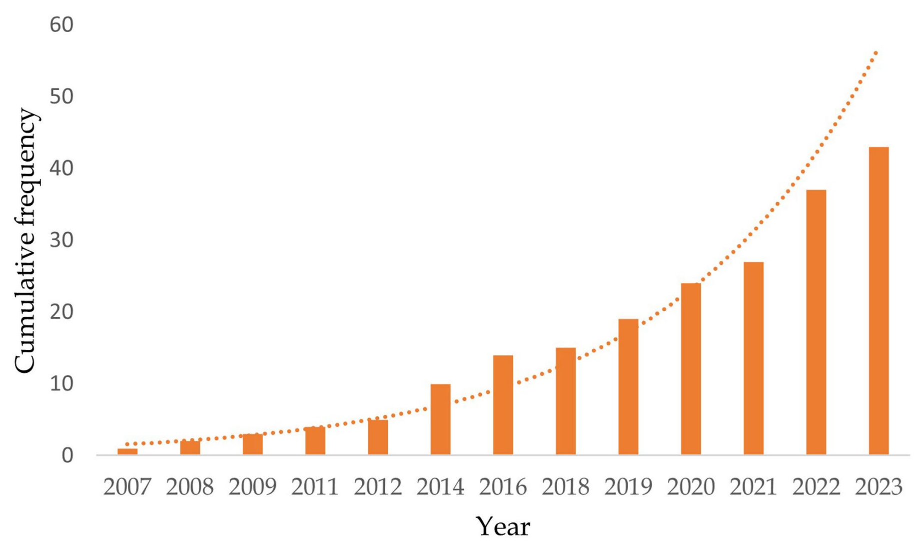

FIGURE 2
Evolution of studies on ILK and climate change mitigation.

FIGURE 3
Mapping of studies of ILK and climate change mitigation.

and Liberia involving participant observation, open interviews, oral and site histories with elders and community leaders, transect walks with local farmers, and participatory global positioning system (GPS) mapping. Chaudhary et al. (2022) applied ethnographic analysis using participant observation and a survey of 229 households in Nepal to understand indigenous agricultural practices that give mitigation benefits. Regasa and Akirso (2019) triangulated FGDs, open in-depth interviews and semi-structured survey with 296 farmers to understand climate smart agriculture (CSA) practices in Ethiopia. In gathering the ethnographic accounts of forest management and use practices in India, Mahalwal and Kabra (2023) used open-ended interviews and FGDs with the local forest users. The blending of research methods can be understood as a way of enhancing the robustness of the methods used.

More than half of the studies explicitly stated that the methods used involved participatory engagement with indigenous and local peoples. The participatory methods existed as: multi-stakeholder participatory scenario mapping (Hallberg-Sramek et al., 2023); participatory visual methods and knowledge exchanges (Tschirhart et al., 2016); participatory mapping of NbS sites (Pittman et al., 2022); participatory action research (Guthiga and Newsham, 2011; Sereenonchai and Arunrat, 2020); participatory interactions with locals involved in REDD+ projects (Cromberg et al., 2014); participatory GIS mapping (Kpienbaareh et al., 2020); participatory workshops with farmers (Avila-Bello et al., 2023); participatory rural appraisal (Brattland et al., 2019); participatory forest monitoring (Paneque-Gálvez et al., 2014); and participant observation (Dressler et al., 2012; Solomon et al., 2016; Chaudhary et al., 2022). Galang and Vaughter (2020) used participatory research to identify local ecological knowledge used in ecosystem services. Knight et al. (2022) and Mahalwal and Kabra (2023) applied ethnography to gather the accounts of ILP on forestry management.

To monitor the effects of climate change on vegetation and human dimensions over time, Salick et al. (2014) engaged indigenous collaborators of the Himalaya in Nepal and Butan over a period of 7 years. Similarly, Buckley et al. (2023) used living laboratories involving co-production of knowledge with indigenous people in New Zealand. The methods involved multidecadal, transdisciplinary, experimental restoration research programme aimed at addressing scientific, social, and economic knowledge gaps for restoration of degraded landscapes as NbS. Each living laboratories project was co-produced by an extended peer community which included landowners and indigenous partners. The authors stated that the programme aimed to produce and mobilise knowledge, both from Western scientific and Indigenous paradigms, to support the use of NbS as a strategic contribution to climate action, biodiversity improvement, and decolonisation. Jones (2019) also used a decolonial and emancipatory approach with the Kaupapa Maori indigenous people of New Zealand.

Role of ILP in climate change mitigation

We identified a range of knowledge applications, experiences and practices of ILP in climate mitigation. We categorised them as CSA, climate smart forestry, indigenous forestry conservation, monitoring forestry and ecosystems, agroforestry, agroecosystem, agrobiodiversity, biodiversity management, EbA, ecosystem restoration and REDD+ (Table 2).

Climate Smart Agriculture is defined by the Food and Agriculture Organisation (FAO) as a practice of making agriculture respond effectively to climate change through focusing on triple objectives of improving food security by increasingly productivity and income, building resilience by adapting to climate change and reducing GHG emissions and their removals where possible (FAO, 2013). A collection

TABLE 1 Key concepts undergirding ILK-climate change mitigation nexus.

Category	Terminology	Scholars
Ecosystem management and monitoring	Ecosystem management Forestry management Environmental management Ecosystem monitoring Community based forest monitoring	Hallberg-Sramek et al. (2023), Knight et al. (2022), Priyadarshini and Abhilash (2019), Mahalwal and Kabra (2023), Tschirhart et al. (2016), Salick et al. (2014), and Paneque-Gálvez et al. (2014)
Ecosystem services	Ecosystem health Nature-based solutions Sacred forests Ecosystem-based adaptation Forests livelihoods	Lewis et al. (2020), Buckley et al. (2023), Pittman et al. (2022), Maru et al. (2023), Chanza and Musakwa (2021a,b) Kunz et al. (2022), Hausner et al. (2020), and Chhatre and Agrawal (2009)
Agroforestry and agroecology	Climate smart agriculture Climate resilient agriculture Agroforestry Field margin vegetation Climate smart forestry Agroecology Agroecosystems Homestead forests	Sereenonchai and Arunrat (2020), Regasa and Akirso (2019), Shelat and Ramachandran (2014), Solomon et al. (2016), Agnoletti et al. (2022), Chaudhary et al. (2022), Galang and Vaughter (2020), Clay and Cooper (2022), Hallberg-Sramek et al. (2022), Nautiyal and Goswami (2022), Kpienbaareh et al. (2020), Avila-Bello et al. (2023), and Baul et al. (2022)
Mitigation	Mitigation-adaptation Indigenous carbon economy REDD+	de Freitas et al. (2018), Mukherjee et al. (2016), Nyong et al. (2007), Hofman et al. (2021), Iniguez-Gallardo and Tzanopoulos (2023), Bong et al. (2016), Cromberg et al. (2014), Dressler et al. (2012), and Robinson et al. (2014)
Vulnerability assessment	Socio-ecological assessment Vulnerability assessment	Brattland et al. (2019) and Kumar and Brewster (2022)
Other	IK-science integration Indigenous representations Indigenous health promotion	Guthiga and Newsham (2011), Martello (2008), and Jones (2019)

of CSA practices identified involved traditional farming practices that are climate resilient and generate low emissions. In measures aimed at boosting crop productivity, Thailand farmers observe CSA practices by not burning rice residues, using rice straw compost, and alternative wetting and drying (Sereenonchai and Arunrat, 2020) whereas in Ethiopia such practices include soil conservation, agricultural intensification, water efficient irrigation and fuel wood conservation (Regasa and Akirso, 2019). Local farmers in Ghana and Liberia adopt soil management practices that increase soil fertility by adding ash, crop residues and food waste. These soil quality improvements create highly fertile and carbon-rich and productive soils capable of supporting sustainable farming practices (Solomon et al., 2016).

Other forms of CSA practices used by ILP involve agroforestry (Robinson et al., 2014; Galang and Vaughter, 2020), agroecosystem (Brattland et al., 2019; Kpienbaareh et al., 2020; Nautiyal and Goswami, 2022) and agrobiodiversity (Agnoletti et al., 2022; Avila-Bello et al., 2023). Agroforestry is defined by Galang and Vaughter (2020) as a land use system that combines aspects of forestry and agriculture to provide natural benefits or ecosystem services that support the livelihoods of rural communities while conserving the environment. Similarly, Avila-Bello et al. (2023) consider agroecosystems as complex systems involving ecological networks and cultural practices that interact to deliver co-evolutionary processes of domestication that perpetuate basic ecological services beneficial to humans and the environment. This complexity can only be understood and promoted by utilising local or indigenous knowledge. Studies have shown that indigenous communities have developed extensive knowledge of the environment that has enabled them to domesticate, conserve and improve agrobiodiversity (Avila-Bello et al., 2023). The management of landscapes and biodiversity is also promoted by ILP. In India, Mahalwal and Kabra (2023) reported that ILK is based on profound understanding of a particular species and the sentiments connected to them. This knowledge informs their livelihood decisions and resource management practices.

Agrobiodiversity results from traditional practices of agroforestry systems that maintain endemic and cultivated species. Under this practice, fruit trees are used to provide shade and food. The litter from shade trees attracts a diversity of decomposer organisms and other species that are useful in carbon sequestration. Shade trees also help to insulate the soil from direct sunlight, maintain organic matter, conserve moisture and maintain soil productivity that is essential in carbon management (Agnoletti et al., 2022). Accordingly, these strategies are climate-sensitive and provide production-protection benefits to indigenous communities and motivate them to conserve the environment (Galang and Vaughter, 2020). In the deployment of these strategies, studies have shown that ILK is critical in the stewardship of ecosystem services provided by ecosystems and agroforestry landscapes (Galang and Vaughter, 2020; Agnoletti et al., 2022).

Hallberg-Sramek et al. (2022) drew from the knowledge and experiences of local forestry managers and users to frame climate smart forestry in Sweden. They stressed the significance of understanding the local perspectives for the successful implementation of climate smart forestry. Climate smart forestry is a recent concept

FIGURE 4
Frequency of methods used to study ILK and climate mitigation.

that has emerged to integrate both climate change mitigation and adaptation to promote mutual benefits of forests to people and global agendas such as GHG stabilisation (Bowditch et al., 2020). Guidelines provided by Jandl et al. (2018) and Bowditch et al. (2020) emphasise that projects focusing on climate smart forestry need to adapt to local contexts in which the forestry resources are used and managed. Drawing on the insights of ILP, Hallberg-Sramek et al. (2022) revealed that the introduction of large-scale exotic plantations interferes with the goals of climate smart forestry as it infringes local livelihoods and interests.

Indigenous forest conservation is widely reported as an approach to demonstrate the important role played by ILP in climate change mitigation. This is largely in the form of conservation of scared forestry sites and tree species (Salick et al., 2014; Chanza and Musakwa, 2021a; Maru et al., 2023). These can be patches of forests protected by local communities for spiritual and cultural uses and are usually protected from human interference, making them distinctively unique from other legally conserved areas. Such sites have been maintained for a long time through taboos, belief systems and culturally observed restrictions and rules that are commonly enforced through customary laws. These venerated sites provide a range of ecosystem services that include protection of rare biodiversity, religious sites, sources of traditional medicines, regulation of extreme weather events, and climate regulation by assimilating carbon (Kuh, 2012; Daye and Healey, 2015). Dudley et al. (2009) argued that sacred sites in some countries can be more effective at protecting natural resources than legally conserved areas. In Ethiopia, Maru et al. (2023) observed that ILK which is attached to sacred forest conservation has encouraged local people to preserve the remnants of natural vegetation thereby contributing to GHG reduction. Chanza and Musakwa (2021a) discovered that indigenous people in some areas of rural Zimbabwe view forests and trees as their own relatives. This belief system is largely common with the elderly citizens who see the loss of trees as an existential threat to their own survival. As such, they jealously guard against abuse of forestry resources and apply strict rules for the protection of sacred places.

Ecosystem-based adaptation and ecosystem-based mitigation have been jointly deployed in the study cases. The former refers to the use of ecosystem services as an overall adaptation strategy to help communities to adapt to the adverse effects of climate change (Chanza and Musakwa, 2021b), whereas the latter is concerned about using ecosystems to mitigate climate change. Both approaches rely on health and well-managed ecosystems whose services should be perpetuated for communities to directly benefit from them or to realise carbon sequestration benefits. In areas where communities live with ecosystems, such benefits can only be maintained by applying locally proven ecosystem and biodiversity conservation practices that involve the people benefiting from them (Nyong et al., 2007; Hausner et al., 2020). In Zimbabwe, Chanza and Musakwa (2021b) reported that communities are motivated to conserve ecosystems if they derive clear benefits such as food, protection against extreme weather and weather events, sites to observe seasonal and climatic changes and spiritual benefits. Hausner et al. (2020) observed that knowledge held by the Sami pastoralists of Norway is critical in guiding EbA strategies for managing pastures under threat from multiple land uses and climate change.

The utility of ILK in forestry monitoring has been widely documented in cases considered in this study. Paneque-Gálvez et al. (2014) stressed that the knowledge and experiences of indigenous and local people can be applied in community-based forestry monitoring and management (CBFM). As an approach, CBFM involves the participation of communities in forestry management to realise co-benefits of biodiversity conservation, climate change mitigation and livelihood enhancement. In its application, scientists or forestry practitioners jointly develop monitoring instruments with local communities to enhance robustness of forestry assessment methods and to achieve conservation and forestry governance objectives (Dressler et al., 2012; Paneque-Gálvez et al., 2014). CBFM approaches can be matched to those gathered by professional scientists yet require lower cost and can provide more detailed and accurate data about the state of forestry resources at the community scale (Paneque-Gálvez et al., 2014). Involvement of local people in forest monitoring can enrich management decisions as this enables understanding of spatial and temporal distribution of determinants of forest quality such as drivers of forest degradation or abundance (Berkes et al., 2000; Paneque-Gálvez et al., 2014). Brattland et al. (2019) add that this is particularly important when science does not give conclusive results on the major drivers of environmental pressure and how to deal with them. Indigenous and local ecological knowledge can give guidance on adaptive actions to be taken towards health ecosystems for managing climate change. Co-production of ecological indicators with ILP can contribute to increased awareness of climate change and biodiversity management, promote strengthening of community institutions, strengthen forestry governance, guard against illegal activities, and enhance support of afforestation projects (Paneque-Gálvez et al., 2014; Kumar and Brewster, 2022; Buckley et al., 2023). As such, CBFM involving ILK can be useful in national forest monitoring systems and programmes such as REDD+ (Dressler et al., 2012; Paneque-Gálvez et al., 2014).

REDD+ is a forest-based climate mitigation programme that in addition to managing deforestation and forest degradation, considers the role of conservation and sustainable management of forests to benefit local communities (Bong et al., 2016). The UNFCCC has developed this programme to incentivise developing countries to reduce emissions from forested landscapes and invest in low carbon trajectories by giving a financial value for the carbon stored in forests (UN, 2016). As such, indigenous and local communities that have large forest stocks can benefit

TABLE 2 Applications of ILK in climate change mitigation.

ILK applications in climate mitigation	Scholars
Climate smart agriculture	Shelat and Ramachandran (2014), Mukherjee et al. (2016), Solomon et al. (2016), Regasa and Akirso (2019), Sereenonchai and Arunrat (2020), and Chaudhary et al. (2022)
Indigenous forestry conservation	Maru et al. (2023), Clay and Cooper (2022), Knight et al. (2022), Kunz et al. (2022), Chanza and Musakwa (2021a), Lewis et al. (2020), Jones (2019), de Freitas et al. (2018), Salick et al. (2014), Guthiga and Newsham (2011), and Priyadarshini and Abhilash (2019)
Agroforestry	Robinson et al. (2014) and Galang and Vaughter (2020)
Agroecosystem	Nautiyal and Goswami (2022), Kpienbaareh et al. (2020), and Brattland et al. (2019)
Agrobiodiversity	Avila-Bello et al. (2023) and Agnoletti et al. (2022)
Biodiversity management	Mahalwal and Kabra (2023) and Tschirhart et al. (2016)
Forestry monitoring	Martello (2008), Paneque-Gálvez et al. (2014), Kumar and Brewster (2022), Pittman et al. (2022), Buckley et al. (2023), and Hallberg-Sramek et al. (2023)
Ecosystem restoration	Buckley et al. (2023) and Hofman et al. (2021)
Climate smart forestry	Hallberg-Sramek et al. (2022)
Ecosystem based adaptation	Iniguez-Gallardo and Tzanopoulos (2023), Chanza and Musakwa (2021b), Hausner et al. (2020), and Nyong et al. (2007)
Ecosystem based mitigation	Iniguez-Gallardo and Tzanopoulos (2023) and Nyong et al. (2007)
REDD+	Bong et al. (2016), Cromberg et al. (2014), Dressler et al. (2012), and Chhatre and Agrawal (2009)

from this programme (Alejo et al., 2021). Many cases that document REDD+ initiatives have attributed their success or failure to the degree of engagement with local communities. In an examination of linkages between drivers of deforestation and livelihoods in Indonesia, Bong et al. (2016) observed that measures to address deforestation and forest degradation affect local communities and influence their role in the implementation of REDD+. The scholars concluded that better understanding of drivers and their importance for local livelihoods will not only contribute to a more locally appropriate design of REDD+ and monitoring systems but will also foster local participation.

Discussion

We have seen some growing interest in examining ILK and climate change mitigation since 2009. This interest exists in all regions of the world. It is most likely that this trend will be maintained as more focus is given on working with indigenous communities to stabilise GHG emissions through various projects across the globe. This rise in studies that connect these topics can be attributed to the following reasons. First, this could be in response to increased acknowledgement of the role of indigenous and local people in climate change mitigation that has been observed by other authors (Garcia-del-Amo et al., 2020; Chanza and Musakwa, 2021b; Maru et al., 2023). Second, this could stem from the increased acknowledgement of the problem of climate change that requires the need to break epistemological and methodological boundaries to work with ILK towards improved understanding of climate change (Ford et al., 2016; Fernandez-Llamazares et al., 2017). Third, the growing call for climate governance that requires that communities experiencing climatic disruptions should have a voice in framing climate adaptation and mitigation responses (Zelli, 2011). Fourth, the increased concern about ethical and equity issues in climate change discourses where calls are being made to include indigenous people who tend to be the worst victims of climatic disturbances despite their limited contribution to the problem (Jones, 2019). Fifth, the existence of platforms such as UNDRIP, IPBES and IIPFCC that recognise the rights of ILP in climate action. These platforms continue to propel the ILP-climate change agenda, including by the IPCC (Ford et al., 2016).

In terms of the methods of articulation, we have observed a spectrum of participatory methods in research and practice in the ILK-climate change mitigation nexus, ranging from more participatory to less participatory methods. These methods vary in the time taken to interact with ILP, the depth of the analysis used in knowledge co-production and role that ILP played in the research. Certain studies featured in this review spanned a period of a number of years and in some cases even decades. Where questionnaires and semi-structured interviews were used alone, these gave less time to interact with indigenous knowledge holders and are less likely to reveal the depth of their knowledge and practices. Less participatory methods have minimum engagement with ILP and can cause bias in knowledge development (Chanza and de Wit, 2013). Instead, more participatory methods (e.g., participatory action research, anthropological methods, community meetings, participatory mapping techniques, participatory forest monitoring, visual methods and living laboratories) create more space for active interactions with communities. In addition, the existence of a wide range of methods used by scholars of indigenous mitigation knowledge suggests fluidity in the deployment of such methods. It also suggests the lack of standard methods that can be used to draw from the knowledge of ILP. However, if methodologies of working with ILP are more fluid, this may present a challenge in using weak methodologies and unethical conduct by researchers who are not sensitive to the interest and rights of the people (Fernandez-Llamazares et al., 2017). To address this challenge, we argue that researchers need to use emancipatory and participatory methods that recognise indigenous people as legitimate contributors to the knowledge of climate change mitigation. Their input should also inform the design of mitigation projects. Our observation corroborate earlier arguments that methodologies for studying ILK in climate change science should not be exploitative, exclusive and unethical (Chanza and de Wit, 2013; Brugnach et al., 2017). Instead, legitimate involvement of indigenous people in mitigation projects should be an ethical requirement set to empower the concerned communities (Brugnach et al., 2017; Hausner et al., 2020). Chanza and de Wit (2013) warn that poorly developed epistemologies and methodologies can entrench the subjugation of indigenous people as their knowledge may not sufficiently perforate the boundaries set by Western worldviews, especially in climate science. Such approach limits knowledge acquisition and knowledge development, and therefore, subjugates the development of the knowledge holders and their communities. The only challenge is that the lengthy period of engagement with ILP used in participatory studies or in the design of mitigation projects may not match with limited timeframes set by research organisations and aid institutions to develop knowledge for project interventions. However, many researchers maintain that tapping from the knowledge and experiences of indigenous people is an emancipatory and decolonial agenda of making the views of people affected by climate change matter in decision processes (Eitzel et al., 2020; Gay-Antaki, 2022).

There are also many ways in which ILP are participating in climate mitigation projects, for example, ranging from CSA techniques, climate smart forestry, protection of sacred sites and ecosystems that act as carbon sinks. The ILP also act as environmental managers through the application of customary and traditional conservation practices that preserve forestry resources and other ecosystems. This role is quite useful in promoting sustainable climate change mitigation projects at the community level. We have found out that as farmers, ILP employ a range of CSA practices that help in both sequestration of carbon and minimising carbon emissions. There is potential to promote these practices and realise more mitigation benefits if they get recognised in projects that mainstream livelihoods of traditional farmers in climate change responses. However, the pressure to develop mitigation projects to meet the set global emission reduction targets may lead to hurriedly designed projects that lack local input. This may keep entrenching the poverty and marginalisation of indigenous people, challenges that need to be addressed to ensure successful projects (Ramos-Castillo et al., 2017). Concern has been raised that projects implemented by non-indigenous people to mitigate climate change may adversely affect their livelihoods and infringe their rights to land and natural resources (Jones et al., 2014; Ramos-Castillo et al., 2017). Experience with some REDD+ projects and other ecosystem management interventions has shown that success of these projects is influenced by how well indigenous and local stakeholders are identified and brought into the design and management processes (Cromberg et al., 2014; Bong et al., 2016). Despite this evidence, there are only a few REDD+ projects that explicitly specify the intention to engage with indigenous peoples and local communities (Vierros, 2017).

Instead of viewing ILP as engaging in activities that drive deforestation and other unsustainable land use practices, we support the argument that they should be seen as part of the solutions to forest loss (Vierros, 2017; Negi et al., 2018). Some studies have shown that indigenous communities' systems of enforcing environmental laws are more effective than those used by government agencies (Chanza and Musakwa, 2021b). In this study, we found some cases in which working with indigenous people does not only serve mitigation priorities but also intersect with poverty management and livelihoods objectives (Chhatre and Agrawal, 2009; Vierros, 2017; Mahalwal and Kabra, 2023). The resilience of some indigenous practices relevant in climate change mitigation also deserves attention. There is evidence that even as deforestation has affected some landscapes, sacred sites have demonstrated remarkable resilience in the face of change and environmental degradation (Reynolds et al., 2017; Negi et al., 2018). This suggests that there is potential by climate change mitigation practitioners to harness such proven experiences towards advancing the goals of climate change mitigation. This justifies the need to tap from ILK contributing to GHG emission reduction targets, the agenda pursued by global climate change mitigation frameworks such as the NDC set by the Paris Agreement.

Our study also sought to identify the direction taken by the ILK-climate change mitigation interface. We found out that ILK and climate change mitigation research is leading to collaborative outcomes between ILP and scientists. Much of this collaboration is happening at the research level and feeding into mitigation practice and policy development. This observation resonates with the views given by Ford et al. (2016), Garcia-del-Amo et al. (2020), and Kumar and Brewster (2022). An approach towards tapping from the experiences of ILP ensures that they participate as equal partners with scientists to develop hybrid knowledge for research and development. Joint research and resource monitoring processes are critical in enhancing knowledge of managing GHG sinks, including diffusing knowledge for climate responsible behaviour by communities. The latter is required to ensure success of climate response projects. If used in developing climate change mitigation interventions, collaborative approaches can lead to co-generation of knowledge and skills that are critical in addressing current challenges with climate change (Brugnach et al., 2017). Collaboration among equitable participants could even yield more benefits. Engaging local contributions could be through community-based monitoring that utilises citizen science where the people act as observers of forestry changes or forest resource monitors (Brattland et al., 2019). Some countries have also strengthened this by incorporating ILK in local decision-making processes through national legislation (Hausner et al., 2020). However, the meaningful incorporation of ILP tend to be more reported and operational in cases drawn from the developed world (Jones, 2019; Hausner et al., 2020; Hallberg-Sramek et al., 2022). Many studies reporting about collaboration initiatives in the South raise questions of ethical conduct, sufficient representations of people rights and their interests, including poverty alleviation to ensure that mitigation objectives are not foiled by limited livelihoods options (Cromberg et al., 2014; Tschirhart et al., 2016; Kunz et al., 2022; Maru et al., 2023).

Conclusion

The interest to work with indigenous and local people to contribute to the knowledge, practice and policy of climate mitigation continues to gather momentum across the world. This study systematically drew on scholarship that addresses the connection of ILK and mitigation of climate change. Our study was also concerned about examining how indigenous and local community viewpoints and methods are located in mitigation scholarship. From the 43 cases considered in this study, research on ILK and climate mitigation has covered most parts of the world. Much of this work has concentrated in regions where indigenous communities occupy areas with abundant forest resources and other ecosystems known to offer high potential for GHG sequestration. We have added to the emerging but fast growing knowledge on the overlaps of ILK and climate change mitigation. This intersection is evident in three main ways: (a) validation and application of concepts used to understand carbon sequestration; (b) GHG emission reduction mainly from natural resources dependent livelihoods; and (c) the application of participatory methodologies in research and the practice of climate change mitigation.

We have observed that indigenous local communities are emerging as key players in climate change mitigation largely because of their strong attachment to the environment, which is now considered to provide great potential for reducing carbon dioxide emissions through interventions to reduce deforestation, planting trees and monitor quality of forest lands. We also found an assortment of methods used for engaging indigenous and local contributors of mitigation knowledge, from less participatory techniques to more participatory methods that recognise ILP as legitimate collaborators of climate mitigation research and practice. While some emphasis has been given on participatory methods of understanding what ILP can do to manage climate change, the same emphasis has not been widely embraced in the implementation of mitigation projects. This is particularly so in the developing world where there appears to be more attention towards promoting projects that mitigate climate change in areas inhabited by indigenous communities. To avoid creating a burden on vulnerable indigenous communities, we have recommended for the deployment of effective participatory methods that are ethical, emancipatory and empowering when collaborating with ILP. This will give clear directions towards development of effective mitigation projects that are sensitive to indigenous and local people's needs, rights and livelihoods priorities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

NC: Conceptualization, Methodology, Writing – original draft. WM: Writing – review & editing. CK: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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