Journal of Environmental Management 373 (2025) 123678

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Short communication

Obstacles to implementing indigenous knowledge in climate change adaptation in Africa

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ARTICLE INFO

Handling Editor: Jason Michael Evans

Keywords:
Africa
Indigenous
Knowledge
Obstacles
Climate change adaptation

ABSTRACT

In a climate change context, indigenous and local knowledge includes the use of traditional practices, crop varieties, and land management techniques that have evolved in response to local climatic conditions. This inter-generational transfer of knowledge is crucial for maintaining and adapting these practices to meet the challenges posed by climate change. Despite the many advantages of using indigenous knowledge in climate change adaptation in Africa, its implementation faces several obstacles. Understanding these obstacles is crucial for integrating indigenous knowledge with scientific approaches to enhance climate resilience effectively. This paper offers an analysis of some of the most critical obstacles that hinder the use of indigenous and local knowledge in climate change adaptation in African countries.

1. The importance of indigenous and local knowledge in climate change context

Many African communities rely on indigenous and local knowledge (ILK) for their agricultural activities, utilising local biophysical indicators such as the behaviour of certain animal species, activities of insects, the flowering of specific plants, astrological indicators, and the timing of seasonal changes to plan their farming activities (Radeny et al., 2019). Indigenous knowledge thus plays a crucial role in climate change adaptation in Africa (Chambon et al., 2024; Leal Filho et al., 2022; Petzold et al., 2020; Hosen et al., 2020).

From a climate change perspective, ILK has many advantages and allows communities to draw on their knowledge of local ecosystems and weather patterns, as well as their traditional practices, to develop effective adaptation, including crop varieties, cropping calendars, livestock breeds, drought and disease-resistant varieties, and land management techniques that have evolved in response to local climatic conditions (Masango and Mbarika, 2022; Redvers et al., 2023). ILK is often passed down through generations, typically orally, ensuring the continuity of practices that have proven effective in managing local ecosystems (Christie et al., 2023). There are various means through which ILK is spread. Table 1 presents some of them.

Albeit not comprehensive, Table 1 outlines the diversity of effective measures that promote the transmission of ILK within and beyond communities. Regardless of the means of dissemination, ILK offers a wealth of benefits in the context of climate change adaptation and mitigation in Africa (Adeola et al., 2024; Chambon et al., 2024). These benefits stem from the deep understanding and relationship that indigenous communities have with their local environments over generations (Ehlers Smith et al., 2021; Leal Filho et al., 2021, 2022; Masango and Mbarika, 2022). This inter-generational transfer of knowledge is crucial for maintaining and adapting these practices to meet the challenges

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https://doi.org/10.1016/j.jenvman.2024.123678
Received 18 August 2024; Received in revised form 8 December 2024; Accepted 8 December 2024
Available online 1 January 2025

Table 1
Some of the measures via which ILK is spread in an African context.

Measure	Description
Oral traditions	Knowledge is passed down through storytelling, songs, and oral history.
Cultural events	Festivals, ceremonies, and gatherings celebrate and teach traditional practices.
Community meetings	Hands-on sessions allow elders to share skills, crafts, or practices with younger generations.
Mentorship initiatives	Pairing younger individuals with elders facilitates direct learning and cultural transmission.
Documentation	Recording ILK through written texts, audio, or video facilitates preservation and sharing.
Educational integration	Incorporating ILK into school curricula and community education initiatives ensures its longevity.
Arts	Using visual arts and music to express and convey traditional stories and knowledge enhances ILK familiarity and continuity.

(Source: Table information based on authors' field experiences.)

posed by climate change (Redvers et al., 2023).

As reflected in Table 2, ILK supports climate change adaptation by offering sustainable, context-specific solutions that modern practices may overlook (Kom and Nethengwe, 2024; Kom et al., 2024). This paper adds to other recent initiatives[1] and literature (e.g., Berkes, 2024) by presenting an overview of ILK in the climate change context of Africa. Its synthesis is based on all authors' field experiences in Africa, which support information conveyed in Tables 1, 2, 4 and 5. Data sources that underpin the analysis presented in Table 3 have been provided in the table. The focus of this paper and the statements made should not distract from the fact that Africa is not a homogeneous continent. It is highly diversified in respect of economic and social conditions, ecosystems, and livelihoods.

Indigenous local knowledge has significantly enhanced the resilience of African communities to the impacts of climate variability and change through practices involving integrated resource management, minimal resource extraction, and efficient recycling processes, all of which are inherently adapted to local environmental conditions (Galappaththi and Schlingmann, 2023; Leal Filho et al., 2022). For instance, reserved grazing land has been a traditional practice used by Maasai pastoral communities in Tanzania to secure dry season feeds for livestock and promote rehabilitation of degraded rangelands and conservation of fragile ecosystems (Selemani, 2020). Indigenous communities often employ sustainable land and water management practices that contribute to both mitigation and adaptation to climate change. Techniques such as agroforestry and rotational use of land help maintain biodiversity, improve soil health, and conserve water, all of which are critical factors for adapting to changing climate conditions (Imoro et al., 2021; Reang et al., 2021). Despite the many advantages of using ILK in climate change adaptation in Africa, its implementation faces several obstacles. Understanding these obstacles is crucial for integrating indigenous knowledge with scientific approaches to enhance climate resilience effectively (Makgopa and Frangton, 2016; Kom and Nethengwe, 2024; Kom et al., 2024). This paper now offers a brief analysis of some of the most important obstacles.

2. Obstacles to implementing indigenous knowledge towards climate change adaptation in African countries

There are several obstacles to effectively leveraging ILK towards climate change adaptation in Africa. For instance, the erosion of indigenous cultures and languages, often due to globalisation, urbanisation, and the influence of Western education, often threatens the transmission

Table 2
The importance of Indigenous and local knowledge in climate change adaptation.

Aspect	Indigenous and local knowledge (ILK) contribution	Relevance to climate change adaptation
Biodiversity conservation	Indigenous communities often possess a deep understanding of local ecosystems, species, and their interactions (Ehlers Smith et al., 2021)	May help protect biodiversity and maintain ecosystem services, which are crucial for climate resilience.
Sustainable resource management	Traditional practices like rotational farming, water conservation, and controlled burning have sustained ecosystems for generations.	Can provide sustainable alternatives to modern agricultural and water practices, reducing vulnerabilities to climate impacts (Galappaththi and Schlingmann, 2023).
Disaster risk reduction	Indigenous knowledge includes early warning systems based on natural signs, e.g., cloud patterns, animal behaviour, or sea level changes.	May enhance community preparedness and minimise risks from extreme weather events like floods, storms, and droughts.
Water resource management	Local water conservation techniques, such as the use of small-scale irrigation systems or natural reservoirs, are adapted to specific climates.	Ensures water availability and efficient use, particularly in drought-prone or water-scarce areas affected by climate change.
Resilient agriculture	Knowledge of diverse, climate-resilient crops and traditional seed varieties that can survive under varying environmental conditions.	Promotes food security by increasing agricultural resilience to extreme weather and changing climate patterns (Kom et al., 2024).
Community-based adaptation	Indigenous governance structures and collective decision-making foster cohesive, adaptive community responses to climate change.	Strengthens social networks and community-driven strategies for climate adaptation, ensuring locally appropriate solutions.
Land stewardship and forest management	Indigenous people often maintain sustainable relationships with forests through agroforestry, selective harvesting, and protecting sacred sites (Reang et al., 2021).	Protects carbon sinks, enhances land use practices, and contributes to the mitigation of climate change by reducing deforestation and degradation.
Cultural Heritage and Identity	Indigenous knowledge is often tied to spiritual and cultural practices, maintaining the balance between humans and nature (Luetz, 2024).	May preserve the cultural integrity of communities while enhancing their adaptive capacity by drawing on historical experience in dealing with change.

(Source: Table information synthesised by authors based on field experiences and supplemented with selected support from the literature.)

of indigenous knowledge from one generation to the next.

As summarised in Table 3, these obstacles may be grouped into a range of categories, including philosophical-paradigmatic impediments, colonial-geopolitical legacies, climatic-geographic realities, and practical, ethnic, and/or sociocultural issues, among others.

Paradigmatic issues include obstacles such as the side-lining of local knowledge by reductionist scientific knowledge production regimes, which are often assumed to have greater validity than traditional knowledge systems (Ahenakew, 2016; Makondo and Thomas, 2018). Paradigmatic obstacles tend to be premised on the presumed epistemological superiority of Western science vis-à-vis ILK (Fair, 2018) and uncritically privilege outsider ('expert') scientific knowledge and technocratic solutions to local problems (Luetz and Nunn, 2023). Clearly, even though the potential of ILK has been widely acknowledged by

[1] Local Indicators of Climate Change Impacts. The Contribution of Local Knowledge to Climate Change Research" (LICI) https://www.licci.eu/.

Table 3
Impediments to the use of indigenous knowledge in climate change adaptation.

Major obstacles hindering the spread of indigenous knowledge towards climate change adaptation	Peer-reviewed literature
Tacit presumption of epistemological superiority of Western science vis-à-vis traditional local knowledge	Fair (2018)
Local knowledge is side-lined by reductionist scientific studies, which are assumed to have greater validity and rigour	Makondo and Thomas (2018)
Many climate change adaptation initiatives are guided by external worldviews/ agendas and funded by foreign donors	McNamara et al. (2020)
Funders typically privilege outsider scientific paradigmatic orientations that uncritically perpetuate technocratic solutions	Luetz and Nunn (2023)
Higher education is widely informed by Western thinking and tends to ignore or side-line indigenous knowledge/inputs	(Bedford et al., 2021; Chabaya and Chabaya, 2023)
Lack of interdisciplinarity in research and educational approaches hinders the integration of multiple perspectives	Schipper et al. (2021)
Disregard for indigenous spirituality ('ecotheology') thwarts the influence of traditional worldviews to counteract profligacy and inform more sustainable mainstream development practices	(Luetz, 2024; Simpson, 2022; Tu'itahi et al., 2021)
Scientific knowledge-production regimes are reticent to accept, accommodate, integrate and/or prioritise traditional knowledge systems	(Ahenakew, 2016; Balehegn et al., 2019; Latulippe and Klenk, 2020; Simpson, 2022; Throsby and Petetskaya, 2016)
Globalisation, urbanisation, and migration are progressively eroding long-held local knowledge while at the same time accelerating the adoption of mainstream worldviews and interests, thus diminishing the inclination of younger generations in preserving traditional ways of living and adapting to change	Degen and Dana (2024)
While traditional knowledge is typically transmitted orally, many indigenous languages are endangered, making it progressively more difficult to preserve and bequeath knowledge based in local languages to future generations	Derhemi and Moseley (2023)
The lack of systematic documentation and diminishing oral knowledge transmission create a growing inter-generational gap between ILK custodians and younger generations	Radeny et al. (2019)
Politically, the distillation of traditional knowledge into categories that reflect the assumptions of science, with its compartmentalisation and artificial division of the world into disciplines, perpetuates the concentration of power in political and scientific centres, thus disempowering indigenous knowledge, communities, and knowledge-holders	(Nelson and Shilling, 2018; Shackleton et al., 2015)
ILK studies are often set in geographic and sociocultural specificity, lack uniformity, and may be additionally impacted by issues of colonisation, globalisation, structural challenges, and dissimilar underlying development patterns	(Ahenakew, 2016; Ford et al., 2016, 2020)
There is little coordinated integration of ILK with climate change adaptation frameworks, policies, and/or strategies	(Leal Filho et al., 2021, 2023)
The process of modernisation and evolving religious beliefs subsumes indigenous spirituality beneath majority religions	(Atabongwoung et al., 2023; Nyadzi et al., 2021)

(Source: Synthesis by authors; supporting data sources have been provided in the table)

communities and development practitioners as a valuable resource for adaptation practices, particularly for ecosystem-based adaptation (Ford et al., 2016, 2020; Makate, 2020), there is still limited recognition of indigenous knowledge sources in climate science dominated by Western scientific knowledge systems and institutions (Zidny et al., 2020; Lam et al., 2020). According to Lam et al. (2020), ILK has been largely neglected in the scholarly climate transformation discourse.

Furthermore, many climate change adaptation initiatives are guided by external agendas and funded by foreign donors (McNamara et al., 2020), which in turn perpetuates the lack of interdisciplinarity in research and educational approaches (Schipper et al., 2021). Relatedly, climate adaptation designs in higher education and the academic training of natural scientists are largely informed by Western approaches and ignore or even marginalise indigenous or traditional knowledge (Bedford et al., 2021; Chabaya and Chabaya, 2023). Furthermore, preference for scientific knowledge production is sometimes underpinned by a deep-seated suspicion of or disregard for traditional worldviews and indigenous spirituality ('ecotheology'); this is particularly regrettable considering the obvious affinities between traditional worldviews and environmental sustainability, which in many places underpin long-standing in situ sustainability and effective adaptation to change (Luetz, 2024; Simpson, 2022; Tu'itahi et al., 2021). In short, scientific knowledge-production regimes need to become more accepting and accommodating of traditional knowledge systems (Ahenakew, 2016; Balehegn et al., 2019; Simpson, 2022; Throsby and Petetskaya, 2016). Besides scientific bias, which has been acknowledged by many scholars (Latulippe and Klenk, 2020; Luetz, 2024; Mervis and Ortega, 2024; Nelson and Shilling, 2018), the oral transmission pattern of ILK over generations also contributes to the apparent erosion and marginalisation of the essence or substance of this important knowledge source (Mahuika, 2019).

There are also various philosophical and functional obstacles to implementing indigenous knowledge in climate change adaptation in Africa. These are outlined in Fig. 1.

Table 4 showcases some obstacles to ILK systems in Africa across different sectors.

These case studies illustrate the common challenges faced by Indigenous groups in Africa, which include external pressures from modernisation and urbanisation.

At a practical level, indigenous knowledge has a pivotal role to play in climate change adaptation in Africa as it is a fast-developing continent where highly sophisticated scientific mechanisms are yet to be fully harnessed (Nyong et al., 2007). The continent also faces several philosophical, social, and political challenges that hinder the effective uptake of indigenous knowledge into climate change adaptation regimes (Paparrizos et al., 2023).

First, colonial exploitation, imperial domination, and globalisation have significantly reshaped Africa's physical and cultural landscapes (Ngoepe and Bhebhe, 2024). Colonial powers imposed foreign governance structures, altered borders, and exploited natural resources, thus displacing indigenous systems of knowledge and governance (Ndlovu-Gatsheni, 2018). The introduction of Western education and economic models often eclipsed traditional knowledge and practices, rendering them less visible and pertinent (Jakaza et al., 2023). Furthermore, globalisation has intensified these trends, strengthening reliance on external expertise and global markets that further undermine ILK. This historical legacy continues to inhibit the integration, appreciation, and prioritisation of ILK in sustainable development strategies and underscores the need for locally adapted indigenous research methodologies in Africa and beyond (Chilisa, 2019; Jakaza, 2023; Ngoepe and Bhebhe, 2024).

Correspondingly, indigenous knowledge-holders sometimes harbour distrust of scientific knowledge as it is conceived as inscrutable or alien (Shin, 2017; Luetz, 2024). Apprehensions may be linked to negative experiences with scientific knowledge, enduring esteem for traditional paradigms, deep-seated cultural attachments, and/or a reluctance to

Table 4
Some obstacles to ILK systems in Africa.

Case Study	Country/ Region	Knowledge Area	Obstacles	Outcome/Impact
Maasai pastoralism	Kenya, Tanzania	Livestock, land management	Land tenure insecurity, policies promoting modernisation, lack of legal recognition	Loss of traditional grazing routes, reduced resilience to climate change
San Bushmen of the Kalahari	Botswana, Namibia	Wildlife tracking, hunting	Government restrictions on traditional hunting, lack of land rights, marginalisation	Loss of livelihood, weakening of cultural practices
Sacred forest groves of the Yoruba	Nigeria	Biodiversity conservation	Urbanisation, land conversion for agriculture, limited policy support	Decline in biodiversity, loss of sacred and ecological knowledge
Dogon Astronomy and agriculture	Mali	Astronomy, agriculture	Disregard for traditional calendars, external development pressures, modernisation	Reduced crop yields, loss of intergenerational knowledge transfer
Zulu traditional healing practices	South Africa	Medicine, healthcare	Marginalisation by formal healthcare systems, limited access to resources for traditional healers	Erosion of cultural identity, underutilisation of local medicinal knowledge

(Source: Table information synthesised by authors based on field experiences)

Table 5
Examples of effective ILK use in climate change adaptation initiatives in Africa.

Cases	Context	Indigenous Knowledge mainstreaming	Outcomes
Farmer-Managed Natural Regeneration (FMNR) in Niger	In the 1980s, much of Niger was affected by severe deforestation and desertification. Farmers were struggling with declining crop yields and environmental degradation.	Farmers in Niger applied traditional knowledge to protect and manage naturally regenerating trees on their farmland. Instead of cutting down all trees for fuel, they selectively pruned certain species to encourage growth, promote soil fertility, and provide shade (Rinaudo et al., 2021).	Over 5 million hectares of degraded land were restored, leading to increased crop yields and improved food security. FMNR helped build resilience to climate change by improving soil moisture retention and reducing the risk of drought (Rinaudo, 2021).
Zai Pits in Burkina Faso	The Sahel region of Burkina Faso is prone to droughts and degraded soils, limiting agricultural productivity.	Zai pits are an ancient technique where small planting pits are dug to capture water and organic matter, enabling crops to survive in dry conditions. Farmers enhanced this traditional practice with modern inputs like compost and fertilisers.	This method has significantly increased agricultural yields, even in drought-prone areas. By integrating traditional knowledge with modern techniques, farmers have improved their resilience to erratic rainfall.
Pastoralist Climate Adaptation in Kenya and Tanzania	Pastoralist communities in the Maasai and Samburu regions of Kenya and Tanzania rely on livestock for their livelihoods but face increasing risks due to unpredictable weather patterns.	Pastoralists have long used seasonal mobility to adapt to environmental changes, moving their herds to areas with better water and pasture availability. This practice is being integrated into national climate adaptation strategies, including the establishment of community-based grazing systems that incorporate traditional knowledge.	Communities have adapted to changing rainfall patterns by relying on time-tested practices that ensure the survival of livestock. This has led to more sustainable land use and better adaptation to climate variability.
Rainwater Harvesting in Ethiopia	Northern Ethiopia is a region prone to severe droughts and soil erosion.	Communities have long practiced water harvesting techniques by building terraces and check dams to conserve rainwater. This traditional knowledge was enhanced with new designs and scaling efforts supported by development programs.	The practice has improved water availability for agriculture and reduced soil erosion, helping farmers withstand periods of drought. The combination of modern engineering and local knowledge has bolstered resilience to climate change.
Community-Based Fisheries Management in Madagascar	Coastal communities in Madagascar rely heavily on marine resources, which are being threatened by climate change, overfishing, and habitat destruction.	Local fishers, guided by Indigenous knowledge of marine ecosystems, worked with conservation organisations to establish Locally Managed Marine Areas (LMMAs). These areas use traditional fishing restrictions, like seasonal closures and rotational fishing, to allow fish populations to recover.	LMMAs have successfully increased fish stocks and improved biodiversity, while providing communities with better long-term food security. This blend of local knowledge and scientific management practices has strengthened community resilience to climate impacts on marine ecosystems.

(Source: Table information synthesised by authors based on field experiences and/or literature)

embrace new technology (Makondo and Thomas, 2018; Zidny et al., 2020). This reticence can have a limiting effect on collaboration and knowledge exchange between indigenous knowledge-holders and Western scientists, thus thwarting opportunities for knowledge co-production (Ahenakew, 2016; Schipper et al., 2021; Zurba et al., 2022). Relatedly, indigenous communities in Africa often face social, economic, and/or political marginalisation, which further constrains their capacity to participate fully and on par in knowledge documentation and decision-making processes. Evidently, perceptions of social exclusion and power differentials are not conducive to knowledge co-production where climate scientists, development practitioners and local/indigenous communities seek to interact effectively for mutual learning with no 'asymmetry of power' (Leal Filho et al., 2023; Shackleton et al., 2015). Examples and literature abound of cases where research effectuating knowledge co-production was compromised or even halted, reflecting an outcome of the issues and sensitivities involved in the co-production of indigenous and Western science (Latulippe and Klenk, 2020; Mervis and Ortega, 2024). There are also positive experiences offering lessons on constructive knowledge co-production research (Zurba et al., 2022).

Furthermore, as technology is making inroads into African communities, indigenous ways of thinking and coping are gradually undermined by modernisation. In this context, indigenous knowledge in climate change adaptation in Africa is coming under pressure from modernity challenges associated with Western education, technology, and majority religions (Atabongwoung et al., 2023; Nyadzi et al., 2021). Lack of systematic documentation and conservation of ILK, typically transmitted orally from generation to generation, increasingly erodes this long-held knowledge source, with younger generations not retaining the same level of interest in or access, attachment, and commitment to traditional knowledge systems and the worldviews that underpin them (Derhemi and Moseley, 2023; Reid et al., 2021).

Finally, several political factors have also combined to hinder the implementation of indigenous knowledge in climate change adaptation

Fig. 1. Schematic representation of philosophical and functional obstacles to implementing indigenous knowledge in climate change adaptation in Africa. (Source: concept by authors)

in Africa (Eguavoen and Wahren, 2015; Shackleton et al., 2015). More specifically, the lack of inclusion in the governance of environmental issues and climate change has led to inadequate resource allocation, which has also limited the uptake of ILK in the design and implementation of climate change adaptation strategies that are based on indigenous knowledge (Ford et al., 2016; Scoville-Simonds et al., 2020).

3. Addressing the problem

This paper has outlined some of the obstacles currently thwarting a

greater uptake of ILK across the continent's climate change context. Some examples of the effective use of ILK in climate change adaptation efforts in Africa are presented in Table 5.

These examples highlight the importance of mainstreaming ILK into broader climate adaptation strategies to address the specific environmental challenges communities face across Africa. The examples also illustrate that efforts to overcome these obstacles should include the formal recognition of ILK in policymaking, developing methodologies for integrating indigenous and scientific knowledge, and promoting inclusive approaches that involve indigenous communities in the design, implementation, and evaluation of climate change adaptation strategies. Also, promoting education and awareness about the potential of ILK in climate change adaptation may significantly improve the recognition of ILK systems and address the existing power dynamics. It may also contribute to engaging indigenous communities in decision-making processes.

In addition, fostering respect for and understanding of indigenous knowledge among non-indigenous actors and ensuring the protection of intellectual property rights are essential steps towards a more effective, ethical, and sustainable use of ILK in climate change adaptation. Addressing these challenges requires a concerted effort from governments, international organisations, researchers, and indigenous communities to ensure that ILK is not only preserved but actively invited and integrated into climate change adaptation strategies.

Furthermore, it is important to address power dynamics and marginalisation by ensuring the meaningful participation and leadership of indigenous communities in decision-making processes related to climate change adaptation. This can be achieved through inclusive and participatory approaches that empower indigenous communities, recognise their rights, and esteem their knowledge systems.

The implications of this paper to theory, policy and practice are twofold.

First, from a theoretical perspective, recognising ILK challenges conventional paradigms of knowledge production, which often prioritise Western scientific frameworks. This inclusion encourages a more pluralistic and interdisciplinary approach to understanding complex social-ecological systems. It can lead to a re-evaluation of existing theories regarding sustainability, conservation, and community resilience, underscoring the significance of place-based knowledge that is often overlooked.

Second, in terms of policy and practice, the paper shows that integrating ILK into policymaking and development initiatives can enhance effectiveness and community buy-in. Traditional practices in resource management, environmental stewardship, and agricultural methods demonstrate resilience and sustainability that can inform contemporary practices. Collaborations between indigenous knowledge holders and practitioners can lead to more culturally appropriate and effective solutions to challenges such as climate change, biodiversity loss, and social inequality. There is also a need for more adequate policies on ILK to ensure the protection and promotion of valuable systems. Current policies often overlook the contributions and rights of Indigenous communities, leading to the erosion of their knowledge and practices. Effective policies should recognise and incorporate ILK in decision-making processes, particularly in areas like environmental management, land rights, and cultural preservation.

By strengthening theoretical perspectives and making policymakers and practitioners more aware of the value of ILK, this paper supports the creation of climate change adaptation frameworks that honour traditional knowledge-holders, respect cultural diversity, underpin locally sustainable development, and esteem, engage, and empower indigenous communities.

CRediT authorship contribution statement

Walter Leal Filho: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Johannes M. Lütz:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Edmond Totin:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Desalegn Ayal:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Edward Mendy:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Funding statement

Open Access funding enabled and organised by the Council of Australian University Librarians (CAUL) and its member institutions.

Declaration of competing interest

There is no conflict of interest between the authors.

Acknowledgements

This paper is part of the "100 papers to accelerate climate change mitigation and adaptation" initiative led by the International Climate Change Information and Research Programme (ICCIRP).

Data availability

No data was used for the research described in the article.

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