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The role of indigenous knowledge in climate change adaptation in Africa

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ABSTRACT

Africa is particularly affected by climate change due to its exposure to climate hazards, high vulnerability, and low adaptive capacity. Yet, Africa is also a continent rich in Indigenous and Local Knowledge (ILK) that has a long history of informing responses to climatic variability and change. This paper explores the extent to which ILK has been used in climate change adaptation in Africa. It deploys a bibliometric analysis to describe the connections between ILK and climatic change adaptation in Africa, complemented by an analysis of ILK literature and case studies. We consider four key dimensions of ILK, 1) type, 2) contexts of application, 3) value for adaptation, and 4) outcomes and effects in responses to climate change in Africa. Examples drawn from 19 countries across Africa highlight ILK systems are closely connected with biocultural relationships associated with observed patterns of climate change and where adaptation can be more effective when informed by ILK. This body of knowledge is critical to the delivery of climate change adaptation in Africa. The paper suggests some measures through which ILK may be more widely leveraged, both for improved adaptation outcomes, as well as enhancing the biocultural heritage value of ILK systems across Africa. The study commends the remarkable value

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of ILK in Africa for climate change adaptation and its value for supplementing climate services, particularly in areas with limited access to modern climate and weather forecasts as well as the encouragement of Indigenous communities to develop senses of ownership and active contribution to the sustainability of the future interventions.

1. Introduction

Indigenous and Local Knowledge (ILK) is a term used to describe the wisdom, techniques, approaches, skills, practices, philosophies, and uniqueness of knowledge within a given culture, which is developed by local communities over years through the accumulation of experiences and informal experiments, and based on an intimate understanding of local contexts (IPCC, 2022; IPCC, 2019a; Chikaire et al., 2012; Hiwasaki et al., 2014; Rhodes et al., 2014; Kolawole et al., 2016). ILK is generally transmitted via oral and practiced traditions (Garcia et al., 2009; World Bank, 1998).

Indigenous people are distinct social and cultural groups that share collective ancestral ties to the lands and natural resources where they live, occupy, or are from. The land and natural resources on which they depend are inextricably linked to their identities, cultures, livelihoods, as well as their physical and spiritual well-being. The International World Group for Indigenous Affairs (IWGIA) and the African Commission of Human and Peoples' Right (ACHPR) have estimated that there are approximately 50 million Indigenous people in Africa (AfDB, 2016) and most Indigenous peoples are farmers, pastoralists, agro-pastoralists, and hunter-gatherers (IFAD/ECG, 2016). ILK has been indentified as crucial when adapting to climate change in Africa and urge to be further studied has been emphasised by the IPCC Working Group II in Chapter 9: Africa (Trisos et al., 2022). Over 30% of the world's indigenous languages come from Africa and are exceptionally rich in ecosystem-specific knowledge on biodiversity, soil systems and water (Trisos et al., 2022). Therefore, identifying and grouping Indigenous people is of relevant first step to further indigineous knowledge usage in Africa. Table 1 presents a range of the Indigenous people in Africa based on their broad ethnolinguistic grouping.

Across Africa, ILK informs decision-making about fundamental aspects of life, from day-to-day livelihood activities to longer-term actions (Leal Filho et al., 2021). This knowledge is integral to socio-cultural complexity, which also encompasses location, language, systems of classification, resource use practices, social interactions, religion, belief, values, rituals, and spirituality (Tengö et al., 2014). These distinctive ways of knowing are important artifacts of the world's cultural diversity (IPCC, 2019a; Macchi et al., 2008) and are considered by ILK users as time tested practice that has been adjusted to local conditions to manage environmental, social, administrative, and health problems including resources use and community integration (Radeny et al., 2019). ILK is therefore a dynamic and essential asset to the survival of the historical and cultural legacy of Indigenous groups, and it is a pillar of social, cultural, political, economic, scientific, and technological identity (Magni, 2017; Ayal et al., 2015) which could contribute to the achievement of sustainable development goals (Tengö et al., 2014).

Although climate change and climatic extremes adversely affect the adaptive capacity of Indigenous communities across the world, many special needs are seen among those in Africa, particularly those who rely on rainfed agriculture for their livelihoods. In such circumstances, ILK is recognised for its potential to play a key role in climate change adaptation (IPCC, 2022; IPCC, 2021; Niang et al., 2014), resources governance, conservation, and sustainable use of biodiversity and ecosystems (IPBES, 2018 & 2012; Tengö et al., 2014). However, there has been limited documentation of ILK in the literature on climate change adaptation in Africa, when compared to other regions. This article aims to contribute to this gap by identifying contexts of application of ILK, the value ILK adds for adaptation and observed outcomes and effects of ILK through its various roles in climate change adaptation across Africa. We

Table 1
Countries in Africa and some of their Indigenous groups.

Location and Countries	Countries and some of their Indigenous Groups
SOUTHERN AFRICA: Angola, Botswana, Eswatini, Lesotho, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe.	**Angola**: Bakongo, Bantu, San, Himba, Khoisan, Kwepe, Kwisi, Ovimbundu, Mbundu, etc; **Botswana:** Balala, Basarwa, Kalanga, Nama, San, Tswana, etc; **Eswatini:** Khoisan, Swazi, Zulu, etc; **Lesotho:** Basotho (Bafokeng, Batloung, Baphuthi, Bakuena, Bataung, Batšoeneng), Khoisan, etc; **Mozambique:** Macua, Tsonga, Makonde, Shangaan, Shona, Sena, Marendje, Ndau, etc; **Namibia:** Damara, Herero, Kavango, Nama, Ovahimba, Ovazemba, Ovatjimba, San, Ovatwa, etc; **South Africa:** Bantu, Griqua, Khoisan, Khoekhoe, Koranna, Nama, Ndebele, San, Sotho, Swazi, Tsonga, Tswana, Venda, Xhosa, Zulu, etc; **Zambia:** Bantu, Bemba, Kaonde, Khoisan, Lozi, Luvale, Nkoya, Ngoni, Tonga, etc; **Zimbabwe:** Bantu, Doma, Kalanga, Ndebele, Shangaan, Shona, Tonga, Oshawa, Venda etc.
NORTH AFRICA: Algeria, Egypt, Libya, Mauritania, Morocco, Sudan, Tunisia, and Western Sahara.	**Algeria:** Amazigh (Berber), Mozabite, Tuareg, etc; **Egypt**: Amazigh (Berber), Beja, Copts, Dom, Nubians, etc; **Libya:** Amazigh (Berber), Imazighen, Tuareg, Toubou (Tebou), Duwwud etc; **Morocco**: Amazigh (Berber), Haratin, Saharawis etc; **Sudan:** Anuak, Azande, Baggara, Beja, Cushit, Dinka, Fur, Murle, Nuban, Nuba, Nuer, Shilluk etc; **Tunisia:** Andalusian**,** Amazigh (Berber), Bahai, Marazig, Jleila etc; **Western Sahara:** Berber, Sahrawis.
EAST AFRICA: Burundi, Comoros, Djibouti. Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Somalia, South Sudan, Tanzania & Uganda.	**Burundi:** Batwa (Twa), Hutu, Tutsi; **Comoros:** Banjar, Malayo-Indonesian/ Polynesians; **Djibouti:** Afar, Dir, Gadabuursi, Isaaq, Issa (Ciise) Somali; **Eritrea:** Agew, Afar, Beja, Bilen, Jeberti, Kunama, Nara, Rashaida, Saho, Tigre, Tigrinya; **Ethiopia**: Afar, Agew, Amhara, Basketo, Dassenech (Daasanach), Erbore (Arbore), Gedeo, Gumuz, Hamer, Irob, Majang (Majengir), Nuer, Nygagaton, Oromo, Shinasha (Bworo or Boro) Sidama, Somalis, Tigre, Wolayta; **Kenya**: Abagusii, Akamba, Aweer (Dahalo), Bantu, Boni, Cushits, Daasanach, Embu, Endorois, Kalenjin, Kamba, Kisii, Kikuyu, Kwegu, Luhya, Luo, Maasai, Meru, Mijikenda, Ogiek, Omotic, Rendile, Sanya, Samburu, Sengwer, Somali, Swahili, Taita, Turkana, Yaaku Waata; **Madagascar:** Antaifasy, Antakarana, Antandroy, Antemoro, Antesaka, Bara, Betsileo, Betsimisaraka, Bezanozano, Côtier, Mahafaly**,** Masikoro**,** Merina, Sakalava, Sihanaka, Tanala, Tsimihety; Vezo; **Malawi**: Chewa, Lambya/Nyiha, Lomwe, Nyakyusa/Ngonde, Ngoni, Nyanja, Sena, Tonga, Tumbuka, Yao; **Mauritius:**

(*continued on next page*)

Table 1 (*continued*)

Location and Countries	Countries and some of their Indigenous Groups
	Chagossians/Ilois, Creoles; **Rwanda:** Tutsi and Hutu; **Seychelles:** Creole; **Somalia:** Ashraf, Benadiri, Boni, Darood, Digil-Mirifle, Dir, Gaboye, Gosha, Hawiye, Isaaq, Oromo, Rahanweyn, Somali, Shabelle, Shekal, Shidle, Tumal, Yibir; **South Sudan:** Ambororo, Anuak (Anyuaa), Azande, Bari, Bongo (Babongo), Boya (Larim), Burun (Maban), Daasanach, Didinga, Dinka, Kara, Latuka, Madi, Moru, Murle, Nilotic, Nuer, Nyangatom, Shilluk, Taposa, Turkana; **Tanzania:** Akiye (Akie), Barabaig, Chagga, Hadzabe, Iraqw, Kalenjin, Maasai, Sandawe, Sukuma; **Uganda:** Bamba, Basongora, Banyabindi, Batwa, Benet, Ik, Kalenjin, Karamojong, Maragoli.
CENTRAL AFRICA: Cameroon, Central African Republic, Chad, Congo Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, & Sao Tome & Principe.	**Cameroon:** Baka, Bagyeli, Bakola, Bedzan, Kirdi, Mbenga Mbororo; **Central African Republic:** Aka, Baka, Banda, Bayaka, Fula, Gbaya, Kara, Kresh, Litho, Mandja, Mbaka, M′bororo Fulani, Ngbandi, Sara, Vidiri, Wodaabe, Yakoma, Yulu, Zande, etc; **Chad:** Baguirmi, Boulala, Fulbe, Hadjerai, Kanembou, Kotoko, Maba, Mbororo Fulani, Salamat, Sara, Shuwa, Taundjor, Toubou, Zaghawa etc; **Congo Republic:** Aka, Baaka, Babi, Babongo, Bakola, Bantu Gyeli (Gyele), Kango, Luma, Mbendjele, Mbenga, Mikaya, Twa (Tswa); **Democratic Republic of Congo:** Baka (Bacwa), Batwa (Twa), Mbuti (Bambuti), Wochua; **Equatorial Guinea:** Benga, Bubi (Bube), Bukeba, Fang, Ndowe; **Gabon:** Akoula, Akwoa, Baka, Babongo, Baghame, Bakoya, Barimba, Batéké , Mbenga, etc; **Sao Tome & Principe:** F*orros, Tongas, Mesticos, Servicais.*
WEST AFRICA: Benín, Burkina Faso, Cape Verde, Cote D'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, N í ger, Nigeria, Sierra Leone, Senegal & Togo.	**Benín:** Adja, Aizo, Bariba, Dendi, Ewe, Fon, Fulani (Peul), Gua/Ottamari, Yoa-Lokpa, Yoruba etc; **Burkina Faso:** Bwa, Gurunsi, Lobi, Mossi, Peul, Senufo, Tuareg; **Cape Verde:** None; **Cote D′ Ivoire:** Akan, Bété , Dida, Ebrié , Gagu, Guéré , Krou, Lobi, Mandé , Senoufo, Voltaique/Gur etc; **Gambia:** Bambara, Creole/Aku, Fulani/Fula/Peulh, Mandinka/Mandé , Jola/Karoninka, Manjago, Serahule, Serer, Wolof, etc; **Ghana:** Akan, Dagbani, Ewe, Ga-Adangme, Guan, Grusi, Gurma, Hausa, Kokomba, Mande, etc; **Guinea:** Conagui. Fulani / Peuhl, Kissi, Kpelle (Guerze), Kono, Loma, Malinké , Manon, Soussou, Toma, etc; **Guinea Bissau:** Balanta, Ejamat, Fula (Fulani), Jola (Diola), Mandinka, Manjaco, Papel, Susu; **Liberia:** Bassa, Belleh (Kuwaa), Gbandi, Gio, Gola, Grebo, Kissi, Kpelle, Krahn, Kru, Loma, Mandingo, Mano, Mende, Sapo, Vai; **Mali:** Berabish, Bozo, Diawara, Dogon, Fulani, Songhaï , Tuareg; **Mauritania:** Amazigh (Berber), Bafour, Haratin, Moor (Bidhan), Senoufo, Soninké ; **N í ger:** Fulani, Toubou, Tuareg; **Nigeria:** Bini **(**Edo), Ibibio-Efik, Hausa/Fulani, Igbo, Ijaw, Kanuri, Nupe, Tiv, Yoruba etc; **Sierra Leone:** Fullah, Kono, Kisi, Krim, Kuranko, Limba, Loko, Madingo, Mende, Sherbro, Susu, Temne, Vai, Yalunka etc; **Senegal:** Berbers, Diola, Fulani, Malinke, Serer, Soninke, Tukolor, Wolof; **Togo:** Adja, Ana-Ife, Éwé**,** Kabyé , Kotokoli, Losso, Mina, Moba, Ouatchi (Gbe).

Source: Authors, 2021

set out with an overview of ILK types and knowledge holders in Africa positioning them in light of climate change adaptation. We then provide an overview of the methods and present the results of the bibliometric analysis. Drawing lessons from examples of adaptation that are demonstrated to be effective when informed by ILK, the discussion outlines measures through which ILK may be more widely leveraged across Africa. The discussion emphasises the importance of ILK for improved adaptation outcomes as well as enhancing the biocultural heritage value of ILK systems. We conclude with a reflection on the value of ILK in Africa for climate change adaptation and its value for supplementing climate services particularly in areas with limited access to modern climate and weather forecasts while on the other hand encouraging Indigenous communities to develop senses of ownership and active contribution to the sustainability of the future interventions.

2. Indigenous and local knowledge in Africa: some trends and data

Various ILKs are traditionally applied in harmony with the natural and spiritual world. These socio-cultural practices are resourcefully designed to address local ecological limitations by maintaining a sustainable utilization and protection of commonly shared natural resources (Ayal et al., 2015; Lalonde, 1991). ILK is practiced day to day and plays a crucial role in various aspects of the well-being of Indigenous communities including forecasts and decision making regarding

Table 2
ILKs in Africa employed to manage resources, improve productivity and respond to various biophysical risks.

Indigenous and local knowledge practice	Description
Crop farming	Crop selection, the timing of specific farm management activity (e.g., land preparation, planting, weeding, & harvesting), irrigation, application of manure for various crop varieties.
Livestock husbandry	Selection of livestock species to the local context, selection of livestock for draughting, transportation and breeding, feed preparation, and management.
Resources management	Rangeland management, soil fertility management, water resources management, sustainable management of wild species, behaviour, and use of wildlife.
Conflict resolution	Settle intra- and inter-seasonal resources-based disputes and conflicts.
Anticipate and manage impending risks	Forecast and manage biological, hydro-metrological, and human-induced social risks using biotic and abiotic indicators.
Indigenous health care and medicine	Treat crop, livestock, and human ailments using ethnoveterinary medicine.
Community maintenance and development	Resource allocation, effective resources utilization plan, strengthening community membership to infrastructure and resources development.
Risk-sharing experiences	Indigenous communities in a different part of Africa have well-established risk-sharing experience targeted to restock the assets of those affected.
Use of Plants	As a source of wild food, building material, household tools, personal uses (dyes, perfumes, soaps), fuelwood and charcoal, medicinal purposes.

Source: authors (2021)

impending climate change risks (Asmamaw et al., 2020; Radeny et al., 2019; Omari et al., 2018; Abednico et al., 2018; Adger et al., 2014; Kebede et al., 2006; Kashem and Islam, 1999; Langill, 1999; Grenier, 1998). A range of ILK practices employed to manage resources, improve productivity, and respond to various biophysical risks are summarised in the table below (Table 2).

Understanding different ILK practices can help effective adaptation planning by establishing a greater diversity of projects or innovative mitigative measures, contextually appropriate interventions, and avoiding unintentional damage to ecosystems or culture (Nyadze et al., 2021; Theodory, 2016). Recognition and adoption of Indigenous technologies in partnership with development interventions have been noted to improve the likelihood of acceptance and adoption of development interventions (Moyo, 2010). Identifying ecological functions of various components of ecosystems, ILK can also be used to support developmental interventions. For example, new agricultural technologies can be designed more appropriately for diverse contexts when ILK is integrated with the design and implementation of an intervention (McNeely et al., 1990; Nkuba et al., 2020a).

The livelihood systems of many African communities are diverse but the majority of ILK communities depend on rainfed subsistence agriculture. Subsistence agricultural systems encompass crop production and animal husbandry with limited application of modern agricultural inputs and early warning systems. Yet these economies and livelihoods are vulnerable to climate change partly due to the limited provision of accurate and context-specific forecast information. As a result, most farmers and pastoralists depend on ILK for their agricultural activities and decisions, as well as a tool to address broader challenges such as conflict resolution over resource allocation (Williams et al., 2019; Radeny et al., 2019; Kolawole et al., 2014).

The emerging risks associated with climate change highlight the need for knowledge that will more effectively contribute toward climate action. Modern scientific knowledge remains inadequate to transform climate policies and manage the full range of impacts of climate change (Mafongoya and Ajayi, 2017), particularly for those most vulnerable. There is, therefore, a growing need to employ ILK to bridge this climate response deficit. ILK is often considered as social capital for the poor.

There are however noted constraints to the role of ILK in climate change adaptation that has particularly acute effects in Africa. For example, the rate of climate change and the scale of its impacts may exceed the patterning built into ILK and may therefore render the kinds of incremental adaptation practices by smallholder farmers and others, less relevant and less effective at current and projected climate change (Lane and McNaught 2009; Orlowsky and Seneviratne 2012). Climatic changes have led to the disappearance and/or changing the behaviour of old practices, due to environmental degradation and frequent climate change and extremes. An example is seen in Maasai, a nomad ethnic group distributed between Kenya and northern Tanzania. For centuries, the Maasai have been using cattle as a source of blood, which is part of their diets. Due to the unfavourable conditions, they have been switching to using camels for mixing blood and milk (Leal Filho et al., 2017).

Many harsh changes have contributed to the decline of ILK accuracy and reputation due to faulty forecast information and a lack of interest from younger generations (Theodory, 2016). Across Africa, there has been disruption of ILK through, for example, colonial education and missionary activity, and a general perception that ILK is outdated and unfavourably contrasted with scientific knowledge. These elements have negatively affected the transmission of ILK across generations (Ifejika Speranza et al., 2010; IPCC, 2019c). There has been a lack of systematic and effective knowledge and skill transfer, dissemination, and documentation of ILK across Africa, which is seen when awareness and attitudes are analysed (Rapholo and Diko Makia, 2020). Further disruption and dislocation have been caused by the influence of monolithic religion and modern education which have labeled ILK forecast experts as a witch and traditional practices against the act of God (Shizha, 2013, Mawere, 2015).

Together with shifting educational norms, there has arisen a lack of recognition and support from policymakers, practitioners, and the scientific community for the potential value of ILK (Radeny et al., 2019; Mafongoya and Ajayi, 2017; Theodory, 2016; Ayal et al., 2015; Kitinya et al., 2012). Urbanisation is occurring faster in Africa than on any other continent and this process has been noted to erode ILK, even though ILK is often integrated into urban environments (Oteros-Rozas et al., 2013; van Andel and Carvalheiro 2013).

However, many communities trust ILK forecasts more than the modern scientific forecast system, particularly in rural areas (Radeny et al., 2019), and many societies in Africa consider elder knowledge holders of ILK as an asset. Knowledge holders are frequently consulted for advice on how to respond to the different environmental uncertainties occurring in their local context (Theodory, 2016). In the broader sense, in Africa ILK has been used to address natural, human-induced, and socio-economic risks, for example, hydro-metrological hazards (including droughts and floods), and health issues using the signals of various biotic and abiotic indicators (Leal Filho et al., 2021). ILK plays a vital role to adapt the impact of climate change and ensuring food security in Africa (Mafongoya and Ajayi, 2017). Importantly, the ILK systems in Africa have well-established informal forecast dissemination platforms across communities and geographies under-serviced by current climate services.

Some of the most common knowledge holders include elders of a community, traditional leaders, and traditional healers; while other groups such as farmers, fishers, beekeepers, pastoralists also possess and share ILK.

In Africa, ILK weather and climate forecasting systems have been playing remarkable roles in resolving diverse impacts of climate change and are often recognized as a key resource for climate change adaptation and mitigation (Nyadze et al., 2021; Adger et al., 2014). In most cases, ILK is recognized as the reference point for intervention which enabled generations to survive and benefit from the risks. Both ILK and scientific knowledge weather and climate forecasting systems are based on observations, experimentations, and validations, however, ILK weather forecasting is based on short-term climate extremes observation whereas scientific weather forecasting is conducted by using aggregated mean values of climate variables. These forecasting systems suffer from limitations and hence, the provision of blended forecast services could help to provide more accurate information (Radeny et al., 2019). Yet they also afford a richer understanding of climate change, one that incorporates local perceptions into analysis by exploring local meanings of space and time, how people and places related to each other, and how local knowledge is built, transmitted, and, most importantly, changed over time.

3. Methods

This research adopted a structured review to explore the role of ILK in climate change adaptation in Africa. The review aimed to identify ILK types, contexts of application, the added value of ILK for adaptation, and observed outcomes and effects of ILK through its various roles in climate change adaptation across Africa.

The rapid pace of academic publications makes it challenging to keep up to date with the trends and advances in scientific fields using traditional literature review methods (Callaghan et al., 2020). Advances in text mining provide opportunities to partially deal with this issue. Over the past decade, several software tools have been developed for this purpose. Here we employ the term co-occurrence analysis to find out what the key focus areas related to the use of ILK for climate adaptation exist in the literature. For this purpose, VOS viewer (version 1.6.17), a software tool for constructing and visualizing bibliometric networks, was used to identify common areas of research and their interlinkages (van Eck and Waltman 2010).

Input data was retrieved from the Web of Science (WoS) a scientific database that archives high-quality peer-reviewed publications. To ensure the collection of all relevant publications, the broad-based search string developed by Petzold et al. (2020) was used and modified to only retrieve literature focused on Africa. Words or terms relating to ILK such as Indigenous, traditional, aboriginal, were used to initiate the search (see Appendix for full search string). To further classify the search, several related terms were included, which are knowledge, research, practice, ritual, belief, institution, values, norms, and skills where any of the formulated terms could be picked up. Each search string included: climate change, global warming, climate variability, extreme event, weather, heatwave, sea-level rise, flood, drought, storm, erosion, desertification, or degradation. The resultant string was concatenated with terms related to human responses to climate change such as resilience, response, adaptation, coping, and coping.

The full text and citation data of the retrieved documents were downloaded from WoS for analysis using VOS viewer. The initial search was conducted on April 12, 2021, and returned 139 articles. Of different WoS Document types, these included Articles, Review Articles, Proceedings Papers, Book Chapters, Data Papers, and Letters. Titles and abstracts of these articles were screened, and 133 articles that were related to the role of ILK for climate change adaptation were selected for final bibliometric analysis using VOS viewer and for further assessment. The exclusion criterion was an irrelevance to the role of ILK for climate change adaptation. Results of the term co-occurrence analysis are presented as a network of nodes and links, where node size is proportional to the frequency of term co-occurrence and link strength is proportional to the strength of the connection between two terms. This potentially indicates concentrations of key themes that have received more attention in the literature and the relative importance of identified themes based on the frequency of occurrence in the literature. Terms that have co-occurred more frequently establish thematic clusters that are shown in different colours on the term map. It is worth noting that, while term co-occurrence analysis provides insights into major thematic focus areas and potential links between different terms, interpretation of the results requires expert knowledge of ILK together with further interpretation of the literature. Overall, this method is useful for gaining an overall understanding of the thematic focus of research fields and relationships between key concepts, geographical and sectoral concentrations, while providing direction for further investigation of the substance of articles under consideration. Given the software limitations, only documents indexed in the WoS were included in the term co-occurrence analysis. We therefore also searched for other possibly relevant documents (including grey literature) using Google Scholar and the same search terms and used the combination of peer-reviewed and grey literature to develop the final set of literature for analysis.

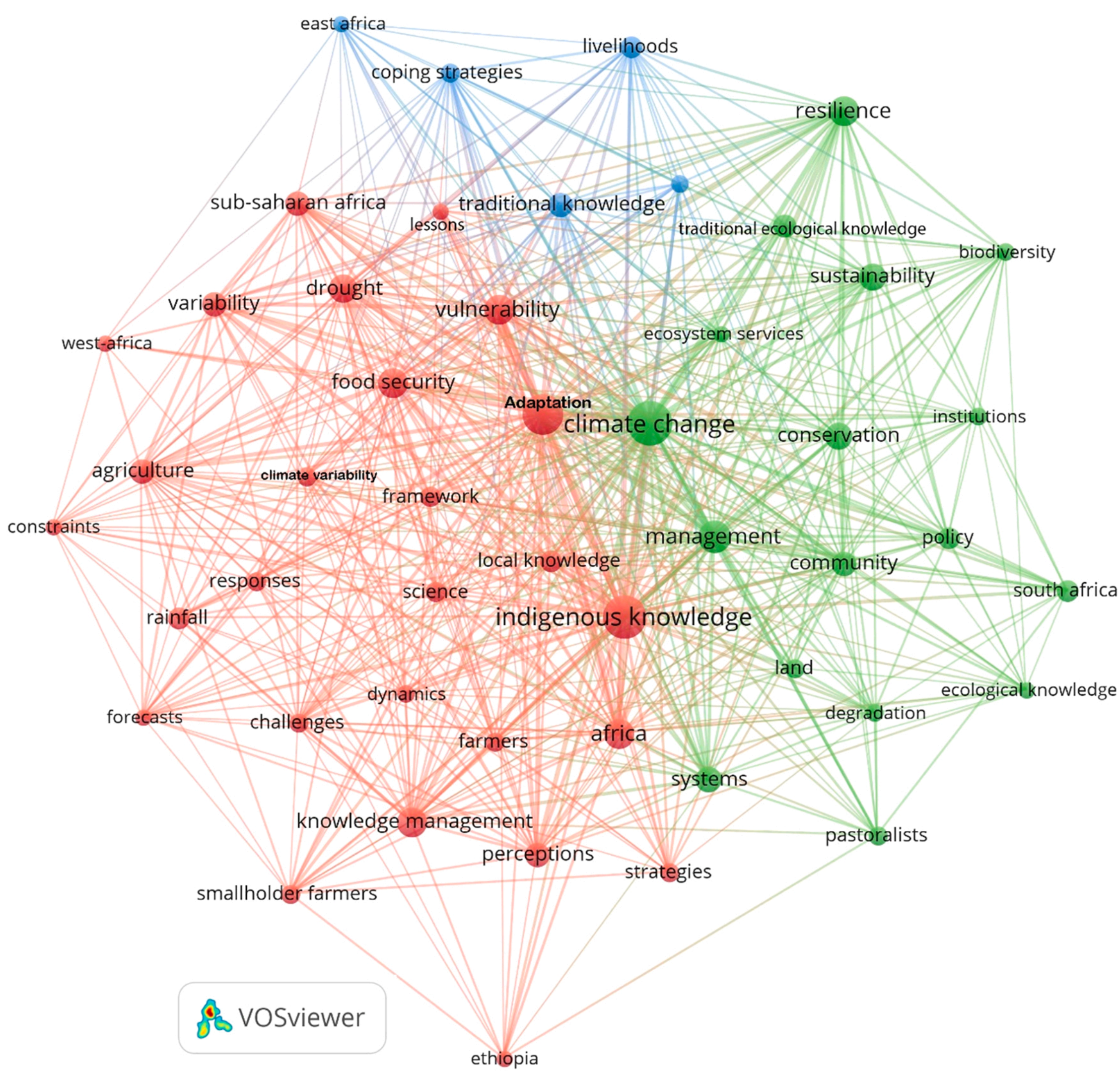

Fig. 1. Results of term co-occurrence analysis showing the commonly used terms and their interactions.
Source: authors(2021).

4. Results and discussion

4.1. Bibliometric analysis

From the bibliometric analysis (Figure1), the role of ILK in adaptation was found to be mostly associated with food security, weather, and climate forecasting, which is used for adaptation decision support, disaster management, and forest resource management. Most of the research on ILKs in Africa has been done in Eastern and Southern Africa. The important association of the term "knowledge management" and its strong connections with the other keywords shows that knowledge management is essential to ensure ILK is effectively utilized for climate change adaptation.

Results of the co-occurrence analysis for a minimum threshold of 15 keywords are shown in Fig. 1. Three major thematic clusters can be identified from this analysis. The largest cluster (red colour) is mainly focused on issues related to the use of Indigenous knowledge in agriculture, indicating that research has mainly focused on this issue. The second major cluster (green colour) is focused on issues related to biodiversity conservation and land degradation. This implies that Indigenous knowledge has also been widely used to prevent land degradation and biodiversity loss and ensure the sustainability and resilience of ecosystems. Finally, the third cluster (in blue) shows that traditional knowledge has also been used for enhancing coping capacity and livelihood options. Interactions between terms in these clusters that elaborate on the role of ILK in climate change adaptation will be further discussed below.

The analysis showed that, apart from the terms included in the search string, terms such as forecast, adaptation, resilience, management, vulnerability, food security, knowledge management, sustainability, conservation, agriculture, community, perceptions, livelihoods, policy, rainfall, farmers, land, pastoralists, and smallholder farmers showed were frequently mentioned. This indicates that collective memories of communities and ILK have particularly been associated empirically in the literature with efforts to enhance adaptation, particularly to water stress, and to improve ecosystem and biodiversity conservation that are critical for food and livelihood security. Fig. 1 also indicates that literature has mainly focused on ILK that has been used by farmers and pastoralists groups and very little observation has been made of the application of ILK outside these main uses. This indicates the role and importance of ILK for farmers and pastoralists (Orlove et al., 2010). Likewise, the term co-occurrence analysis also illustrates the same farmers and pastoralists are the most vulnerable to climate-related risks. Investigating the literature further, this is due to both the direct impacts of climate change and both lack of supportive policy and framework, and context-specific downscaled climate services, particularly for weather forecasting. Contextually situated, livelihoods and food security are further challenged by resources degradation, loss of biodiversity, and decline of ecosystem services, which act in concert to constrain their adaptation or coping responses.

Fig. 1 indicates a major focus in the literature has been on how ILK has been used by farmers and pastoralists highlighting the high reliance of such groups on ILK for decisions relating to rain-fed agriculture (Orlove et al., 2010). In Malawi, research validates the accuracy of farming communities' perception of climatic changes and demonstrates how local knowledge can be used to improve adaptation to droughts and rainfall variability by measures such as shifting from aliens or non-native crops to native ones and investing in local livestock that are more resistant to water stress (Kalanda-Joshua et al., 2011; Nkomwa et al., 2014). Similar findings have been reported in Burkina Faso regarding the convergence of local farmers' rainfall forecasts with scientific ones and the utility of rainfall prediction based on Indigenous knowledge for taking adaptive measures (Roncoli et al., 2002). Elsewhere, in central Tanzania and Uganda, farmers rely on their familiarity with seasonal patterns and use local knowledge and experiences to practice timely cultivation in response to rainfall variability and this enhances their coping capacity, thereby ensuring their livelihood and food security (Orlove et al., 2010; Slegers, 2008).

Close connection between ecological knowledge, land, and degradation may be interpreted as to its significance for mitigating land degradation. This could, for instance, be achieved through temporal restrictions on resource exploitation based on local knowledge and experiences of the state of the ecosystem as practiced by herders in the African Sahel (Berkes et al., 2000). For instance, Indigenous knowledge has been effective in implementing a fallow cultivation system that contributes to forest management, thereby ensuring the provision ecosystem services that are critical for enhancing adaptive capacity and coping with climatic stressors (Nyong et al., 2007).

The important position of the term 'knowledge management' and its strong connections with the other keywords associated with adaptation shows that proper knowledge management is essential to ensure Indigenous knowledge is effectively utilized for climate change adaptation. A case study from Malawi demonstrates enhancing knowledge management through facilitating interactions between various stakeholders such as scientists, farmers, pastoralists, and policy makers is important and can ensure effective integration of local knowledge into adaptation plans and policies (Kalanda-Joshua et al., 2011; Nkomwa et al., 2014; Roncoli et al., 2002). It is argued that integrating Indigenous climate knowledge into management practices and modern technologies can also fine-tune scientific predictions and measures and enhance their local buy-in through improved communication mechanisms (Nyong et al., 2007; Orlove et al., 2010). Local consumption can be further strengthened by engaging local stakeholders in the adaptation planning processes. Such processes wherein locals can participate in planning and implementation stages also enhance local capacities and facilitate long-term sustainability and resilience benefits (Nyong et al., 2007). Indeed, traditional ecological knowledge can provide multiple co-benefits (Nyong et al., 2007) and this is reflected in the term co-occurrence analysis that, among other things, shows strong connections between traditional ecological knowledge and terms such as resilience, sustainability, biodiversity, and ecosystem services.

4.2. Case studies

In order to elaborate on how ILK is relevant in adaptation to climate change in Africa, several case studies drawn from 19 countries across the continent have been described in more detail (Fig. 2).

African farmers and pastoralists are not passive victims of the adverse impacts of climate change and extremes. Rather, ILK has been used by these actors to adapt to climate change and conserve their environment in various parts of Africa. For example, Mafongoya and Ajayi (2017) reported various situations where ILK was used in addressing climate-related challenges across several regions of Africa including in Lesotho, Malawi, Nigeria, Zimbabwe, and Zambia. Case studies from across the continent indicate that the communities are aware that a well-conserved environment helps them reduce the risk famine, food insecurity, and poverty-associated climate variability and disasters (Mafongoya and Ajayi, 2017). ILK has helped communities develop a variety of measures to survive climate changes, such as growing drought tolerant and early maturing Indigenous crops, gathering wild fruits and vegetables, cultivating wetlands, and diversifying and selling livestock.

The phonology of Indigenous tree varieties such as *Cyphostemmao rondo*, and *Acalypha fruticosa* in Kenya (Kitinya et al., 2012), *Milicia excels* in Uganda (Radeny et al., 2019), and *Vachellia tortilis* and aloe tree across multiple countries (Ayal et al., 2015) are used to forecast and adjust community farming activities. In Ethiopia, pastoralists and agro-pastoralists used the behaviour and activities of biotic and abiotic indicators such as insects, birds, trees, and other wildlife (Balehegn et al., 2019; Ayal et al., 2015), the moon-star alignment, and animal intestine interpretation to forecast long-term and short-term weather conditions to inform adjustments to farming activities and rangeland

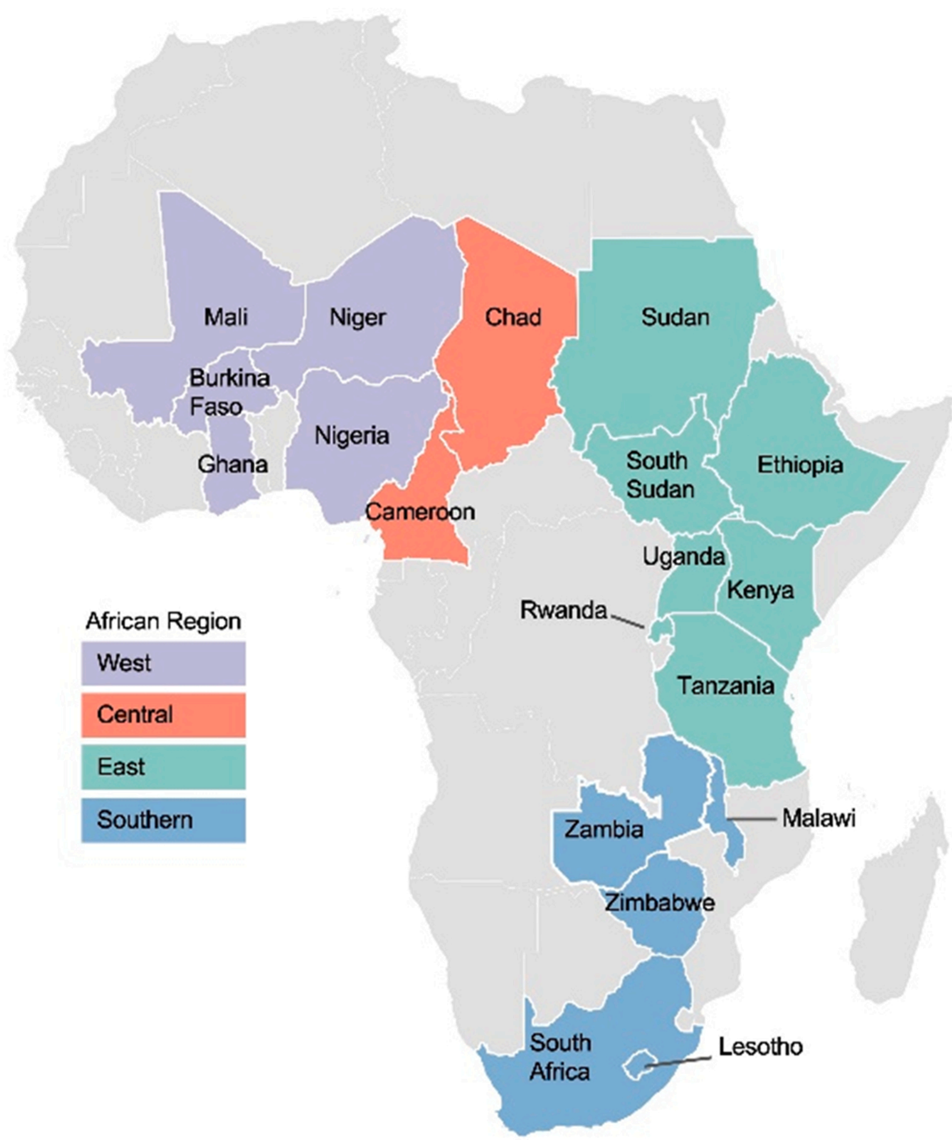

Fig. 2. Examples of Indigenous Knowledge and Local Knowledge are drawn from 19 countries across Africa. Visualisation indicates the four regions of Africa from which the case studies are drawn. Note: IK and LK practices are spread across multiple countries, (e.g., the meteorological inference drawn from observation of plants and behaviour of animals common to Ethiopia, Tanzania, and Uganda, see Table 3); IK and LK practices are not necessarily evenly spread across any single country (e.g., observations of flowering of peach trees localised to Swayimane, South Africa, see Table 3).

management systems (Radeny et al., 2019; Ayal et al., 2015). In the Sahel region, ILK has been used to manage climate-related risks to water and agricultural production. For example, an Indigenous water harvesting technique originating from the Sahel and known as zai pits or tassa helps restore degraded drylands through climate-smart agriculture (UNHCR, 2020). The design and positioning of the pits ensures they capture erratic rainfalls allowing infiltration of water to irrigate the seeds, which increases soil fertility and crop yields.

In general, ILK weather and climate forecasting plays a crucial role and is trusted to reduce climate-related risks in Africa. In Kenya, in addition to weather and climate forecasting, ILK is applied for land use and rangeland management to maximize milk production and hence, ensure food security and alleviate poverty (Amwata, 2013). In Ethiopia ILK is also used to warn and manage risks related with flood, conflict, geo-hazards, and livestock and human health problems (Ayal et al., 2015). Farmers in Cameroon value their ability to accurately observe and anticipate local conditions in various ways to serve their local realities more aptly than outside forecasts (Tume et al., 2020). Further, community-based adaptation in Zimbabwe has been shown to reduce the vulnerability as well as improve the resilience of the local people to climate variability and change and these measures have helped sustain Indigenous practices (Mugambiwa, 2018). Table 3.

As previously noted, farming communities' perception of climatic changes has been validated with meteorological records to demonstrate the accuracy of locally appropriate ILK (Kalanda-Joshua et al., 2011; Nkomwa et al., 2014). When applied to decision making informed by ILK, this perception accuracy has leveraged improved adaptation to droughts and rainfall variability by measures such as shifting from non-indigenous to native crops and investment in locally bred livestock that are more resistant to water stress (Kalanda-Joshua et al., 2011; Nkomwa et al., 2014). Similar findings have been reported in Burkina Faso regarding the convergence of local farmers' rainfall forecasts with scientific ones and the utility of rainfall prediction based on ILK for taking adaptive measures (Roncoli et al., 2002). Elsewhere, in central Tanzania and Uganda, farmers rely on their familiarity with seasonal patterns and use locally informed ILK and experiences to practice timely cultivation in response to rainfall variability and this enhances their coping capacity, thereby ensuring their livelihood and food security (Orlove et al., 2010; Slegers, 2008; Nkuba et al., 2020b).

Yet Indigenous weather forecasting is becoming less effective among the *Haya* people in Tanzania. In views of the *Haya community*, in the past, it was possible to predict the weather of the following day because there were specific periods for certain rainfall levels and temperatures, but in recent years climatic variability has complicated the legibility and

Table 3
Some situations where ILK has been used in Africa.

Indigenous and local knowledge	Where it is found	Situation where it has been used	Strategies	Reference/Literature where it is documented
Indigenous agronomic practices	Ghana (Gowrie Kunkua and SoeKabre communities) 75 HHI*	Organic manure		(Aniah et al., 2019)
Biotic Plant phenology Animal behaviour Bird migration Wind direction	Western Uganda (Ruteete) 60 Interviews Rakai District, Uganda 150 HHI*, 2 FGDs*, 15 KI*	Weather forecasting and understanding seasonal changes. Fine tuning scientific forecasts	Information in farming (onset and cessation) Composite decision making in farming	(Nyakaisiki et al., 2019) (Orlove et al., 2010)
Plant phenology (Flowering of peach trees)	Swayimane, South Africa 100 HHI*, 3 FGDs*	Weather prediction Planning farm activities Adaptation	Water harvesting Water conservation Irrigation planning	(Basdew et al., 2017)
Plant phenology Animals, Weather and cosmological indicators	Gwanda, Zimbabwe Literature review	Forecasting Malaria	Development of disease calendars Development of a community-based malaria early warning system	(Macherera and Chimbari, 2016)
Trees	Masvingo, Zimbabwe 60 HHI* 15 KI*	Management of forest resources	Minimal damage to the environment	(Tanyanyiwa and Chikwanha, 2011)
Meteorological, Plant-based and behaviour of animals	Ethiopia 200 HHI*, 4 FGDs*, 8 KI* Tanzania 77 HHI*, 3 FGDs* Uganda: 120 HHI*	Decision support in Agriculture	Availability of location-specific forecasts	(Radeny et al., 2019)
Indigenous crop varieties Organic manure (crop residue and cow dung)	Rwanda 100 KI*	Crop productivity	Increased resilience	(Taremwa et al., 2016)
Traditional Crop varieties	Nandi, Kenya Mixed HHI, KI & FGDs	Crop productivity	Increased food security	(Songok et al., 2011) (Nakashima et al., 2012)
Tree Phenology Behaviour of animals, crickets, and ants	Chikhwawa district, Malawi 10 KI, 3 FGDs, 19HHI	Decision support in crop productivity	Management of risk	(Nkomwa et al., 2014)
Traditional water dams	Tanzania Literature review	Scheduled Fishing time Traditional Farming	Fish regeneration Environmental protection	(Kihila, 2017)
Traditional diviners to control strong wind	Missenyi and Muleba Districts, Tanzania Mixed HHI, KI & FGDs	Means to control the blowing strong winds	Protection of the home garden with bananas	(Theodory, 2020)

* Household Informant (HHI), Key Informants (KI), Focus group discussion (FGD)

interpretation of prediction signs (Theodory, 2016).

Close connections between ecological knowledge and local resource allocations are used for better land use management outcomes. For example, temporal restrictions on resource exploitation based on locally informed ILK and experiences of the state of the ecosystem as practiced by herders in the African Sahel (Berkes, et al., 2000). Further, ILK has been effective at implementing a fallow cultivation system that contributes to forest management, thereby ensuring the provisioning ecosystem services that are critical for enhancing adaptive capacity and coping with climatic stressors (Nyong et al., 2007).

There is empirical evidence of the successful integration of ILK with the formal adaptation strategies to climate change and other development endeavours at the local scale (Briggs and Sharp, 2004; Theodory, 2020). Integrating Indigenous climate knowledge into management practices and modern technologies can also fine-tune scientific predictions and measures and enhance their local buy-in through improved communication mechanisms (Nyong et al., 2007; Orlove et al., 2010, Leal Filho, Matandirotya, Lütz et al., 2021). Thus, greater efforts to identify, document and validate the potentials that ILK may contribute to development, particularly on climate change adaptation is therefore highly important for socially engaged research on Africa with the potential to contribute towards climate action on the continent. This can be achieved by engaging local stakeholders in the adaptation planning processes. Such processes wherein locals can participate in planning and implementation stages also enhance local capacities and facilitate long-term sustainability and resilience benefits (Nyong et al., 2007). Indeed traditional ecological knowledge can provide multiple co-benefits (Nyong et al., 2007) and this is reflected in the term co-occurrence analysis that, among other things, shows strong connections between traditional ecological knowledge and terms such as resilience, sustainability, biodiversity, and ecosystem services.

5. Conclusions

Africa is rich in time-tested and context-specific ILK used to respond to climatic variability and change. This intangible asset is not limited to merely coping with climate impacts as ILK has contributed substantively towards climate change adaptation. It has been used in different expressions including forecasting and managing natural and human-induced hazards. The ILKs are inbuilt into local culture and hence, accepted by the local community to rescue their property and life from climate-related hazards including drought, floods, diseases, conflict, manage resources, and ensure food security (Tengö et al., 2014). While ILK has the potential to fill the information gap in modern scientific knowledge, currently ILK has faced serious challenges due to a lack of proper knowledge transfer, documentation, dissemination, the influence of religion and education, lack of recognition of forecasters, and environmental degradation and extinction of biological indicators.

This paper has some limitations. The first one is that it could only sample a set of examples of ILK in practices in some countries, and was unable to cover the whole of Africa. In addition, we have referred to documented and verifiable ILK practices and did not focus on undocumented ones. Finally, the study looked at ILK in a climate change context and did not investigate other themes.

Despite these limitations, the paper provides a welcome addition to the literature since it describes various ILK tools and processes, some of which are playing a key role in supporting African communities to cope with changing climate conditions.

Apart from developments in Africa, ILK is also widely practiced in other regions, such as in Latin America, where there are evidences that ILK can collaborate with scientific knowledge to advance understanding of the slow-onset effects of climate change adaptation in the region (Iwama et al., 2021). Similar evidences are also seen in Asia. A study undertaken by Madhanagopal and Pattanaik (2020) demonstrated some means via which fishermen's local knowledge and perceptions in the face of climate change may assist their work. In the Pacific region, many island communities have been successfully using their ILK to cope with extreme weather conditions (McNamara and Prasad, 2014).

A final conclusion that can be made is that climate change has itself had a negative impact on the accuracy of ILK, which has negatively affected perceptions of its efficacy. Thus, development interventions, particularly those associated with weather and climate forecast services should aim to preserve and consider the ILK in their planning and operational activities (IPCC, 2022). Blending ILK with scientific knowledge could help the services provision implementation to be cost-effective and successful on one hand, and also encourage Indigenous communities to develop senses of ownership and active contribution to the sustainability of future interventions.

CRediT authorship contribution statement

Walter Leal Filho: Conceptualisation of the paper and structure, visuliazation, conclusion. **Jelena Barbir:** coordination of the manuscript, introduction, results and dsicussion development, paper structure, **Juliet Gwenzi:**, contribution to introduction, visuliazation, **Desalegn Ayal:** elaboration of the results and discussion text, contribution with data collection, **Nicholas P. Simpson:**, elaboration of the results and discussion text, **Lydia Adeleke:**, contribution with data collection, assistance with data processing, **Behiwot Tilahun:** contribution to introduction, **Innocent Chirisa:** contribution to introduction, contribution with data collection, **Shine Francis Gbedemah:** contribution to introduction, contribution with data collection, **Daniel M. Nzengya:** contribution with data collection, assistance with data processing, **Ayyoob Sharifi:** methodology, elaboration of literature review, **Theobald Theodory:** contribution with data collection, assistance with data processing, **Sidat Yaffa:** contribution with data collection, assistance with data processing.

Appendix

TS= (("indigen* knowledge" OR "indigen* research" OR "indigen* practice*" OR "indigen* ritual*" OR "indigen* belief*" OR "indigen* institutions" OR "indigen* value*" OR "indigen* norm*" OR "indigen* skill*" OR "traditional ecological knowledge" OR "tradition* knowledge" OR "tradition* research" OR "tradition* practice*" OR "tradition* ritual*" OR "tradition* belief*" OR "tradition* institutions" OR "tradition* value*" OR "tradition* norm*" OR "tradition* skill*" OR "aborigin* knowledge" OR "aborigin* research" OR "aborigin* practice*" OR "aborigin* ritual*" OR "aborigin* belief*" OR "aborigin* institutions" OR "aborigin* value*" OR "aborigin* norm*" OR "aborigin* skill*" OR "tribal knowledge" OR "tribal research" OR "tribal practice*" OR "tribal ritual*" OR "tribal belief*" OR "tribal institutions" OR "tribal value*" OR "tribal norm*" OR "tribal skill*" OR "native knowledge" OR "native research" OR "native practice*" OR "native ritual*" OR "native belief*" OR "native institutions" OR "native value*" OR "native norm*" OR "native skill*" OR "folk knowledge" OR "multiple knowledge systems") AND ("clim* change" OR "global warming" OR "climate variability" OR "extreme event" OR "extreme weather" OR "heat wave" OR "sea level*" OR "flood*" OR "drought" OR "storm*" OR "erosion" OR "desertif*" OR "degrad*") AND ("adapt*" OR "resilien*" OR "respon*" OR "coping" OR "cope") AND ("africa*")).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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