

Filho, Walter Leal et al.

Article — Published Version

Is indigenous knowledge serving climate adaptation? Evidence from various African regions

Development Policy Review

Provided in Cooperation with:

John Wiley & Sons

Suggested Citation: Filho, Walter Leal et al. (2023) : Is indigenous knowledge serving climate adaptation? Evidence from various African regions, Development Policy Review, ISSN 1467-7679, Wiley, Hoboken, NJ, Vol. 41, Iss. 2, <https://doi.org/10.1111/dpr.12664>

This Version is available at:

<https://hdl.handle.net/10419/287897>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.















You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<http://creativecommons.org/licenses/by-nc/4.0/>

Is indigenous knowledge serving climate adaptation? Evidence from various African regions

Walter Leal Filho^{1,2}  | Franziska Wolf³  | Edmond Totin⁴  |
Luckson Zvobgo⁵  | Nicholas Philip Simpson⁶  |
Kumbirai Musiyiwa⁷  | Jokastah W. Kalangu⁸  | Maruf Sanni⁹  |
Ibidun Adelekan¹⁰  | Jackson Efitre¹¹  | Felix Kwabena Donkor¹²  |
Abdul-Lateef Balogun¹³  | Serafino Afonso Rui Mucova¹⁴  |
Desalegn Yayeh Ayal¹⁵ 

¹International Climate Change Information and Research Programme, Hamburg University of Applied Sciences, Germany

²Department of Natural Sciences, Manchester Metropolitan University, Manchester, UK

³Hamburg University of Applied Sciences, European School of Sustainability Science and Research, Germany

⁴Ecole de Foresterie Tropicale, Université Nationale d'Agriculture du Benin, Benin

⁵Climate System Analysis Group (CSAG), University of Cape Town, Cape Town, South Africa

⁶African Climate and Development Initiative, University of Cape Town, Cape Town, South Africa

⁷Department of Crop Science and Post-Harvest Technology, School of Agricultural Sciences, Chinhoyi University of Technology, Chinhoyi, Zimbabwe

⁸School of Water Resource Science Technology, South Eastern Kenya University, Nairobi, Kenya

⁹National Centre for Technology Management (Federal Ministry of Science and Technology), Obafemi Awolowo University, Ile-Ife, Nigeria

¹⁰Department of Geography, Faculty of the Social Sciences, University of Ibadan, Ibadan, Nigeria

¹¹Makerere University, College of Natural Sciences, Department of Zoology, Entomology and Fisheries Sciences, Kampala, Uganda

¹²Faculty of Geography Education, University of Education, Winneba, Ghana

¹³Geospatial Analysis and Modelling Research (GAMR) Group, Department of Civil & Environmental Engineering, Universiti Teknologi PETRONAS (UTP), Perak, Malaysia

¹⁴Faculty of Natural Sciences, Lúrio University, Mozambique

¹⁵Addis Ababa University, College of Development Studies, Center for Food Security Studies (CFSS), Addis Ababa, Ethiopia

Correspondence

Franziska Wolf, Hamburg University of Applied Sciences, European School of Sustainability Science and Research, Ulmenliet 20, 21033 Hamburg, Germany.
Email: franziska.wolf@haw-hamburg.de

Summary

Motivation: Communities across the global south use their rich indigenous and local knowledge (ILK) to predict weather events and climate hazards. ILK may assist efforts to address climate change challenges in Africa and make subsequent decisions regarding climate adaptation.

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2023 The Authors. *Development Policy Review* published by John Wiley & Sons Ltd on behalf of ODI.

Funding information

UK government's Foreign, Commonwealth & Development Office; International Development Research Centre, Grant/Award Number: Grant number 109419-001; UK government; International Development Research Centre

Purpose: The article documents evidence of the ILK's potential in reducing vulnerability to climate change and/or improving the resilience of communities. The study also reflects on major barriers that hinder the improved mainstreaming of ILK into adaptation strategies.

Methods and approach: The present study uses two main methods: a literature review and a presentation of case studies from a sample of African countries where ILK informs adaptation options, including indigenous land-tenure practices and weather prediction. The selected case studies highlight the historical legacy of ILK and its effectiveness in reducing vulnerability and the impacts of climate change.

Findings: The results indicate that, despite being acknowledged as a valuable resource for climate adaptation, current national adaptation policies on the African continent still show serious gaps in effectively integrating ILK systems within the legal frameworks to reduce vulnerability.

Policy implications: ILK should be better integrated with modern climate change adaptation strategies to anticipate more effective responses. Both rural communities and relevant government agencies should complement the use of ILK with climate change strategies, so as to maximize its contribution to the effective implementation of climate change policies.

KEYWORDS

adaptation, Africa, climate change, indigenous knowledge, local knowledge, weather forecasting

1 | INTRODUCTION

Traditionally, African communities rely on indigenous and local knowledge (ILK) to anticipate or respond to climatic variability (Apraku et al., 2021; Donkor & Mearns, 2022; Mafongoya & Ajayo, 2017; Zvobgo et al., 2022). The use of ILK in farming systems, including livestock management, is widespread across Africa, such as in early-warning systems (Jiri et al., 2015; Mapfumo et al., 2016; Soropa et al., 2015) or as indicators of the quality of the rainy season (Mengistu, 2011; Soropa et al., 2015). In Kenya, the flowering of coffee trees is an indication that the rainy season is near (Kangalawe et al., 2011), while the blossoming of peach trees in Botswana, South Africa, Tanzania, and Zimbabwe is linked to the beginning of the rainy season (Kolawole, 2014; Mapfumo et al., 2016). Soil-fertility management is another area in which ILK is used, whereby indigenous farmers classify soils according to their potential for crop production and crop yield (Osbahe & Allan, 2003). For many decades, ILK land-management practices have also been shown to conserve carbon in soils (Schafer, 1993).

There is a growing interest in documenting ILK for its intrinsic heritage value and its practical use in potentially supporting relevant and locally acceptable climate change adaptation (Audefroy & Cabrera Sánchez, 2017; Leal Filho, Matandirotya, et al., 2021; Leal Filho, Ogogue, et al., 2021; Mugambiwa, 2018). Though a great deal of empirical research has been devoted to ILK, this type of knowledge has not yet been adequately articulated in adaptation and mitigation planning, especially in the global south (Ajani et al., 2013; Donkor et al., 2019; Ford, Cameron, et al., 2016; Leal Filho, Totin, et al., 2021; Zvobgo et al., 2022). The main criticism of indigenous and local knowledge is in its locally specific influence, endemic to a social group, which may limit its scalability (Apraku et al., 2021). ILK is also predominantly preserved in the memories of elders and is handed down orally to the following generation (Battiste, 2007), but the intergenerational transmission of knowledge is currently under threat, particularly due to urbanization and the perceived declining reliability of ILK by the younger population (Fernández-Llamazares et al., 2015; Rankoana, 2022). The literature also points to some barriers that constrain the deployment of ILK in support of climate change adaptation. The validation of ILK is considered a major barrier due to its patterns that

differ from scholarly theoretical and methodological approaches. For example, indigenous and local systems are often embedded in tacit knowledge, i.e. oral recitations, songs, dances, hunting, or farming practices, etc. (Brondízio et al., 2021; Ohajunwa & Mji, 2018).

Because of these limitations, modern knowledge systems are often considered to be far more reliable. The challenge to ILK is in its preservation and transmission, together with a demonstration of its effectiveness. At the same time, the knowledge deficit on climate risk is compounded by the limited capacity of modern knowledge systems to capture the local context and community values and aspirations (Ford, Stephenson, et al., 2016). This poor articulation of local needs and expectations hinders the increased use of seemingly adequate scientific-led technologies (Kebebe et al., 2015). The tension between the two knowledge systems suggests the need for climate strategies to combine, in a balanced way, both traditional and modern knowledge, particularly where they complement each other.

The impacts of climate change on local communities go beyond immediate threats to food supply, for which there is evidence that climate change has reduced total agricultural productivity growth in Africa by 34% since 1961, more than in any other region (Ortiz-Bobea et al., 2021). Climate change also affects water availability (Biao, 2017; Descroix et al., 2018; Thompson et al., 2017), health (Agusto et al., 2015; Beck-Johnson et al., 2017), and human settlements, which are particularly exposed to floods, droughts, and heat waves (Douglas et al., 2008; Kundzewicz et al., 2014). Acknowledging the value of ILK for a better-integrated adaptation to climatic risks, especially in regions that rely on rain-fed agriculture, may contribute to the overall goal of sustainable climate adaptation—Sustainable Development Goal (SDG) 13. With the sixth assessment of the Intergovernmental Panel on Climate Change (IPCC), there is already an attempt to articulate the complementarity between ILK and scientific knowledge (Leal Filho, Barbir, et al., 2022), whereas previous assessment reports have largely excluded ILK because of a lack of empirical evidence to demonstrate acceptable levels of validity (Alexander et al., 2011).

The overlapping concepts of “local” and “indigenous” knowledge have been used interchangeably in the literature. Indigenous knowledge (IK) is embedded in specific systems of cultural meanings or restricted to a particular geographic location (Mistry, 2009). Rýser (2011) defined IK “as the knowledge that an Indigenous (local) community accumulates over generations of living in a particular environment.” Darr and Mears (2017) speak of local knowledge as being deeply rooted in a specific social context based on practical experience. Integrating both terms, the United Nations Educational, Scientific and Cultural Organization (UNESCO) suggests that local IK refers to the understandings, skills, and philosophies developed by societies with long histories of interaction with their natural surroundings (IPCC, 2014, 2019; UNESCO, n.d.). In this article, and in line with IPCC terminology, the combined terms are referred to as ILK and are used interchangeably due to the long history of local knowledge in the case studies identified, where, in contrast to other regions of the world, it is generally challenging to disaggregate local knowledge from IK.

This article focuses on case studies across Africa where the deployment of ILK is linked to reductions in poverty or vulnerability to climate change, and it reflects on the overall outcomes for climate change adaptation. It documents evidence of the ILK's potential in reducing vulnerability to climate change and/or improving the resilience of communities. The study also reflects on major barriers that hinder the improved mainstreaming of ILK into adaptation strategies and suggests some measures to protect indigenous peoples' interests and stop “side-lining and marginalising ILK as negligible or insignificant” (Leal Filho, Matandirotya, et al., 2021).

2 | METHODOLOGY

There is a perceived need for studies aiming to identify how ILK may assist efforts to address climate change challenges in Africa. But in order to succeed, research should not only identify current trends, but also establish a framework that allows lessons to be learned. Consistent with this approach, this article deploys two approaches: (1) a literature review; and (2) case studies for weather-forecasting analysis. Combined, these two approaches cater for a greater understanding of how ILK is being used in support of climate change adaptation.

2.1 | Literature review

An analysis of the literature was undertaken to capture insights on ILK, based on selected academic literature published in peer-reviewed journals. There was no time limit for the selection of the publications. This choice was made purposely to increase the chances of including all relevant literature. The selection of the cases was guided by the following research questions: (1) what knowledge do community members use to address climate challenges? (2) what is the rationale of ILK? and (3) how effective is this knowledge in predicting and coping with climate risk?

The journal articles were identified through Web of Science and Scopus. Topic = (local OR indigenous OR traditional AND knowledg* AND adapt* AND Africa AND Sector).

AFRICA – afric* OR algeria OR angola OR benin OR botswana OR “burkina faso” OR burundi OR “cabo verde” OR cameroon OR “central african republic” OR chad OR congo OR “democratic republic of congo” OR “cote d’ivoire” OR djibouti OR egypt OR “equatorial guinea” OR eritrea OR eswatini OR ethiopia OR gabon OR gambia OR ghana OR guinea OR guinea-bissau OR kenya OR lesotho OR liberia OR libya OR malawi OR mali OR mauritania OR morocco OR mozambique OR namibia OR niger OR nigeria OR rwanda OR senegal OR “sahrawi arab democratic republic” OR “sierra leone” OR somalia OR “south africa” OR “south sudan” OR sudan OR tanzania OR togo OR tunisia OR uganda OR zambia OR zimbabwe.

Sector = agricultur* OR “water resource” OR forest* OR energy OR “human health.”

Only empirical articles published in English that focused on ILK use to serve human responses to climate challenges were considered. Publications in other major languages used across the continent (i.e. Arabic, French, and Portuguese) were not included in this assessment. In addition, review articles and more theoretically grounded publications were also excluded. The review yielded 924 publications, from which 557 were excluded as their scope did not match the inclusion criteria, and 367 were considered for further ILK analysis.

2.2 | ILK case studies for weather forecasting

Case studies that assessed the reliance of ILK forecasts or that indicated the climate indices or hazard forecasts were prioritized. The cases were also selected based on the ILK-related adaptation response type that contributed to one of the following: (1) poverty reduction; (2) improvement in the livelihoods of the indigenous groups and communities; or (3) evidence of risk reduction, either directly or perceived by the authors. Ten case studies that fit the above criteria were selected for analysis (see Table 1).

3 | RESULTS—ILK FOR CLIMATE ADAPTATION

Table 1 also summarizes the actual ILK adaptation types and responses as identified in the study. It demonstrates how African communities use ILK to predict weather and climate hazards and points out the role of these predictions in decision-making that is key for climate adaptation. It also provides some quantified insights into how smallholders rely widely on ILK for farming-related decisions, e.g. timing of planting, seed varieties, water and pasture storage, preservation of food and seeds, relocations, and holiday and event planning. Overall, the cases illustrate a wide variety of adaptive practices used by farmers, fisherfolk, and communities. The sample also shows a specific geographical focus on countries in West and Southern Africa.

Concerning shorter-term predictions linked with climate variability, as illustrated by Table 1, ILK of the natural environment has proven helpful for farmers and pastoralists as early warning and alert signs. Even so, the evidence of effectiveness is not generalizable across all geographic areas or indicators. In sub-Saharan Africa, established forms of ILK include observations of and inferences drawn from animal behaviour, cloud type and cover, and specific vegetation phenomena. The early-warning alert signs, or indicators have been useful in specific contexts for predicting weather conditions and/or climatic impacts, including the onset of rains, rainfall yield (high or low amount of rainfall),

TABLE 1 Common indicators used by communities and smallholder farmers for weather and climate hazard prediction informed by indigenous and local knowledge possessed across Africa.

No.	Indicator category	Indicator type	Weather/ Climate hazard	Economic activity	Region/Country	Implications on adaptation	Primary focus of adaptation action	Relevance/ Reliance	Source
1	Flora; Fauna	Animal behaviour, e.g. cattle, wild animals and insects; Reading of local plant body languages.	Short-term weather, rains, season quality, droughts	Pastoral	Borana (Ethiopia)	Pastoralists adjust their farm decisions and save pasture and water if drought is predicted.	Vulnerability reduction, risk reduction and cost-efficient management	96% of respondents	(Ayal et al., 2015)
2	Weather/ Meteorological; Fauna; Astrological	Cloud type and cover, direction and strength of wind, very high night temperatures. Animal behaviour included birds, insects, and some large animals. Flowering of specific trees as indicative of the onset of the rainy season. Interpreting alignment of the moon and stars, size and appearance of the star, and appearance and form of cloud cover.	Seasonal quality forecasting, onset rains, particular storms, long-term forecasting	Smallholder farming, pastoral	Borana (Ethiopia), Lushoto (Tanzania) and Hoima and Rakai (Uganda)	Use IK forecast to plan agricultural calendar among the planting dates, possible seed variety based on predicted season length and quality.	Poverty reduction through risk diversification	In Borana, Ethiopia, IK weather forecasting is the main source of weather information (97%), in Lushoto, Tanzania 68% use IK forecasts	(Radeny et al., 2019)
3	Flora; Fauna; Astrological	Fruit-tree production, behaviour of birds and insects.	Long- and short-term rainfall predictions; onset rain, drought.	Smallholder farmers	Chiredzi, Zimbabwe	Farmers adopted different strategies in crop, field, and farm management practices to cope.	Vulnerability reduction through risk diversification		(Jiri et al., 2015)
4	Fauna; Flora; Astrological	Animal behaviour – the behaviour of ducks and cows. Tree behaviour - mango and tamarind trees flowering, new leaves for Baobab tree. Dark clouds and wind speed and direction to predict the onset of the rains.	Storms, onset of the rainy season.	Smallholder farmers	Kilifi, Kenya	Make key planting dates for various crops.	Vulnerability and risk reduction through foresight planning	62% of the farmers rely on IK forecasting	(Mwaniki & Stevenson, 2017)

(Continues)

TABLE 1 (Continued)

No.	Indicator category	Indicator type	Weather/Climate hazard	Economic activity	Region/Country	Implications on adaptation	Primary focus of adaptation action	Relevance/Reliance	Source
5	Weather/ Meteorological; Fauna; Fauna; Astrological	Constellation of stars, animal behaviour, cloud cover and type, blossoming of certain indigenous trees, appearance and disappearance of reptiles, to migration of bird species.	Storms, season quality, droughts, onset of rain, cessation of rainfall	Smallholder farmers	Free-State, South Africa	Farmers use the predictions to prepare land, choose seed variety types (drought-tolerant if poor rainy season is predicted, and long-term variants if predicting good season), plan sowing dates and the overall agricultural calendar.	Vulnerability and risk reduction through foresight planning and effective management		(Zuma-Netshukhwi et al., 2013)
6	Fauna; Fauna	Army of locusts moving in the same direction indicates a looming drought, animal behaviour—snakes moving same direction, bees flying one direction, much noise from frogs in the afternoon—all indicate drought is coming; horse playfully jumps and butterflies fly together means good rainy season.	Drought, season quality	Smallholder farmers, communities	Eastern Cape, South Africa	Using IK drought predictions, farmers and communities preserve food in advance and seeds for the next season.	Poverty reduction through effective foresight planning	64.4% relied on IK in their farming practice and drought risk reduction	(Muyambo et al., 2017)
7	Weather/ Meteorological; Fauna; Fauna	Appearance of butterflies, acacia roots shooting depicts the end of growing season, decline in wind speed means end of rainy season, tree flowing (<i>Dombeya rotundifolia</i>) indicates time for planting.	Onset rains, lowland flooding, storms, cessation of rainy season	Local communities, smallholder farmers	Sinazongwa, Zambia	Locals use IK flood predictions to move people and personal belongings to the upland areas prior to flooding. Use IK onset of rainy season to plan timing of planting.	Vulnerability and risk reduction through effective management		(Kanno et al., 2013)

TABLE 1 (Continued)

No.	Indicator category	Indicator type	Weather/ Climate hazard	Economic activity	Region/Country	Implications on adaptation	Primary focus of adaptation action	Relevance/ Reliance	Source
8	Flora; Fauna; Astrological	Lunar observation—approaching full moon signifies approaching ocean flooding, cloud study—thick dark clouds signify approaching heavy rain, behaviour of aquatic animals—migration pattern of a crab species signifies freshwater flooding.	Flooding	Coastal fisheries	Coastal communities in Nigeria	Through IK flood forecasts, holidays for school children are issued, markets are closed, fishermen are cautioned.	Vulnerability and risk reduction through effective management		(Fahyi & Olukoi, 2013)
9	Weather/ Meteorological; Fauna; Fauna.	Moon appearance and position, star quantity and appearance, air temperature, wind direction, and animal behaviour to predict short-term traditional drought.	Drought, rainy season start and quality and storms	Smallholder farmers	Gaza, Mozambique	Used the predictions to make farm-related decisions, such as the type of crops to plant each season, when to start planting and precautionary measures to take to avoid losses or prevent hardship	Vulnerability and risk reduction through foresight planning and effective management	92% of the farmers rely on IK predictions	(Salite, 2019)
10	Fauna; Fauna; Weather/ Meteorological	Use phenology of vegetation—appearance of new leaves and flowers, observe baobab trees, appearance of certain insects and butterflies. Observe the behaviour of birds, domestic birds—ducks and ducklings. Cloud type and cover, air temperature (cool air temperature).	Rain onset, storms	Local communities, smallholder farmers	Yendi, Ghana	IK predictions enabled farmers to prepare their lands for crop cultivation to feed themselves and sell part of the farm produce to earn income	Poverty reduction through effective operations and income generation	40.8% reported using IK predictions. 55% of them ranked IK forecast as the most reliable method, 25% reported IK as reliable. Overall, 80% rely on IK forecasts.	(Adamu et al., 2021)

Notes: The relevance or reliability is as attributed by authors in the articles, which in some cases are based on the comparison of farmers' IK prediction type to the observed/scientific predictions.

and drought. Yet indigenous and local predictions can be in disagreement, as shown in Kenya, where Borana herders' predictions varied (Ayal et al., 2015). For the Borana herders, intestine reading, followed by animal body language and plant body language have been perceived as reliable and acceptable prediction methods, but the accuracy of indigenous weather forecasting appears to have reduced now and then, due to recent natural and social developments affecting Borana ILK holders, e.g. loss of specific trees relevant for forecasting, absence of documentation, dwindling oral transmission, or the influence of alcoholism, modern education, and Christianity, leading to increased mismatches between ILK-based forecasts and reality and the declining popularity of ILK weather forecasting (Ayal et al., 2015).

The rather high usage and acceptance of ILK, however, at least for weather prediction, might also be explained by a lack of access to science-based weather information or time-delayed dissemination of such forecasts. For example, in Borana, Ethiopia, ILK weather forecasting was the main source of weather-related information used by 97% of the farmers and pastoralists. The complementarity of indigenous and modern sources of climate-related information is a challenge. This is illustrated by the preference of 68% of farmers in Lushoto, Tanzania, who mostly rely on indigenous sources for farming decisions (Radeny et al., 2019). The same study showed that access to science-based forecasts reduced the use of ILK forecasts, such as in Uganda, where no farmers used ILK due to better access to radio weather forecast data (Radeny et al., 2019). In contrast, in Kalify, Kenya, the adoption of ILK forecasts was still high despite most smallholders having access to weather forecasts. However, those farmers still perceived a lack of accuracy in such radio forecasts, which reduced trust in this information source (Mwaniki & Stevenson, 2017).

Concerning longer-term predictions linked with climate change and its impacts, the majority of the ILK forecasts in the case studies (see Table 1) predicted the onset of rains, season quality, and length, but only a few offered long-term climate hazard predictions (e.g. Jiri et al., 2015, for Zimbabwe; Radeny et al., 2019, for Ethiopia, Tanzania and Uganda). In most cases, it may be expected that ILK will continue to be used predominantly to predict the onset of rains and particular weather events like storms, which are short-term predictions to address climate variability, but it remains unclear if these indicators are contributing to long-term climate predictions beyond seasonal forecasts.

Complementing Table 1, Table 2 summarizes the distinctive benefits of ILK and related practices in local climate change adaptation strategies, underscoring the value and importance of securing these knowledge systems for vulnerability reduction, poverty alleviation, and sustained local livelihoods.

4 | DISCUSSION

In Africa, ILK is mostly used to enhance agricultural productivity, food security, livelihoods, and to provide income to reduce vulnerability and alleviate poverty. However, most of the adaptation options in the case studies are incremental responses to climatic changes (such as improving planting schedules, switching to other seeds, and preventive measures) with some potential to cause future maladaptation. For example, wetland cultivation by indigenous and local people results in the disappearance of wetlands, including all the associated biodiversity they support (Kingsford et al., 2016; Menbere & Menbere, 2018).

Drawing partly from the case studies assessed, Table 2 highlights the roles and benefits of ILK and the practices for not only incremental climate change adaptation but also for securing local livelihoods, for example, through diversifying agricultural production, farming income, and even migration. However, culture lock-ins can have maladaptive outcomes where ILK adaptation type and practices are not reducing the climate risk (Antwi-Agyei et al., 2018).

Furthermore, ILK-based adaptation practices are difficult to upscale due to inherent cultural and geographical boundaries (Crate et al., 2017; Everard et al., 2019; Martinez-Levasseur et al., 2017). Thus, ILK's contribution to transformative adaptation—by definition a fundamental, systemic change—has been limited. Transformative adaptation recognizes the importance for departures from business-as-usual approaches to more systematic responses to climate change and management of unavoidable climate risks (Termeer et al., 2017; Wilson et al., 2020). The

TABLE 2 Benefits of ILK knowledge/practices in climate change adaptation strategies.

Consequence of climate change	Climate change adaptation ILK knowledge/practice	Role/benefits of ILK
Increased climate extremes, e.g. flood, drought, heat stress	Indigenous weather forecasting using biotic and abiotic indicators	Help to adjust crop-planning date, pasture, and water management
	Changing crop-planning date, use early-maturing crop variety	Reduce crop failure
Aggravation of erosion	Re-terracing of collapsed slopes, changes in land use to match slope stability. Fallowing, re-seeding, trench, bench terracing, vegetative barriers, rainwater harvesting, check dam, tree plantation, contour ploughing	Reduce the velocity of runoff, facilitate runoff percolation, and increase soil moisture
Reduced availability of pasture	Rotation grazing, hay making, temporary migration with their herds	Reduce death of livestock
	Using emergency fodder in droughts (jackfruit leaves, sugarcane tops, banana stems, water hyacinth, etc.)	Increases population of livestock during difficult periods, reduces drought risk on livestock
Water scarcity + pollution	Rainwater harvesting, digging walls	Used for domestic purpose and livestock in bad times
	Water management	Effective use of water resources, social justice through socially accepted allocation criteria
	Micro irrigation to augment shortfall in rain	Stimulate soil and water conservation through integrated watershed management
Aggravated livestock + crop diseases and pests	Use traditional medicines and treatments, sell aged and less productive livestock, shift to disease-tolerant crop variety and livestock species	Reduce livestock death, crop failure, and increase production
Decreased crop yield	Crop diversification, rely on drought and flood-tolerant crop variety	Increase production and reduce crop failure
	Micro cropping, crop rotation	Farmers maximize land use while reducing the risks associated with single crop failure
	Cultivation of varieties adapted to the depth of flooding	Boost the productive capacity of the soil; enhance food security during climate-induced flooding, cultivation of multi-purpose crops
	Raised field agriculture	Help crops cope with unpredictable weather patterns
	Mulching/cover cropping	Reduced soil loss, improves water-holding capacity of soil, reduces soil erosion, reduced evapotranspiration
	Manure	Improve soil fertility and soil moisture

(Continues)

TABLE 2 (Continued)

Consequence of climate change	Climate change adaptation ILK knowledge/practice	Role/benefits of ILK
	Planting deeper than usual	Ensure crop survival, enhance food availability
	Planting ahead of rains	Ensure crop survival, reduce the risk of crop failure, enhance food availability
	Intensive manure application	Improve soil fertility, increase food availability
Food insecurity + malnutrition	Local climate forecasts (e.g. Krishi Panchang)	Boost farm productivity during extreme events
	Postponed festival, marriage ceremony, change their eating habit	Help to save food items and money
	Seasonal migration	Increase household income and ensure food security
	Multi-species composition of herds to survive extremes	Reduces drought risk on livestock, increase food availability
	Culling of weak livestock for food during drought	Reduce loss of livestock, reduce drought risk on livestock
Soil erosion + desertification	Re-terracing of collapsed slopes, changes in land use to match slope stability	Enhance soil conservation by controlling water runoff and promoting slope stability
	Agroforestry: Planting of particular species of trees and other agricultural crops, vegetables	Control soil erosion, preservation of patches of forests, food availability, carbon sequestration, reforestation, reducing vulnerability to flash floods
	Mixed land use, crop rotation	Conserve land cover and preserve the productive capacity of the soil, minimize pests and diseases, reduce chemical use, and erosion
Environmental degradation + desertification	Land-use change, cover with economically valuable and environmentally friendly trees	Improve the ecosystem services and hence, income of the community and individuals

Adapted from: Nadeem et al., 2009; Nyong et al., 2007; Pandey et al., 2003; Patel, 2020; Rivera-Ferre et al., 2013; UNPFII, 2007.

concept of intentional transformative adaptation (ITA) (Colloff et al., 2021) suggests an opportunity for ILK to be integrated into overall adaptation efforts. Integrating ILK may be helpful in supporting superordinate transformative action by empowering local communities and facilitating community buy-in, which is important in raising the acceptability of specific climate change adaptation procedures (Austin et al., 2017; Leal Filho, Wolf, et al., 2022; McGregor, 2014).

ILK is widely recognized by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Convention on Biological Diversity (CBD) as a valuable resource for adaptation processes, particularly for ecosystem-based adaptation (Ford, Cameron, et al., 2016; Nalau et al., 2018; UNFCCC, 2013). Despite this recognition, the need for improved integration of ILK and scientific knowledge—also termed “bridging knowledge systems” (Tengö et al., 2017)—in science-policy processes is still limited (Diver, 2017; Tengö et al., 2014; Tengö et al., 2017).

Table 3 offers an overview of how current National Adaptation Plans (NAPs) in the 10 assessed case-study countries have currently integrated and dealt with ILK. It shows that many NAPs recognize the need to integrate ILK and explicitly list this in the official documents. However, it is unclear how this is translated into concrete projects and initiatives on the ground. Here, more research is needed.

A matter that remains unclear is how the integration of ILK into transformative forms or national adaptation planning can happen in practice. To effectively bridge knowledge systems, Nalau et al. (2018) both highlighted and criticized an inherent bias of adaptation that needs to be dissolved: current models of ILK integration as well as scientific knowledge scrutinize neither Western thinking nor the current notions of development or adaptation options. Tschakert et al. (2016, p. 24) highlighted the limitations of this kind of thinking:

purely scholarly driven research design would not have allowed us to appreciate the central importance of creative and co-produced learning environments over more rigorous research design, analysis, and evaluation which, while allowing for certain types of learning opportunities, block others.

Indigenous communities may, in turn, perceive the integration of knowledge systems as a different kind of colonization (Nalau et al., 2018). There are ways and means to overcome such barriers and go beyond local, place-based impacts, as highlighted in Tengö et al.'s (2017) review. Two key aspects are:

- **Engagement of knowledge carriers and institutions:** adaptation involving ILK represents a collaborative, iterative, and inclusive process in which everyone participating has stakes in decision-making, although participation does not guarantee, in and of itself, that ILK is adequately and appropriately built into adaptation (UNFCCC, 2013, p. 4). Moreover, collaboration is likely to fail if the relationship among the involved actors is not based on trust, if power asymmetries exist, marginalized groups are overlooked, and if it does not follow cultural, ethical, and legal protocols (Nalau et al., 2018; Tengö et al., 2014; Makondo & Thomas, 2018).
- **Building trust and communication:** Local knowledge is generally context-specific and manifests differently across place and time, so ILK may be contradictory to scientific and technological understandings of universal knowledge and development (Klenk et al., 2017). According to Tengö et al. (2014), the difference in understanding of ILK, i.e. differing worldviews and experiences, can be a potential source of disagreement. Language and literacy may also represent barriers for understanding and participation (UNFCCC, 2013).

There is a growing consensus among climate scholars and development practitioners that research on climate change adaptation should not rely on “Western” knowledge alone, and the engagement of diverse knowledge systems is crucial for effective and context-specific climate adaptation planning (Ban et al., 2017; Mantyka-Pringle et al., 2017; Tripl et al., 2018). If there is a common agreement regarding the benefits of integrating ILK into formal climate change adaptation strategies, there is, however, relatively limited empirical evidence portraying how it can take place in practice. From our perspective, this paradigm shift would require a range of actions, and we outline three shifts that could help to transform climate research approaches to be more inclusive.

First, a change of the programmatic mindset that guides most scientific work is required. Scientists only trust evidence generated through a “rigorous” Western science-based protocol with statistically analysed data that demonstrate acceptable levels of reliability and validity (Tranfield et al., 2003). This mental shift would create space for the decolonization of climate science that is heavily guided by colonial legacies such as languages and approaches (Liboiron, 2021; Schipper et al., 2021; Trisos et al., 2022). The change would also allow scientists to reconsider what “science” means and what can be labelled as scientific outcomes. Climate research is exclusionary, framed by Western science-based approaches, and though traditional knowledge does follow the same path, this knowledge system is grounded on careful observation of environmental changes that indigenous communities have relied on for many decades to cope with climate challenges (Ankrah et al., 2021; Hosen et al., 2019; Liboiron, 2021).

TABLE 3 Overview of existing National Adaptation Plans (NAPs) that mention ILK in the 10 African case-study countries.

Country	NAP key focus	ILK reference	Source
Ethiopia	<p>Integrate currently disparate sectoral and regional adaptation initiatives to mainstream climate change adaptation holistically within Ethiopia's long-term development path.</p> <p>Mainstream and institutionalize the implementation of climate change adaptation in the country's development governance structures to ensure continuity and consistency of pragmatic efforts, and by strengthening the institutional memory.</p> <p>Mobilize resources from public and private climate finance sources and from both domestic and international sources to enable the country to implement its climate change adaptation initiatives and to develop appropriate technical, material, and expert capacities.</p> <p>Establish resilient systems that can withstand disasters and risks imposed by climate change through building collaborative partnerships among the relevant stakeholders and enhancing the thematic integration among different development sectors.</p>	Enhancing research and development of traditional ecological knowledge (TEK) systems, such as local climate change adaptation practices, skills, and institutions.	Federal Democratic Republic of Ethiopia (2019, pp. 26, 28, 62).
Tanzania	<p>Build the capacity of Tanzania to adapt to climate change impacts.</p> <p>Enhance resilience of ecosystems to the challenges posed by climate change.</p> <p>Enable accessibility and utilization of the available climate change opportunities through implementation.</p> <p>Enhance participation in climate change mitigation activities that lead to sustainable development.</p> <p>Enhance public awareness on climate change.</p> <p>Enhance information management on climate change.</p> <p>Put in place a better institutional arrangement to adequately address climate change.</p> <p>Mobilize resources including finance to adequately address climate change</p>	<p>Promoting effective documentation of IK on climate change adaptation and mitigation in diverse sectors.</p> <p>Promoting appropriate IK practices.</p>	United Republic of Tanzania, 2012, pp. x, 57, 68, 69, 71.
Uganda	-----		
Zimbabwe NAP process ongoing. NAP roadmap document published)	<p>Strengthening the role of private sector in adaptation planning.</p> <p>Enhancing the capacity of government to develop bankable projects through trainings.</p> <p>Improving management of background climate information to inform climate change planning.</p> <p>Crafting a proactive resource-mobilization strategy for identifying and applying for international climate finance as requests for funds are primarily reactive at present, focusing on emergency relief rather than climate change risk reduction, preparedness, and adaptation.</p> <p>Developing a co-ordinated monitoring and evaluation policy for programmes and projects, as many institutions within the government currently lack a systematic approach to monitoring and evaluation.</p>	Findings to be based on and guided by the best available science and, as appropriate, traditional and IK.	Government of Zimbabwe, 2019, p. 7.

TABLE 3 (Continued)

Country	NAP key focus	ILK reference	Source
Kenya	<p>Highlight the importance of adaptation and resilience-building actions in development. Integrate climate change adaptation into national and county-level development planning and budgeting processes.</p> <p>Enhance the resilience of public and private sector investment in the national transformation, economic and social and pillars of Vision 2030 to climate shocks.</p> <p>Enhance synergies between adaptation and mitigation actions to attain a low-carbon climate-resilient economy.</p> <p>Enhance resilience of vulnerable populations to climate shocks through adaptation and disaster risk reduction (DRR) strategies.</p>	<p>Mostly IK</p> <p>Via academia and research institutions</p> <p>Public Benefit Organizations information and communication technologies (ICT) sector.</p>	<p>Republic of Kenya, 2016, pp. 13, 31, 37, 38.</p>
South Africa	<p>Reduce human, economic, environmental, physical, and ecological infrastructure vulnerability and build adaptive capacity.</p> <p>Develop a co-ordinated Climate Services system that provides climate products and services for key climate-vulnerable sectors and geographic areas.</p> <p>Develop a vulnerability and resilience methodology framework that integrates biophysical and socioeconomic aspects of vulnerability and resilience.</p> <p>Facilitate mainstreaming of adaptation responses into sectoral planning and implementation.</p> <p>Promote research application, technology development, transfer, and adoption to support planning and implementation.</p> <p>Build the necessary capacity and awareness for climate change responses.</p> <p>Establish effective governance and legislative processes to integrate climate change in development planning.</p> <p>Enable substantial flows of climate change adaptation finance from various sources.</p> <p>Develop and implement a monitoring and evaluation system that tracks implementation of adaptation actions and their effectiveness.</p>	<p>Based on best available science on observed climate and projected climate changes as well as relevant traditional knowledge on climate impacts and potential responses.</p> <p>Invest in knowledge.</p> <p>Severe Weather Warning System (SWWS) integrates risk knowledge.</p> <p>Develop and implement an effective communication and outreach programme.</p>	<p>Republic of South Africa, 2020, pp. 16, 21, 33, 47, 84.</p>
Zambia (NAP process ongoing for completion in Q1/2023)	<p>Strengthen institutional co-ordination and collaboration for adaptation planning in Zambia.</p> <p>Establish a system of integrating climate change adaptation in plans and budgets.</p> <p>Develop an overarching national plan that prioritizes medium- to long-term high-level adaptation actions for key economic sectors affected by climate change.</p> <p>Strengthen the capacity for implementing the NAP.</p> <p>Develop a strategy for mobilizing financial and other resources for NAP implementation in Zambia.</p>		<p>Zambia Ministry of Lands and Natural Resources, 2021</p>

(Continues)

TABLE 3 (Continued)

Country	NAP key focus	ILK reference	Source
Nigeria	Reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience. Facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes, and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.	Guided by the best available science IK networks.	Nigeria Federal Ministry of the Environment, 2020, pp. 15, 21, 33.
Mozambique	Mozambique becomes resilient to the impacts of climate change, reducing to a minimum the climate risks to people and property, restoring and ensuring the rational use and the protection of the natural and physical capitals. Identify and make use of the opportunities to reduce greenhouse gas (GHG) emissions that simultaneously contribute to the sustainable use of the natural world and the access to financial and technological resources at affordable prices and the reduction of the pollution and the environmental degradation, promoting low-carbon development. Build the institutional and human capacity as well as explore opportunities to access technological and financial resources to implement the NCCAMS.	Local knowledge must be used and integrated, for example, in water purification. Transmit local knowledge on observed weather phenomena and mechanisms for adapting to extreme weather events. Facilitate the interaction between scientific and local knowledge about climate change. Systematize and document scientific, technical, and local climate change knowledge.	Government of Mozambique, 2012, pp. 30, 45.
Ghana	Articulation of the country's vision of climate change adaptation, its adaptation objectives and principles, the roles played by stakeholders within the national government, and priority adaptation actions to be undertaken. It will also provide a reference point for bringing together various adaptation planning efforts from different sectors, sub-national structures and scales of decision-making. Align the NAP process with existing policies, strategies, and adaptation research. Identify specific themes that are particularly relevant and/or unique to the country context. Serve as a basis for stakeholder engagement.	Traditional or indigenous knowledge to cope with the adverse impacts of climate change. Important to document IK into early-warning systems and research.	Ghana Environmental Protection Agency, 2018, p. 14.

Source: Authors' compilation.

Second, limited funding flows to climate research in general, and more specifically to local knowledge evidence in the global south, is a major barrier. A recent study on thematic prioritization of funding for climate change research in Africa shows that while institutions from the global north—principally Europe and North America—received 78% of funding for climate research, African institutions received only 14.5% (Overland et al., 2021). Most local and indigenous knowledge is generated in the global south—Africa, Latin America, and Asia (David-Chavez & Gavin, 2018)—and this funding discrepancy means that climate-related local knowledge is not fully captured in climate research to create space for the integration. This suggests that funding bodies need to set more dedicated allocations for documenting the practical integration of local knowledge. Tengö et al. (2017) call for substantial investments of both time and funds to support knowledge-holders and institutions, underscoring the large efforts needed to properly consider the diverse contexts in which ILK exists.

Finally, the integration of local knowledge/indigenous knowledge and scientific knowledge should not just be seen as a combination of the two knowledge systems. The integration should be part of a more complex co-production process where climate scholars and local/indigenous communities interact effectively and are interested in questioning how local knowledge resonates in the scientific framing or vice-versa (Abu et al., 2020). It is about co-generation of knowledge, not a category of stakeholder, often researchers, pretending to know enough about local needs and aspirations to be able to offer solutions that are sufficiently finished to require little or no subsequent local adaptation (Chilisa et al., 2017). This co-operation calls for an ethical shift, humility from both “scientists” and local communities for mutual learning with no “asymmetry of power” that gives one group more power to determine the direction that the co-operation takes (Kant & Norman, 2019; Liboiron, 2021). Here we challenge climate research to be more flexible with regard to its approach that should not only be grounded in the Western perspective of “science.”

5 | CONCLUSIONS AND LESSONS LEARNED

This article has provided an overview of the role and extent to which ILK has been deployed in support of climate change adaptation strategies. The evidence gathered here suggests that, in different contexts, this knowledge can help in the use of previous experience as a tool to address particular events.

Whereas it is not new in the field of social sciences (Audefroy & Cabrera Sánchez, 2017), ILK does have some specific features. First, ILK tends to be neither rigid nor static, but rather to be dynamically shaped by external influences and socio-cultural transformation (Theodory, 2016). Second, it can be applied in various contexts related to climate change adaptation (Galloway McLean, 2010; Green & Raygorodetsky, 2010; Naess, 2013), especially in relation to extreme climate events. One of the major events that drew the attention of scientists (Orlove et al., 2010) to the issue of the relevance of ILK in relation to extreme events was the 2004 tsunami in the Indian Ocean. It was reported that those living in local communities drew on it to deal with the aftermath of the disaster (Hiwasaki et al., 2014).

Scholars are beginning to pay more serious attention to the issue of ILK. Article 7.5 of the Paris Agreement also gave credence to the vital role of integrating local and indigenous knowledge in understanding climate change and developing relevant actions for adaptation. The UN Sustainable Development Goals (SDGs) also emphasize the role of ILK as a cross-cutting issue, which may help in achieving the SDGs, especially when it comes to addressing poverty (Leal Filho, Azul, et al., 2021). For instance, fisherfolk are known to be able to forecast imminent extreme events such as hurricanes, floods, or tsunamis by observing winds, clouds, the colour of the sky, and the movement of birds and animals (Audefroy & Cabrera Sánchez, 2017). Other indigenous practices have also been used in adapting to the impacts of climate change, as outlined in this article.

This study has some limitations. The first is that its scope is limited to certain ILK practices used in Africa and it did not consider issues relevant to other geographical regions. Second, the research was limited to a review of the literature combined with case studies and exchanges with a limited set of specialists. Despite these limitations, the

study provides a valuable contribution to the literature, since it illustrates how ILK is being used across a number of communities in western, eastern, and southern Africa. Also, the case-study approach used serves to illustrate some specific features around the extent to which ILK is being used across a number of countries not often included in previous studies.

One lesson from the article is that greater effort is needed to better integrate ILK with modern climate change adaptation strategies. This would be likely to lead to more effective responses. In addition, in order to yield the expected benefits, ILK should be compatible with the socio-cultural context of the community where it is used, since local circumstances may vary. Finally, there is a need to build the capacity of both rural communities and relevant government agencies to complement the use of ILK with climate change strategies, and so maximize its contribution to the effective implementation of climate change policies.

AUTHOR CONTRIBUTION STATEMENT

Walter Leal Filho: Conceptualization, writing—contribution to conclusions, final editing. **Franziska Wolf:** Conceptualization—conceptual revision, writing—contributions to results, discussion, conclusions, editing and final editing of all parts, corresponding author. **Edmond Totin:** Conceptualization—conceptual revision, writing—contributions to introduction, results, discussion, conclusions, editing and final editing of all parts. **Luckson Zvobgo:** Writing—contributions to introduction, methodology, interpretation, and final editing of case studies, final editing. **Nicholas Philip Simpson:** Writing—editing of introduction, methodology, discussion, final editing. **Kumbirai Yusiyma, Jokastah Kalungu, Maruf Sanni, Ibidun Adelekan, Jackson Efitre, Felix Kwabena Donkor, Abdul-Lateef Balogun, Serafino Afonso Rui Mucova, Desalegn Yayeh Ayal:** Contribution of case studies (equal).

ACKNOWLEDGEMENTS

Open access funding enabled and organized by Projekt DEAL.

FUNDING INFORMATION

N.P.S. received financial support from the UK government's Foreign, Commonwealth & Development Office and the International Development Research Centre, Ottawa, Canada (Grant number 109419-001). This article was supported by the International Climate Change Information and Research Programme, and is part of the "100 papers to accelerate climate change mitigation and adaptation" initiative (<https://www.haw-hamburg.de/en/ftz-nk/programmes/100papersclimate/>).

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

ORCID

Walter Leal Filho  <https://orcid.org/0000-0002-3993-8974>

Franziska Wolf  <https://orcid.org/0000-0002-9724-5586>

Edmond Totin  <https://orcid.org/0000-0003-3377-6190>

Luckson Zvobgo  <https://orcid.org/0000-0003-3400-8003>

Nicholas Philip Simpson  <https://orcid.org/0000-0002-9041-982X>

Kumbirai Musiyiwa  <https://orcid.org/0000-0001-5300-605X>

Jokastah W. Kalangu  <https://orcid.org/0000-0002-0000-0866>

Maruf Sanni  <https://orcid.org/0000-0001-8313-9910>

Ibidun Adelekan  <https://orcid.org/0000-0002-3407-8549>

Jackson Efitre  <https://orcid.org/0000-0002-7158-3966>

Felix Kwabena Donkor  <https://orcid.org/0000-0001-8353-8313>

Abdul-Lateef Balogun  <https://orcid.org/0000-0002-0418-3487>

Serafino Afonso Rui Mucova  <https://orcid.org/0000-0001-7637-0671>

Desalegn Yayeh Ayal  <https://orcid.org/0000-0001-8966-2673>

REFERENCES

- Abu, R., Reed, M. G., & Jardine, T. D. (2020). Using two-eyed seeing to bridge Western science and Indigenous knowledge systems and understand long-term change in the Saskatchewan River Delta, Canada. *International Journal of Water Resources Development*, 36(5), 757–776. <https://doi.org/10.1080/07900627.2018.1558050>
- Adanu, S. K., Abole, T., & Gbedemah, S. F. (2021). Farmers' perceptions on climate change and adaptation strategies in Yendi Municipality, Ghana. *Future of Food: Journal on Food, Agriculture and Society*, 9(4), 1–12. <https://www.thefutureoffood-journal.com/index.php/FOFJ/article/view/419>
- Agusto, F. B., Teboh-Ewungkem, M. I., & Gumel, A. B. (2015). Mathematical assessment of the effect of traditional beliefs and customs on the transmission dynamics of the 2014 Ebola outbreaks. *BMC Medicine*, 13, 96. <https://doi.org/10.1186/s12916-015-0318-3>
- Ajani, E. N., Mgbenka, R. N., & Okeke, M. N. (2013). Use of indigenous knowledge as a strategy for climate change adaptation among farmers in sub-Saharan Africa: Implications for policy. *Asian Journal of Agricultural Extension, Economics & Sociology*, 2(1), 23–40. <https://doi.org/10.9734/AJAEES/2013/1856>
- Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., Oettlé, N., Rosenzweig, C., Sakakibara, C., Shadrin, V., Vicarelli, M., Waterhouse, J., & Weeks, B. (2011). Linking indigenous and scientific knowledge of climate change. *Bioscience*, 61(6), 477–484. <https://doi.org/10.1525/bio.2011.61.6.10>
- Ankrah, D. A., Kwapong, N. A., & Boateng, S. D. (2021). Indigenous knowledge and science-based predictors reliability and its implication for climate adaptation in Ghana. *African Journal of Science, Technology, Innovation and Development*, 14(4), 1007–1019. <https://doi.org/10.1080/20421338.2021.1923394>
- Antwi-Agyei, P., Dougill, A. J., Stringer, L. C., & Codjoe, S. N. A. (2018). Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. *Climate Risk Management*, 19, 83–93. <https://doi.org/10.1016/j.crm.2017.11.003>
- Apraku, A., Morton, J. F., & Apraku-Gyampoh, B. (2021). Climate change and small-scale agriculture in Africa: Does indigenous knowledge matter? Insights from Kenya and South Africa. *Scientific African*, 12, e00821. <https://doi.org/10.1016/j.sciaf.2021.e00821>
- Audefroy, J. F., & Cabrera Sánchez, B. N. (2017). Integrating local knowledge for climate change adaptation in Yucatán, Mexico. *International Journal of Sustainable Built Environment*, 6(1), 228–237. <https://doi.org/10.1016/j.ijsbe.2017.03.007>
- Austin, K. G., Lee, M. E., Clark, C., Forester, B. R., Urban, D. L., White, L., Kasibhatla, P. S., & Poulsen, J. R. (2017). An assessment of high carbon stock and high conservation value approaches to sustainable oil palm cultivation in Gabon. *Environmental Research Letters*, 12, 014005. <https://doi.org/10.1088/1748-9326/aa5437>
- Ayal, D. Y., Desta, S., Gebru, G., Kinyangi, J., Recha, J., & Radeny, M. (2015). Opportunities and challenges of indigenous biotic weather forecasting among the Borena herders of southern Ethiopia. *Springerplus*, 4, 617. <https://doi.org/10.1186/s40064-015-1416-6>
- Ban, N. C., Eckert, L., McGreer, M., & Frid, A. (2017). Indigenous knowledge as data for modern fishery management: a case study of Dungeness crab in Pacific Canada. *Ecosystem Health and Sustainability*, 3(8), 1379887. <https://doi.org/10.1080/20964129.2017.1379887>
- Battiste, M. (2007). Research ethics for protecting indigenous knowledge and heritage: Institutional and researcher responsibilities. In N. K. Denzin & M. D. Giardina (Eds.), *Ethical futures in qualitative research: Decolonizing the politics of knowledge* (pp. 111–132). Left Coast Press.
- Beck-Johnson, L. M., Nelson, W. A., Paaijmans, K. P., Read, A. F., Thomas, M. B., & Bjørnstad, O. N. (2017). The importance of temperature fluctuations in understanding mosquito population dynamics and malaria risk. *Royal Society Open Science*, 4(3), 160969. <https://doi.org/10.1098/rsos.160969>
- Biao, E. I. (2017). Assessing the impacts of climate change on river discharge dynamics in Oueme River Basin (Benin, West Africa). *Hydrology*, 4(4), 47. <https://doi.org/10.3390/hydrology4040047>
- Brondizio, E. S., Aumeeruddy-Thomas, Y., Bates, P., Carino, J., Fernández-Llamazares, Á., Ferrari, M. F., Galvin, K., Reyes-García, V., McElwee, P., Molnár, Z., Samakov, A., & Shrestha, U. B. (2021). Locally based, regionally manifested, and globally relevant: Indigenous and local knowledge, values, and practices for nature. *Annual Review of Environment and Resources*, 46(1), 481–509. <https://doi.org/10.1146/annurev-environ-012220-012127>
- Chilisa, B., Major, T. E., & Khudu-Petersen, K. (2017). Community engagement with a postcolonial, African-based relational paradigm. *Qualitative Research*, 17(3), 326–339. <https://doi.org/10.1177/1468794117696176>
- Colloff, M. J., Gorddard, R., Abel, N., Locatelli, B., Wyborn, C., Butler, J. R. A., Lavorel, S., van Kerkhoff, L., Meharg, S., Múnera-Roldán, C., Bruley, E., Fedele, G., Wise, R. M., & Dunlop, M. (2021). Adapting transformation and transforming adaptation to climate change using a pathways approach. *Environmental Science & Policy*, 124, 163–174. <https://doi.org/10.1016/j.envsci.2021.06.014>

- Crate, S., Ulrich, M., Habeck, J. O., Desyatkin, A. R., Desyatkin, R. V., Fedorov, A. N., Hiyama, T., Iijima, Y., Ksenofontov, S., Mészáros, C., & Takakura, H. (2017). Permafrost livelihoods: A transdisciplinary review and analysis of thermokarst-based systems of indigenous land use. *Anthropocene*, 18, 89–104. <https://doi.org/10.1016/j.ancene.2017.06.001>
- Darr, A., & Mears, A. (2017). Locating local knowledge in global networks: Scouting in fashion and football. *Poetics*, 62, 1–14. <https://doi.org/10.1016/j.poetic.2017.03.001>
- David-Chavez, D. M., & Gavin, M. C. (2018). A global assessment of Indigenous community climate research. *Environmental Research Letters*, 13(12), 123005. <https://doi.org/10.1088/1748-9326/aaf300>
- Descroix, L., Guichard, F., Grippa, M., Lambert, L., Panthou, G., Mahé, G., Gal, L., Dardel, C., Quantin, G., Kergoat, L., Bouaïta, Y., Hiernaux, P., Vischel, T., Pellarin, T., Faty, B., Wilcox, C., Malam Abdou, M., Mamadou, I., Vandervaere, J.-P., ... Patuere, J.-E. (2018). Evolution of surface hydrology in the Sahelo-Sudanian Strip: An updated review. *Water*, 10(6), 748. <https://doi.org/10.3390/w10060748>
- Diver, S. (2017). Negotiating Indigenous knowledge at the science-policy interface: Insights from the Xáxl'p Community Forest. *Environmental Science & Policy*, 73, 1–11. <https://doi.org/10.1016/j.envsci.2017.03.001>
- Donkor, F. K., Howarth, C., Ebhuoma, E., Daly, M., Vaughan, C., Pretorius, L., Mambo, J., MacLeod, D., Kythreotis, A., Jones, L., Grainger, S., Golding, N., & Anderson, J. A. (2019). Climate services for development: The role of early career researchers in advancing the debate. *Environmental Communication*, 13(5), 561–566. doi:<https://doi.org/10.1080/17524032.2019.1596145>
- Donkor, F. K., & Mearns, K. (2022). Harnessing Indigenous Knowledge Systems for Enhanced Climate Change Adaptation and Governance: Perspectives from Sub-Saharan Africa. In E. E. Ebhuoma & L. Leonard (Eds.), *Indigenous Knowledge and Climate Governance*. Springer. https://doi.org/10.1007/978-3-030-99411-2_14
- Douglas, I., Alam, K., Maghenda, M., McDonnell, Y., McLean, L., & Campbell, J. (2008). Unjust waters: Climate change, flooding and the urban poor in Africa. *Environment and Urbanization*, 20(1), 187–205. <https://doi.org/10.1177/0956247808089156>
- Everard, M., Gupta, N., Scott, C. A., Tiwari, P. C., Joshi, B., Kataria, G., & Kumar, S. (2019). Assessing livelihood-ecosystem interdependencies and natural resource governance in Indian villages in the Middle Himalayas. *Regional Environmental Change*, 19, 165–177. <https://doi.org/10.1007/s10113-018-1391-x>
- Fabiyyi, O. O., & Oloukoï, J. (2013). Indigenous knowledge system and local adaptation strategies to flooding in coastal rural communities of Nigeria. *Journal of Indigenous Social Development*, 2(1), 1–19. <https://journalhosting.ucalgary.ca/index.php/jisd/article/view/63051>
- Federal Democratic Republic of Ethiopia. (2019). *Ethiopia's Climate Resilient Green Economy*. National Adaptation Plan. <https://www4.unfccc.int/sites/NAPC/Documents/Parties/Final%20Ethiopia-national-adaptation-plan%20%281%29.pdf>
- Fernández-Llamazares, A., Díaz-Reviriego, I., Luz, A. C., Cabeza, M., Pyhälä, A., & Reyes-García, V. (2015). Rapid ecosystem change challenges the adaptive capacity of local environmental knowledge. *Global Environmental Change*, 31, 272–284. <https://doi.org/10.1016/j.gloenvcha.2015.02.001>
- Ford, J. D., Cameron, L., Rubis, J., Maillet, M., Nakashima, D., Willox, A. C., & Pearce, T. (2016a). Including indigenous knowledge and experience in IPCC assessment reports. *Nature Climate Change*, 6, 349–353. <https://doi.org/10.1038/nclimate2954>
- Ford, J. D., Stephenson, E., Cunsolo Willox, A., Edge, V., Farahbakhsh, K., Furgal, C., Harper, S., Chatwood, S., Mauro, I., Pearce, T., Austin, S., Bunce, A., Bussalleu, D., & J., Finner, K., Gordon, A., Huet, C., Kitching, K., Lardeau, M.-P., ... Sherman, M. (2016b). Community-based adaptation research in the Canadian Arctic. *Wiley Interdisciplinary Reviews: Climate Change*, 7(2), 175–191. <https://doi.org/10.1002/wcc.376>
- Galloway McLean, K. (2010). *Advance guard: Climate change impacts, adaptation, mitigation and indigenous peoples – a compendium of cases studies*. United Nations University – Traditional Knowledge Initiative. https://i.unu.edu/media/tfm.unu.edu/publication/242/UNU_Advance_Guard_Compendium_2010_final_web.pdf
- Ghana Environmental Protection Agency. (2018). *Ghana's National Adaptation Plan Framework*. NAP Global Network. <https://napglobalnetwork.org/wp-content/uploads/2020/04/napgn-en-2018-ghana-nap-framework.pdf>
- Government of Mozambique. (2012). *National Climate Change Adaptation and Mitigation Strategy*. Green Growth Knowledge Partnership. <https://www.greengrowthknowledge.org/sites/default/files/downloads/policy-database/MOZAMBIQUE%29%20National%20Climate%20Change%20Adaptation%20and%20Mitigation%20Strategy.pdf>
- Government of Zimbabwe. (2019). *National Adaptation Plan (NAP) Roadmap for Zimbabwe*. NAP Global Network. <https://napglobalnetwork.org/wp-content/uploads/2019/04/napgn-en-2019-nap-roadmap-for-zimbabwe.pdf>
- Green, D., & Raygorodetsky, G. (2010). Indigenous knowledge of a changing climate. *Climatic Change*, 100(2), 239–242. <https://doi.org/10.1007/s10584-010-9804-y>
- Hiwasaki, L., Luna, E., & Shaw, R. (2014). Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities. *International Journal of Disaster Risk Reduction*, 10(A), 15–27. <https://doi.org/10.1016/j.ijdr.2014.07.007>
- Hosen, N., Nakamura, H., & Hamzah, A. (2019). Using traditional ecological knowledge to adapt to climate change in Interior Sarawak. *Environment-Behaviour Proceedings Journal*, 4(11), 185–191. <https://doi.org/https://doi.org/10.21834/e-bpj.v4i11.1716>

- Intergovernmental Panel on Climate Change. (2014). Human security. In *Intergovernmental Panel on Climate Change* (Ed.), *Climate change 2014 – impacts, adaptation and vulnerability: Part A: Global and sectoral aspects: Working Group II Contribution to the IPCC Fifth Assessment Report* (pp. 755–792). Cambridge University Press. <https://doi.org/10.1017/CBO9781107415379.017>
- Intergovernmental Panel on Climate Change. (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Cambridge University Press. <https://doi.org/10.1017/9781009157988>
- Jiri, O., Mafongoya, P., & Chivenge, P. (2015). Indigenous knowledge systems, seasonal 'quality' and climate change adaptation in Zimbabwe. *Climate Research*, 66, 103–111. <https://doi.org/10.3354/cr01334>
- Kangalawe, R., Mwakalila, S., & Masolwa, P. (2011). Climate change impacts, local knowledge and coping strategies in the great Ruaha River catchment area, Tanzania. *Natural Resources*, 2, 212–223. <https://doi.org/10.4236/nr.2011.24027>
- Kanno, H., Sakurai, T., Shinjo, H., Miyasaki, H., Ishimoto, Y., Saeki, T., Umetsu, C., Sokotela, S., & Chiboola, M. (2013). Indigenous climate information and modern meteorological records in Sinazongwe District, Southern Province, Zambia. *Japan Agricultural Research Quarterly (JARQ)*, 47(2), 191–201. <https://doi.org/10.6090/jarq.47.191>
- Kebebe, E., Duncan, A. J., Klerkx, L., de Boer, I. J., & Oosting, S. J. (2015). Understanding socio-economic and policy constraints to dairy development in Ethiopia: A coupled functional-structural innovation systems analysis. *Agricultural Systems*, 141, 69–78. <https://doi.org/10.1016/j.agsy.2015.09.007>
- Kant, L., & Norman, E. (2019). You must be joking! Benign violations, power asymmetry, and humor in a broader social context. *Frontiers in Psychology*, 10, 1380. <https://doi.org/10.3389/fpsyg.2019.01380>
- Kingsford, R. T., Basset, A., & Jackson, L. (2016). Wetlands: Conservation's poor cousins. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26(5), 892–916. <https://doi.org/10.1002/aqc.2709>
- Klenk, N., Fiume, A., Meehan, K., & Gibbs, C. (2017). Local knowledge in climate adaptation research: Moving knowledge frameworks from extraction to co-production. *WIREs Climate Change*, 8(5), e475. <https://doi.org/10.1002/wcc.475>
- Kolawole, O. D. (2014). Whither sustainable rural development? A critical exploration of remote communities in and around the Okavango Delta, Botswana. *Spanish Journal of Rural Development*, 5, 99–114. <https://ubrisa.ub.bw/handle/10311/1319>
- Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L. M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G. R., Kron, W., Benito, G., Honda, Y., Takahashi, K., & Sherstyukov, B. (2014). Flood risk and climate change: Global and regional perspectives. *Hydrological Sciences Journal*, 59(1), 1–28. <https://doi.org/10.1080/02626667.2013.857411>
- Leal Filho, W., Azul, A. M., Brandli, L., Lange Salvia, A., Özuyar, P. G., & Wall, T. (2021). No poverty. In W. Leal Filho (Ed.), *Encyclopedia of the UN Sustainable Development Goals*. Springer. <https://doi.org/10.1007/978-3-319-95714-2>
- Leal Filho, W., Barbir, J., Gwenzi, J., Ayal, D., Simpson, N. P., Adeleke, L., Tilahun, B., Chirisa, I., Gbedemah, S. F., Nzengya, D. M., Sharifi, A., Theodory, T., & Yaffa, S. (2022). The role of indigenous knowledge in climate change adaptation in Africa. *Environmental Science & Policy*, 136, 250–260. <https://doi.org/10.1016/j.envsci.2022.06.004>
- Leal Filho, W., Matandirotya, N. R., Lütz, J. M., Alemu, E. A., Brearley, F. Q., Baidoo, A. A., Kateka, A., Ogendi, G. M., Adane, G. B., Emiru, N., & Mbih, R. A. (2021). Impacts of climate change to African indigenous communities and examples of adaptation responses. *Nature Communications*, 12(1), 1–4. <https://doi.org/10.1038/s41467-021-26540-0>
- Leal Filho, W., Ogoeue, N., Ayal, D., & da Silva, I. (2021c). *African handbook of climate change adaptation*. Springer Nature.
- Leal Filho, W., Totin, E., Franke, J. A., Andrew, S. M., Abubakar, I. R., Azadi, H., Nunn, P. D., Ouweneel, B., Williams, P. A., Simpson, N. P., & The Global Adaptation Mapping Initiative Team (2021d). Understanding responses to climate-related water scarcity in Africa. *Science of the Total Environment*, 806, Part 1, Article Number 150420. <https://doi.org/10.1016/j.scitotenv.2021.150420>
- Leal Filho, W., Wolf, F., Moncada, S., Salvia, A. L., Balogun, A. L. B., Skanavis, C., Kounani, A., & Nunn, P. D. (2022b). Transformative adaptation as a sustainable response to climate change: Insights from large-scale case studies. *Mitigation and Adaptation Strategies for Global Change*, 27, Article 20. <https://doi.org/10.1007/s11027-022-09997-2>, 1, 26
- Liboiron, M. (2021). Decolonizing geoscience requires more than equity and inclusion. *Nature Geoscience*, 14, 876–877. [doi:https://doi.org/10.1038/s41561-021-00861-7](https://doi.org/10.1038/s41561-021-00861-7).
- Mafongoya, P. L., & Ajayo, O. C. (Eds.) (2017). *Indigenous knowledge systems and climate change management in Africa*. Technical Centre for Agricultural and Rural Cooperation. CTA.
- Makondo, C. C., & Thomas, D. S. G. (2018). Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environmental Science & Policy*, 88, 83–91. <https://doi.org/10.1016/j.envsci.2018.06.014>
- Mantyka-Pringle, C. S., Jardine, T. D., Bradford, L., Bharadwaj, L., Kythreotis, A. P., Fresque-Baxter, J., Kelly, E., Somers, G., Doig, L. E., Jones, P. D., Lindenschmidt, K. E., River, S., & Partnership, D. (2017). Bridging science and traditional knowledge to assess cumulative impacts of stressors on ecosystem health. *Environment International*, 102, 125–137. <https://doi.org/10.1016/j.envint.2017.02.008>
- Mapfumo, P., Mtambanengwe, F., & Chikowo, R. (2016). Building on indigenous knowledge to strengthen the capacity of smallholder farming communities to adapt to climate change and variability in southern Africa. *Climate and Development*, 8(1), 72–82. <https://doi.org/10.1080/17565529.2014.998604>

- Martinez-Levasseur, L. M., Furgal, C. M., Hammill, M. O., & Burness, G. (2017). Challenges and strategies when mapping local ecological knowledge in the Canadian Arctic: The importance of defining the geographic limits of participants' common areas of observations. *Polar Biology*, 40, 1501–1513. <https://doi.org/10.1007/s00300-016-2071-2>
- McGregor, D. (2014). Lessons for collaboration involving traditional knowledge and environmental governance in Ontario, Canada. *AlterNative: An International Journal of Indigenous Peoples*, 10(4), 340–353. <https://doi.org/10.1177/117718011401000403>
- Menbere, I. P., & Menbere, T. P. (2018). Wetland ecosystems in Ethiopia and their implications in ecotourism and biodiversity conservation. *Journal of Ecology and the Natural Environment*, 10(6), 80–96. <https://doi.org/10.5897/JENE2017.0678>
- Mengistu, D. K. (2011). Farmers' perception and knowledge of climate change and their coping strategies to the related hazards: Case study from Adiha, central Tigray. *Ethiopia Agricultural Sciences*, 2(2), 138–145. <https://doi.org/10.4236/as.2011.22020>
- Mistry, J. (2009). Indigenous knowledges. In R. Kitchin & N. Thrift (Eds.), *International encyclopedia of human geography* (pp. 371–376). Elsevier. <https://doi.org/10.1016/B978-008044910-4.00101-2>
- Mugambiwa, S. S. (2018). Adaptation measures to sustain indigenous practices and the use of indigenous knowledge systems to adapt to climate change in Mutoko rural district of Zimbabwe. *Jàmhá*, 10(1), 388. <https://doi.org/10.4102/jamba.v10i1.388>
- Muyambo, F., Bahta, Y. T., & Jordaan, A. (2017). The role of indigenous knowledge in drought risk reduction: A case of communal farmers in South Africa. *Jàmhá: Journal of Disaster Risk Studies*, 9(1), a420. <https://doi.org/10.4102/jamba.v9i1.420>
- Mwaniki, F., & Stevenson, R. B. (2017). Farmers' uses of indigenous knowledge and practices to cope with climate change in Kilifi County, Kenya. *The International Journal of Climate Change: Impacts and Responses*, 9(4), 53–65. <https://doi.org/10.18848/1835-7156/CGP/v09i04/53-65>
- Nadeem, S., Elahi, I., Hadi, A., & Uddin, I. (2009). *Traditional knowledge and local institutions support adaptation to water induced hazards in Chitral*. Pakistan. <https://www.cabdirect.org/cabdirect/abstract/20103145281>
- Naess, O. L. (2013). The role of local knowledge in adaptation to climate change. *WIREs Climate Change*, 4(2), 99–106. <https://doi.org/10.1002/wcc.204>
- Nalau, J., Becken, S., Schliephack, J., Parsons, M., Brown, C., & Mackey, B. (2018). The role of indigenous and traditional knowledge in ecosystem-based adaptation: A review of the literature and case studies from the Pacific Islands. *Weather, Climate, and Society*, 10(4), 851–865. <https://doi.org/10.1175/WCAS-D-18-0032.1>
- Nigeria Federal Ministry of the Environment. (2020). Nigeria's National Adaptation Plan Framework. NAP Global Network, 1–56. <https://napglobalnetwork.org/wp-content/uploads/2021/06/napgn-en-2020-Nigeria-National-Adaptation-Plan-NAP-Framework.pdf>
- Nyong, A., Adesina, F., & Elasha, B. O. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change*, 12(5), 787–797. <https://doi.org/10.1007/s11027-007-9099-0>
- Ohajunwa, C., & Mji, G. (2018). The African indigenous lens of understanding spirituality: Reflection on key emerging concepts from a reviewed literature. *Journal of Religion and Health*, 57(6), 2523–2537. <https://doi.org/10.1007/s10943-018-0652-9>
- Orlove, B., Roncoli, C., Kabugo, M., & Majugu, A. (2010). Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change*, 100(2), 243–265. <https://doi.org/10.1007/s10584-009-9586-2>
- Ortiz-Bobea, A., Ault, T. R., Carrillo, C. M., Chambers, R. G., & Lobell, D. B. (2021). Anthropogenic climate change has slowed global agricultural productivity growth. *Nature Climate Change*, 11, 306–312. <https://doi.org/10.1038/s41558-021-01000-1>
- Osbahr, H., & Allan, C. (2003). Indigenous knowledge of soil fertility management in southwest Niger. *Geoderma*, 111(3–4), 457–479. [https://doi.org/10.1016/S0016-7061\(02\)00277-X](https://doi.org/10.1016/S0016-7061(02)00277-X)
- Overland, I., Fossum Sagbakken, H., Isataeva, A., Kolodzinskaia, G., Simpson, N. P., Trisos, C., & Vakulchuk, R. (2021). Funding flows for climate change research on Africa: Where do they come from and where do they go? *Climate and Development*, 14(8), 705–724. <https://doi.org/10.1080/17565529.2021.1976609>
- Pandey, D. N., Gupta, A. K., & Anderson, D. (2003). Rainwater harvesting as an adaptation to climate change. *Current Science*, 85(1), 46–59. <https://www.jstor.org/stable/24107712>
- Patel, S. K., Agrawal, G., Mathew, B., Patel, S., Mohanty, B., & Singh, A. (2020). Climate change and women in South Asia: A review and future policy implications. *World Journal of Science, Technology and Sustainable Development*, 17(2), 145–166. <https://doi.org/10.1108/WJSTSD-10-2018-0059>
- Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P., & Solomon, D. (2019). Indigenous knowledge for seasonal weather and climate forecasting across East Africa. *Climatic Change*, 156, 509–526. <https://doi.org/10.1007/s10584-019-02476-9>
- Rankoana, S. A. (2022). Indigenous knowledge and innovative practices to cope with impacts of climate change on small-scale farming in Limpopo Province, South Africa. *International Journal of Climate Change Strategies and Management*, 14(2), 180–190. <https://doi.org/10.1108/IJCCSM-04-2021-0040>

- Republic of Kenya (2016). *Kenya National Adaptation Plan 2015-2030. Enhanced climate resilience towards the attainment of Vision 2030 and beyond*. Republic of Kenya. https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Kenya_NAP_Final.pdf
- Republic of South Africa. (2020). National Climate Change Adaptation Strategy. https://unfccc.int/sites/default/files/resource/South-Africa_NAP.pdf
- Rivera-Ferre, M. G., Di Masso, M., Mailhost, M., López-i-Gelats, F., Gallar, D., Vara, I., & Cuellar, M. (2013). Understanding the role of local and traditional agricultural knowledge in a changing world climate: The case of the Indo-Gangetic Plains. In *CGIAR-CCAFS Program*. Center for Agrofood Economy and Development-CREDA-UPCIRTA, and Institute of Sociology and Peasant Studies. University of Cordoba. <http://hdl.handle.net/10261/280593>
- Ryser, R. C. (2011). Indigenous people and traditional knowledge [Internet]. *Berkshire Encyclopedia of Sustainability*, 1–17. http://www.academia.edu/841635/Indigenous_and_Traditional_Knowledge
- Salite, D. (2019). Traditional prediction of drought under weather and climate uncertainty: Analysing the challenges and opportunities for small-scale farmers in Gaza province, southern region of Mozambique. *Natural Hazards*, 96, 1289–1309. <https://doi.org/10.1007/s11069-019-03613-4>
- Schafer, J. (1993). Introducing agronomy students to the concepts of indigenous and cultural knowledge. *Journal of Natural Resources and Life Sciences Education*, 22(1), 22–26. <https://doi.org/10.2134/jnrnlse.1993.0022>
- Schipper, E. L. F., Ensor, J., Mukherji, A., Mirzabaev, A., Fraser, A., Harvey, B., Totin, E., Garschagen, M., Pathak, M., Antwi-Agyei, P., Tanner, T., & Shawoo, Z. (2021). Equity in climate scholarship: a manifesto for action. *Climate and Development*, 13(10), 853–856. <https://doi.org/10.1080/17565529.2021.1923308>
- Soropa, G., Gwatibaya, S., Musiyiwa, K., Rusere, F., Mavima, G. A., & Kasasa, P. (2015). Indigenous knowledge system weather forecasts as a climate change adaptation strategy in smallholder farming systems of Zimbabwe: Case study of Murehwa, Tsholotsho and Chiredzi districts. *African Journal of Agricultural Research*, 10(10), 1067–1075. <https://doi.org/10.5897/AJAR2013.7205>
- Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio*, 43, 579–591. <https://doi.org/10.1007/s13280-014-0501-3>
- Tengö, M., Hill, R., Malmer, P., Raymond, C. M., Spierenburg, M., Danielsen, F., Elmqvist, T., & Folke, C. (2017). Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. *Current Opinion in Environmental Sustainability*, 26–27, 17–25. <https://doi.org/10.1016/j.cosust.2016.12.005>
- Termeer, C., Dewulf, A., & Biesbroek, G. R. (2017). Transformational change: Governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, 60(4), 558–576. <https://doi.org/10.1080/09640568.2016.1168288>
- Theodory, T. F. (2016). *Dealing with change: Indigenous knowledge and adaptation to climate change in the Ngoni River Basin, Tanzania* [Doctoral dissertation, Rheinische Friedrich-Wilhelms-Universität Bonn]. University of Bonn Institutional Repository. <https://bonndoc.ulb.uni-bonn.de/xmlui/handle/20.500.11811/6876>
- Thompson, C. S., Mendoza, C. A., & Devito, K. J. (2017). Potential influences of climate change on ecosystems within the Boreal Plains of Alberta. *Hydrological Processes*, 30(11), 2110–2124. <https://doi.org/10.1002/hyp.11183>
- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14(3), 207–222. <https://doi.org/10.1111/1467-8551.00375>
- Trippel, M., Grillitsch, M., & Isaksen, A. (2018). Exogenous sources of regional industrial change: Attraction and absorption of non-local knowledge for new path development. *Progress in Human Geography*, 42(5), 687–705. <https://doi.org/10.1177/0309132517700982>
- Trisos, C. H., Adelekan, I. O., Totin, E., Ayanlade, A., Efitre, J., Gameda, A., Kalaba, K., Lennard, C., Masao, C., Mgaya, Y., Ngaruiya, G., Olago, D., Simpson, N. P., & Zakiideen, S. (2022). Africa. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegria, M. Craig, S. Langsdorf, S. Lösche, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Chapter09.pdf
- UNESCO. (n.d.). Local and indigenous knowledge systems. <https://en.unesco.org/links>
- UNFCCC. (2013). *Best practices and available tools for the use of indigenous and traditional knowledge and practices for adaptation, and the application of gender-sensitive approaches and tools for understanding and assessing impacts, vulnerability and adaptation to climate change* (UNFCCC Technical Paper FCCC/TP/2013/11). United Nations. <https://unfccc.int/documents/7927>
- United Nations Permanent Forum on Indigenous Issues. (2007). *Climate change: An overview* (Paper prepared by the Secretariat of the United Nations Permanent Forum on Indigenous Issues). United Nations. http://www.un.org/esa/socdev/unpfi/documents/climate_change_overview_en.doc
- United Republic of Tanzania (2012). *National Climate Change Strategy*. Vice Presidents Office, United Republic of Tanzania. <https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1704.pdf>

- Wilson, R. S., Herziger, A., Hamilton, M., & Brooks, J. S. (2020). From incremental to transformative adaptation in individual responses to climate-exacerbated hazards. *Nature Climate Change*, *10*, 200–208. <https://doi.org/10.1038/s41558-020-0691-6>
- Zambia Ministry of Lands and Natural Resources (2021). *Zambian national adaptation plan*. Global Water Partnership. <https://www.gwp.org/en/GWP-SouthernAfrica/PARTNER/partnerships/country-water-partnerships/Zambia/zambian-national-adaptation-plan/>
- Zuma-Netshiukhwi, G., Stigter, K., & Walker, S. (2013). Use of traditional weather/climate knowledge by farmers in the South-western Free State of South Africa: Agrometeorological learning by scientists. *Atmosphere*, *4*(4), 383–410. <https://doi.org/10.3390/atmos4040383>
- Zvobgo, L., Johnston, P., Williams, P. A., Trisos, C. H., Simpson, N. P., & Global Adaptation Mapping Initiative Team. (2022). The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: a structured assessment. *Sustainability Science*, *17*, 2077–2092. <https://doi.org/10.1007/s11625-022-01118-x>

How to cite this article: Filho, W. L., Wolf, F., Totin, E., Zvobgo, L., Simpson, N. P., Musiyiwa, K., Kalangu, J. W., Sanni, M., Adelekan, I., Efitre, J., Donkor, F. K., Balogun, A.-L., Mucova, S. A. R., & Ayal, D. Y. (2023). Is indigenous knowledge serving climate adaptation? Evidence from various African regions. *Development Policy Review*, *41*, e12664. <https://doi.org/10.1111/dpr.12664>