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Indigenous knowledge and climate change adaptation in Africa: a systematic review

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Abstract

Indigenous people are often considered victims of climate change impact rather than agents of adaptation. Emerging studies in Africa have shifted the attention to indigenous knowledge (IK) to support the development of effective climate change adaptation strategies. This study adopted a systematic literature review methodology to analyse the following: (i) characterization of IK, (ii) potential of IK for knowledge co-production, (iii) IK for climate change causes and impact identification, (iv) IK for formulating and implementing climate change interventions, and (v) documentation and conservation of IK as a resource for climate change adaptation. Results show that there is no consensus on the definition of IK. However, certain identical elements in the available definitions are relevant for contextualization. IK has been useful in the formulation of different climate change adaptation strategies: management practices, early warning, and risk and disaster management. IK has the potential for knowledge co-production relevant for developing robust adaptation measures. Weather and climate services remain a critical area where IK and scientific knowledge (SK) are integrated to enhance forecast reliability and acceptability for local communities. IK is disappearing because of modernization and rural-urban migration, changing landscape and shifting religious beliefs. We suggest the need for more research into the complexity of the IK, proper documentation and storage of IK, and developing effective approaches to integrate IK with SK such that it is well received among researchers and policymakers. While doing this, it is important to maintain the unique features that distinguish IK from other forms of knowledge.

Keywords: climate change, indigenous knowledge, co-production, Africa, climate services

Review Methodology: This study is the result of a systematic review of articles indexed in the Scopus database. It followed the three main processes of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines: identification, screening, and eligibility. The criteria for the search include journal articles publish only in English and for the period between 2000 and 2020 within the region of Africa. Based on the emerging themes and the dimensions of scholarship on the subject, we crafted five main research questions that examined the role of IK in climate change adaptation in African and presented results in a way that consistently answer the questions.

Introduction

Indigenous people and their knowledge have an important role to play in responding to societal challenges. For several millennia, indigenous people have utilized their long-term generated knowledge to sustainably explore and adapt to their environment for survival. It is exactly this knowledge that has protected them from current and previous environmental uncertainties that threaten their existence [1]. Indigenous people form unique social and cultural groups that share collective ancestral ties to the landscape and natural resources that are inextricably linked to their identities, cultures, livelihoods, and their physical and spiritual well-being. They maintain and speak languages that are different from their official national language and have customary leaders and organizations different from what is known in mainstream society or culture [2]. While the way of life of many indigenous people keeps on eroding, it is estimated that there are approximately 476 million indigenous people across the globe, constituting over 6% of the global population and accounting for about 15% of the extremely poor [2]. In Africa, the number of indigenous people is estimated to be around 50 million [3].

Many indigenous people, especially those in Africa, are faced with multiple challenges, including illiteracy, scarcity of land and resources, marginalization, and poverty, which necessitate the need to support them to improve their resilience and livelihoods [3]. In Africa, indigenous peoples are often not formally recognized as custodians of their lands, territories, and natural resources, and public investments in basic services and infrastructure for indigenous people are inadequate. For several reasons including their level of illiteracy and poverty, indigenous people face multiple barriers to participate fully in the formal economy, political processes and decision-making, access to justice, and adaptation planning and implementation. This legacy of inequality and exclusion has made indigenous communities more vulnerable to the impacts of disease outbreaks and natural hazards including climate change [2].

Climate change impact remains an important factor exacerbating these challenges [4]. Globally, climate change remains an unprecedented challenge of our time. The environmental, social-economic, and agricultural sectors of many countries are at risk, yet, not every country and people have the capacity to deal with climate change impact [5]. The unpredictability of weather and climatic conditions in addition to extreme events, such as violent storms, droughts and floods pose serious risks to poor indigenous communities [6]. Ironically, indigenous people who have not participated in industrial activities are disproportionately affected by the impact of climate change [7].

Indigenous communities have long been recognized as particularly vulnerable to the impacts of climate change because their livelihoods, culture, spirituality and social systems largely depend on their immediate environment [8]. This is especially so in many countries in Africa where food production, for example, is predominantly rain-fed; as a result, the dependence of indigenous people on agricultural livelihoods is negatively affected [9]. Indigenous people located in areas exposed to severe climate change are often diverse in cultural backgrounds with different languages and origin in addition to peculiar indigenous knowledge (IK) about their environment. These people have over the years developed IK that helps them manage their exposure to environmental changes. According to Ajibade and Eche [8], they possess knowledge on practices such as agriculture, fishing, hunting, foraging and the use of medicinal plants. Also, indigenous people have long-term knowledge on managing the impact of climate change and may have to offer valuable knowledge to learn from for future adaptation to climate change. For example, indigenous African farmers have developed a systematic approach to gathering indigenous ecological knowledge for predicting weather and seasonal climate for decision-making about climate variability and change problems [10–13].

Following the typology of climate change adaptation used by Smith *et al.* [14], IK contributes to almost all types of adaptation. First, concerning timeliness and intent of adaptation to climate stimuli, IK is used to formulate autonomous adaptation measures in response to climate impacts. For example, indigenous farmers respond to changing precipitation patterns by changing crop variety, planting/sowing or harvesting dates [15,16]. IK, when used, contribute to the formulation of planned adaptation measures which are conscious policy options aimed at altering the adaptive capacity of a system (e.g., agricultural system). For instance, feedback from indigenous people helps in deliberate crops selection and resource distribution across different agro-climatic zones [17]. Secondly, for spatial and temporal scope, form and extent of change, IK-based adaptation measures are mostly developed to manage local communal problems rather than regional and national and could be long term and short term taking the form of simple behavioral changes [18] to major structural changes such as land-use changes to improve yield [17].

Arguably, IK can provide insight for effectively dealing with greater challenges of climate change [19, 20]. Despite the benefits, the unique knowledge and experiences of indigenous people remain largely underutilized in the planning and implementation of adaptation interventions [21]. For example, according to Makondo and Thomas [21], the IPCC acknowledges the importance of including IK in adaptation interventions, yet engagement of indigenous people was largely ignored and limited in scope in its fourth and fifth assessment reports. The authors also indicate that the suggested adaptation interventions although designed for the most vulnerable including indigenous people, in particular, IK holders or experts are mostly neglected. Therefore, although greatly impacted, knowledge held by indigenous communities is rarely considered in academic, policy, and public discourses on climate change [22].

The past decades have, however, seen a growing interest in the potential role of IK in managing climate change impacts and uncertainties [23]. This paradigm stems from the recognition of both the increasing threats of climate change and the value that IK has for impact identification and adaptation [6]. Some scholars have explored the value of IK in natural resource management, water resource management, fisheries and aquatic conservation, and risk and disaster management, and health [24–28], while others looked at IK application for weather and seasonal climate forecasts [10, 29–32]. However, the interest in IK in recent times is challenged by the gradual disappearance of the knowledge among indigenous communities. Mafongoya and Ajayi [33] consider the fading away of IK a tragedy in that IK remains a social capital for poor indigenous people who relied upon their knowledge for food production and to ensure survival. For example in Zimbabwe, IK served as a social capital that enabled the necessary communal participation, networking, and responsibility led by traditional chiefs to gather and store food crops in anticipation of indigenously predicted droughts.

Many studies have focused on the use of IK for climate change adaptation but insufficient studies have performed a systematic review of the existing literature. Shaffril *et al.* [4], for example, focused on indigenous people in the Asia Pacific regions. To the best of our knowledge, no systematic review of the subject has focused on Africa as a whole. Therefore, given the arguments above, and the fact that climate change impacts are very important for indigenous people in Africa, we studied the role of IK possessed by indigenous people in addressing climate change uncertainties. To do this, we synthesized the most recent works on IK and climate change through a systematic review of existing literature focusing on two main objectives: (i) improve understanding on the use of IK for climate change adaptation; and (ii) contribute to climate change adaptation policy debates by identifying the potentials for co-production of knowledge through the integration of IK with scientific knowledge for decision-making under climate uncertainty. Here, we focus on climate change impacts on agriculture production and livelihoods [5, 34].

Methodology

Review protocol and research questions

This study draws upon a collection of evidence of IK's utility through a systematic review of literature indexed in the Scopus database. According to Robinson and Lowe [35], traditional literature review approaches are often incomprehensive and encounters reviewer bias; therefore, it is vital to review past literature using the systematic review approach. Scopus database is one of the leading repositories of latest and relevant research articles with special advance and comprehensive search functionality that provides access to multidisciplines [36].

In a recent extensive systematic review without geographic or date restrictions, Klenk *et al.* [37] identified the main research themes on local knowledge in the climate adaptation literature. These themes include reflexive questioning of IK, IK as a perception, response/adaptive capacity, as co-produced, as a scientific benchmark, integrating IK with other forms of knowledge, barriers to scaling up IK, community impact, loss of IK, and IK as a priority. In addition to these themes, scholarly work on the subject can be summarized into three main dimensions: first, providing evidence to back the occurrence of climate change and elaborating its implications at the local level among vulnerable groups [30, 38–40]; second, helping in the development and implementation of adaptation actions at different levels [41–44]; and third, promoting indigenous people's rights and sense of ownership for adaptation projects [23]. This review is therefore structured to provide a synthesized view of IK and climate change around these three dimensions and further elaborate on the need for co-production of knowledge through the integration of IK with scientific knowledge for climate sensitive decision making. Based on the emerging themes identified by Klenk *et al.* [37] and the three main dimensions of scholarship on the subject, we crafted four main research questions that examine the role of IK in climate change adaptation in African. Following the stepwise approach depicted in Fig. 1, this study aims at answering the following research questions:

1. How is IK understood in different contexts and spaces?
2. What are the potentials for co-production of knowledge through the integration with scientific knowledge for decision making?
3. How has IK been utilized for climate change adaptation in the African space?
4. How is IK used for formulating and implementing climate change interventions?
5. How can IK be documented and conserved as a resource to manage climate change?

Conceptualizing IK by examining its origin and the various ways in which it has been referred to or applied with particular interest to climate change is essential for understanding the context. IK has been widely used and in most cases operationalized under different context and school of thoughts. Moreover, different people have different sets of IK that may differ from one community to another. Also, co-production of knowledge between scientists and indigenous people although not new is receiving greater attention in recent emerging literature. It is argued that such integration has value for developing adaptation strategies and early warning systems, for example. Making a case for *co-production* of knowledge to manage climate change remains an interesting trajectory to pursue effective uptake of innovations that improve resilience against climate change. Unraveling the various dimensions in which scholarly work on IK has been performed across Africa consolidates the relevance of the subject and in addition to existing opportunities. Scholarship on IK and climate change is rather extensive and requires detail and more guided organization of the outcomes. Some researchers and policymakers remain skeptical about the inclusion of indigenous knowledge in scientific and policy-making discourse for several intrinsic and extrinsic reasons [46]. The need to evaluate existing

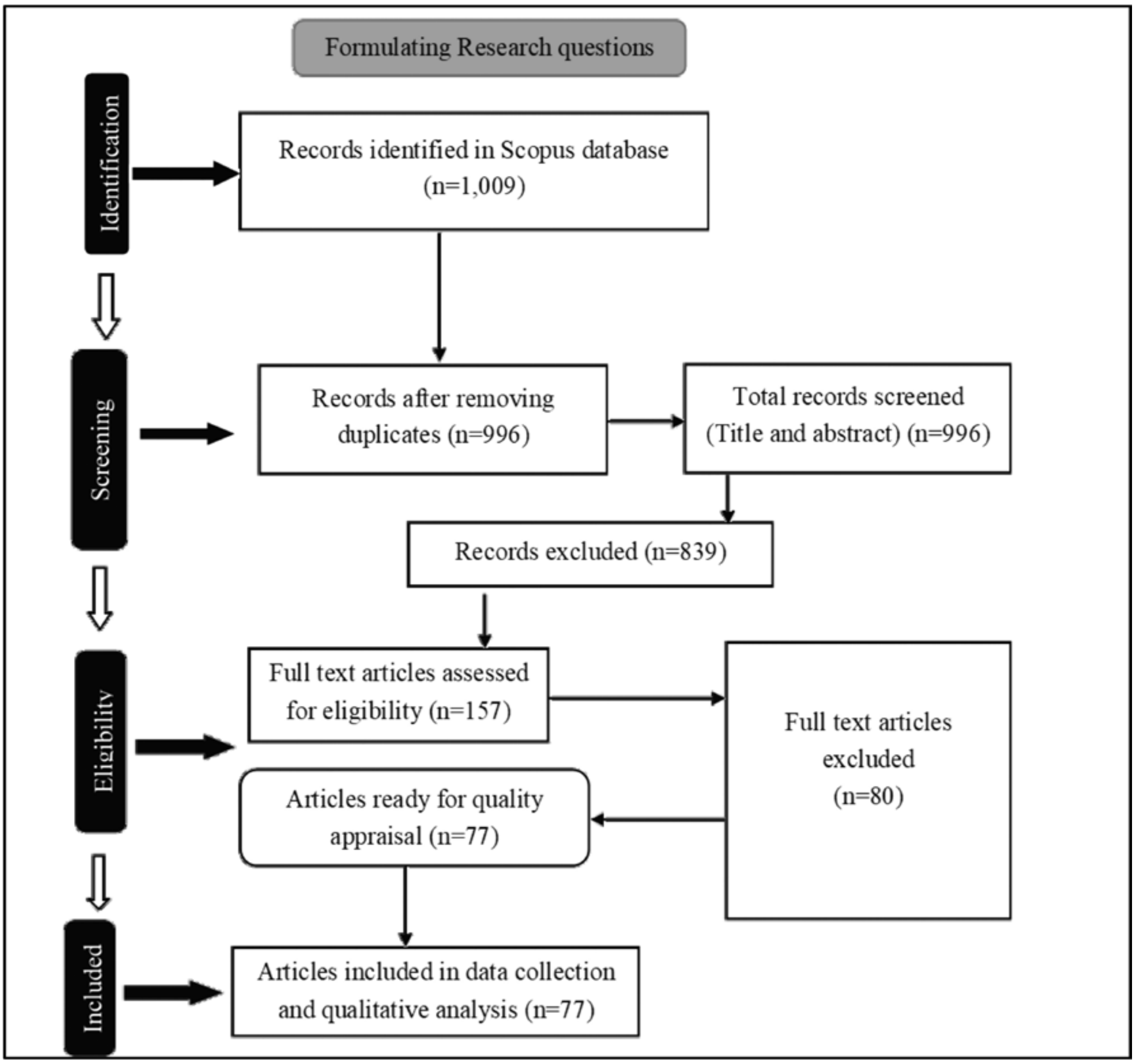

Figure 1. The PRISMA flow diagram detailing the process for systematic review (adapted from Moher *et al.* [45] and Shaffril *et al.* [4]).

ideas on how to promote and safeguard IK for societal benefit remains vital, otherwise, IK may be completely eroded over time.

Literature search

The methodology used for the literature search is similar to that of Moher *et al.* [45] and Shaffril *et al.* [4]. The methodology followed three main processes for the systematic search of literature: identification, screening, and eligibility.

Identification

We performed an electronic search of the literature in Scopus on the 21st July 2020. Here we focused on key terminology and their synonyms and related terms. Table 1 shows the search strings and documents yielded. The criteria for the search include journal articles published only in English and for the period between 2000 and 2020 within the region of Africa. Papers published in other languages and before the year 2000 were excluded in the search. We focused on the period 2000–2020 in order to obtain a broader overview of the literature on the subject. In cases where the combination of keywords such as "climate change," Scopus uses Boolean operators such as OR and AND functionality for the search.

Screening

The authors screened all 1009 gathered articles in stage 3 of the identification process by first checking and removing duplicates and then carefully reading the titles and abstracts to remove nonrelevant documents. We focused on articles published in English to ensure better first-hand understanding of the content. The screening resulted in 157 articles which were related to IK and climate change in Africa.

Table 1. Search strings and results.

Stages	Search string	Documents yielded
1	((TITLE-ABS-KEY ("indigenous knowledge" OR "local knowledge "OR "traditional knowledge "OR "farmers knowledge" OR "indigenous forecast" OR "traditional ecological knowledge" OR "indigenous science" OR "ethnoscience" OR "rural knowledge" OR "folk knowledge" OR "ancestral knowledge" OR "ancient knowledge") AND PUBYEAR >1999))	20,211
2	(((TITLE-ABS-KEY ("indigenous knowledge" OR "local knowledge "OR "traditional knowledge "OR "farmers knowledge" OR "indigenous forecast" OR "traditional ecological knowledge" OR "indigenous science" OR "ethnoscience" OR "rural knowledge" OR "folk knowledge" OR "ancestral knowledge" OR "ancient knowledge") AND PUBYEAR >1999))) AND (climate AND change)	4237
3	(((TITLE-ABS-KEY ("indigenous knowledge" OR "local knowledge "OR "traditional knowledge "OR "farmers knowledge" OR "indigenous forecast" OR "traditional ecological knowledge" OR "indigenous science" OR "ethnoscience" OR "rural knowledge" OR "folk knowledge" OR "ancestral knowledge" OR "ancient knowledge") AND PUBYEAR >1999))) AND (((climate AND change)) AND (Africa)) AND (adaptation) AND (LIMIT-TO (LANGUAGE, "English"))	1009

Eligibility

Further, the full text of potential documents was examined to select the most eligible articles. Following the suggestion of Kitchenham and Charters [47], we evaluated the 157 screened documents against the research questions as mentioned in section "Review protocol and research questions." In all, a total of 77 papers were obtained after the eligibility. We ensure that selected articles have substantially engaged the subject of study. All 77 papers are listed in appendix.

Data collection

Using a standardized data sheet in MS Excel, relevant information was extracted from the selected papers. To ensure the quality of data extracted, the content of each article was ranked (low, moderate, and high) based on the recommendations of Petticrew and Roberts [48]. As performed by Shaffril *et al.* [4], only articles categorized as high and moderate were analyzed. The ranking was based on the experts' evaluation of the methodology and content of the articles. In the datasheet, general information on the aim, methods, and results of the studies was compiled. Analysis and presentation of the results are structured in line with the research questions.

Results and discussions

Characterizing indigenous knowledge

Results show that indigenous people in Africa like those in other parts of the world are explicitly good custodians of their environment. Over a long period, they have assimilated detailed knowledge about the functionality of their immediate environment through experiences, insights into nature and society relationship, and communal and institutional practices developed by keen observations, monitoring, innovation, practice, and experimentation. For several generations, the accumulated IK is orally passed on for the survival of society [49, 50]. In context, IK encompasses local agro-environmental indicators, technical knowledge, and socio-cultural and historical information used as a response to various challenges [51]. IK can be defined as knowledge posed by a group of people living in a particular geographical area [52]. Berkes *et al.* [53] explained it as a cumulative body of knowledge, practice, and belief, evolved by adaptation processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with their environment. Mafongoya and Ajayi [33] also view it as know-how that is generated by several generations to guide their understanding and interactions with their surrounding environment. In short, IK is borne out of the long-term experience and experimentation of adjusting to environmental changes using indigenous techniques and methods.

The literature reveals a growing recognition for IK among researchers and policymakers because of its potential to contribute to the promotion and sustainability of development activities. Nonetheless, agreement on the definition and conceptualization of IK remains limited; several researchers have suggested different labels and competing definition for it [33, 53–55]. *First*, it is tagged by different names: local knowledge, traditional knowledge, farmers' knowledge, traditional ecological knowledge, ethnoscience, folk knowledge, rural knowledge, and indigenous science [33]. In this study, however, a closer look at the titles of the 77 selected articles show only four different names have been used: indigenous knowledge (n = 52), local knowledge (n = 10), traditional knowledge (n = 7), traditional ecological knowledge (n = 2), and titles with unrelated terms (n = 6). Although these terms may have different connotations, they are often used interchangeably throughout the literature. Nonetheless, IK remains the dominant terminology used in the searched literature. Similarly, Ngulube and Onyancha [56] performed a more extensive search of the terminology, in general, using an informetric approach and found the term IK to be the most used with about 3663 publications followed by traditional knowledge used in 3015 publications.

Second, IK is differently defined in the different strands of literature suggesting that IK is context-specific. A closer look at the broad nature of available literature suggests that there is not a single definition of IK due to the varying viewpoints and circumstances upon which it is utilized. The different perspective and academic backgrounds of the authors and the multidisciplinary context of IK contribute to the varied definitions and terminology that exist on the subject. However, what remains visible is the unique similarity in the definitions. A unique feature that runs through all definitions is an accumulation of observations and experiences, which are orally transmitted or via demonstration, and continually dynamic in nature [56, 57]. In most cases, the use of different terminology arises when scholars attempt to translate this knowledge into western terms [58]. In an attempt to conceptualize IK, Ngulube and Onyancha [56] argue for the need for a framework that captures the main characteristics of IK rather than focusing on finding an all-inclusive definition.

The context-specific nature of IK and the fact that it is generated by local people offer different opportunities for sustainable climate change adaptation governance, emphasized by the IPCC [59–61]. The knowledge, skills, and experiences of indigenous people are key in shaping sustainable climate interventions and meeting the needs of the most vulnerable. In that, interventions developed based on IK will maximize community level ownership and ensure a more transparent and engaging process that captures the ideas and opinions of local people. Beyond the terminological and definition question is the attempt to differentiate IK from scientific knowledge (SK) [10, 11, 13, 44, 62, 63]. Summarizing, the existing literature considered IK as a body of knowledge of people living close to nature and generated over a period of time through experiences and experimentation, often passed on from one generation to another, while SK is generally understood to involve western technology or techniques. SK and IK are distinctively considered to be respectively global and local in nature. Further, IK is qualitative and limited to specific geographic locations compared to SK that is more quantitative and universally applicable. Yet, both remain dynamic and evolving through innovation and experimentation [62]. Thus, indigenous people continue to adjust their IK to improve resilience against environmental changes including droughts, floods, disease, and pest infestations among others even if it requires that they include SK [13]. Therefore, the ability of indigenous populations in Africa to cope with environmental hazards including climate change is evidence of the applicability of IK since it remains the basis upon which local-level communication and decisions, especially in agriculture, are built [57].

The differences between IK and SK present an opportunity to view the world from two different angles. However, it is vital today, more than ever, to recognize that the world as it is, cannot resolve its challenges including climate change by isolating knowledge systems. Both knowledge systems need to complement each other. One area where the divide between IK and SK has been bridged is climate information services. It has been recognized that both knowledge systems have different benefits and that integrating them can produce weather and seasonal climate forecasts that are locally relevant and better trusted [13, 23, 64]. Moreover, attempts have been made to quantify indigenous people forecasts and present them in a format that could be easily integrated with scientific forecasts [65, 66].

Co-production of knowledge for climate change adaptation

The published literature shows a growing trend that encourages a paradigm shift from a one-directional top-down approach where knowledge is solely sourced from scientists for the development of climate adaptation strategies to a two-directional bottom-up approach that is participatory and people centered. It is argued that the latter compared with the former ensures uptake and better utilization of adaptation information by indigenous communities [37, 64, 67]. The discourse on knowledge co-production encourages the involvement and inclusion of knowledge from indigenous people and relevant stakeholders in addition to researchers or scientists. Scholars on the subject have suggested that co-production should run through the entire research and development process. It emphasizes the need to co-define the problem, co-design, and co-create the solution. Ideally, knowledge of indigenous people must be included in the formulation of research questions, data gathering and analysis [13, 23, 64]. Therefore, co-production in climate change adaptation can be defined as the engagement of scientific and indigenous knowledge in designing, creating, and producing climate change adaptation interventions to address the complex problem of climate variability and change in a way that recognizes and uses the expertise in a balanced manner.

The advent of co-production has increased the possibilities to use IK because of its ability to make indigenous communities the center of developing adaptation measures. However, a common challenge that precludes the agenda of co-production is the fact that IK is portrayed to be at odds with SK, in that IK varies in scope (spatial and temporal scale) and is qualitative in nature, making it incompatible with SK. IK is also under pressure from the global environmental change that results in rapid changes in landscapes that harbor indigenous ecological indicators used for local decision-making. Also, the frequent occurrence of extreme events remains unpredictable using IK because they fall outside the experiences of indigenous people [68]. Finally, the rapidly changing socio-economic conditions continue to trigger a massive exodus of indigenous people to urban areas which consequently erode IK over time [52].

However, the existing literature presents clear arguments to support the relevance of including IK in climate change adaptation [13, 63, 64, 69, 70]. These arguments can be structured into three lines of thinking. First, indigenous people know their area and have a better understanding of the problem they face (the frequency, severity and impact) and must be the first point of contact with regards to designing effective solutions. Second, the amount of knowledge possessed by indigenous people has served them well in the past to adapt to critical environmental challenges including climate change. Experiences derived from long-term use of IK will serve as a good foundation for developing new strategies to improve their resilience and improve the acceptability and uptake of such strategies in the field by smallholder farmers. Third, the inclusion of IK in the design and implementation of climate change adaptation project will increase the uptake of such innovations. Co-production can create a sense of ownership of innovations among indigenous people. Furthermore, IK offers researchers insight into understanding the contexts and needs of indigenous people.

Given the above benefits of IK, scholars are increasingly using co-production to integrate IK and SK in the development of early warnings including climate services [13, 44, 63, 71]. The integration of IK with SK is perceived to build upon the strengths of both knowledge systems and reduce existing weaknesses. Consequently, some case studies have suggested guiding frameworks for best practices in enhancing integration of IK and SK. For instance, using a participatory approach in Papua New Guinea, Mercer *et al.* [62] proposed a framework as an important initial step in which relevant IK and SK may be integrated to reduce a community's vulnerability to environmental hazards. Also, Ebhuoma [69] found that although indigenous farmers in the Delta state of Nigeria rely on IK, future climate variability could overwhelm their ability to use this knowledge for weather and seasonal climate forecast. The authors proposed a framework underpinned by the multiple evidence-based approaches, which aims at providing a step-by-step guide on how seasonal climate forecasts from scientific models can be integrated to compensate for the limitations of IK. Other case studies have moved a step further to implement the integration by employing ICT approaches. Examples of such cases are Masinde [72, 73] who designed an innovative drought early warning system that integrates IK and SK using information technology and indigenous knowledge with intelligence. Nyadzi *et al.* [10] and Nyadzi [64] also proposed and implemented respectively an integrated architecture of hydroclimatic information services that combine IK and SK to improve the reliability and acceptability of climate information services, to reduce the challenges of climate variability rice farmers in Ghana face.

While the existing literature agrees on the value of integrating IK and SK, the discourse on the potential problems are hardly discussed. A number of factors are likely to affect the capability of IK and SK integration. First, to achieve a meaningful integration of IK and SK, power relations remain an important issue to consider. Unequal balance of power during the process of integration and co-production could result in apathy of the knowledge sharers who might feel less powerful. Equal opportunities must be given to all knowledge holders without the attempt of one knowledge system dominating the other, as it is the tendency for SK to do so. In addressing power imbalances in co-production, Vincent *et al.* [74] argue that power dynamics, if not adequately managed, will impede the effectiveness of co-production and pose risks for long-term sustainability. Second, integrating IK and SK requires that indigenous people and scientist continue to learn and improve their experiences in knowledge acquisition, interpretation, storage, and sharing. The inability of IK or SK to lose its potency will affect the outcome of the integration. This is especially a concern for IK as it keeps eroding. Third, for effective integration of IK and SK, there is need for knowledge platforms that ensure that retrieving, storing, and sharing knowledge are done in a way that ensures faster transfer and universalization of the knowledge. Information and communication technology-enabled platforms have such capabilities. For example, Nyadzi [75] utilized Sapelli mobile app to collect IK in a form that allows integration with SK. Fourth, the choice of methods to integrate IK and SK can preclude the success of the integration. Selected methods must be responsive and flexible enough to capture and handle both knowledge systems in a manner that does not affect their distinct characteristics. Indigenous communities, for example, have complex societal organizational structures and values that influence their knowledge. When these are not properly handled, the anticipated benefits from the integration could be hindered. Finally, not all knowledge holders are motivated to share knowledge. Incentive systems remain central to ensuring that knowledge sharers are rewarded for taking the time to observe, record, generate, and share new knowledge. Moreover, incentives can determine flow and access to knowledge for integration.

IK for climate change causes and impact identification

Given the relevance of climate change awareness in building a resilient society, several scholars have attempted to document at the local level the knowledge of indigenous populations on climate change [43, 76–78]. Often, scholars argue that the lack of awareness is a significant barrier to climate change adaptation in developing countries including those in Africa. Results from several studies have shown an overwhelming awareness of climate impacts among indigenous communities. Indigenous people may not understand the concept of climate change or global warming but have accumulated IK about the changing climatic conditions and its effect on their livelihood.

Akinyemi [76], for example, reports that majority of indigenous people in selected communities in Botswana perceived drastic changes in the climate. They observed a decrease in rainfall and increase in wind strength increasing air temperature or heat, increasing drought conditions and drying rivers which have resulted in an increased frequency of hunger, human, crop, and animal diseases. Similar observations were made by Gyampoh *et al.* [43] and in addition, the authors report that indigenous people within the Offin Basin in Ghana also perceived an increase in sunshine intensity and seasonal changes in rainfall patterns.

Scholars have attempted to corroborate indigenous people perception of observed changes in climatic conditions to the scientific meteorological recordings. Results of these validation analyses show that observations by indigenous people are consistent with meteorological recordings [43, 76, 77, 79, 80]. Aside the climate change detection, IK also offers valuable information regarding the causes and consequences of climate change in specific communities. IK attributes the causes of climate change to both human actions and divine intercessors: the power of God and ancestral spirit [21, 39, 49, 57, 81, 82]. While the human cause is linked to the larger climate change discourse, the divine cause can also be indirectly connected to humans. Mekuriaw [83], for example, argues that for indigenous people to believe that climate change is a sign of God's punishment due to human disobedience indirectly supports the arguments for anthropogenic causes of climate change. Certainly, the lack of stewardship as a result of human's destruction of nature though seems to fall under God's divine authority is also a cultural way of attributing causes to human actions. IK does not only claim to perceive changes but also supports its claims with tangible examples that champions the reality of climate change and drives the debate against climate skeptics [83]. IK also provides several illustrations to elaborate these changes in rather simple ways that SK strives to achieve via countless laborious processes and the use of complex technologies.

Different groups of indigenous people have clear ideas on how climate change is impacting their livelihood. While the majority of the studies focused on crop farmers [43, 75, 78, 79, 84, 85], several scholars have also examined climate change impact from the perspectives of pastoralists [49, 86–89] and fishermen [49, 90]. Whether growing crops, rearing animals, or fish, indigenous people identify drought and flooding as the two main effects of climate change that hamper their livelihood. Specifically, among the coastal communities in Ghana, fishermen reported that flood resulting from heavy rains decrease visibility and make water inaccessible due to the fear of drowning [90]. Pastoralist in southern Ethiopia reports that increase in droughts triggers a reduction in water and pasture availability that results in decreased livestock productivity, death of livestock, conflicts as a result of boundary trespassing for pasture, and in some cases, school drop-outs due to communal migration [91]. Also among rain-fed farmers in Africa lies the challenge of predicting the weather or seasonal climate for farm decision-making: decrease in rainfall results in loss of seeds, crop failures, and low yields [42, 43, 88, 92].

IK for the formulation and implementation of climate change interventions

The available research has provided strong evidence supporting the role of IK in enhancing the resilience of indigenous communities in the face of climate change [23, 42, 71, 91, 93]. Indigenous people possess unique know-hows to offset the negative impact of climate sensitive challenges [10, 51, 63, 88]. The application of IK for responding to climate change in agriculture has been reflected in terms of farm management practices, early warning, and risk and disaster management.

Indigenous farmers in Africa consider their IK on farming systems and practices to be effective in managing climate change. This is because the use of IK is relatively inexpensive and depends more on local materials and indigenous varieties, and compared to modern scientific farming systems and practices, it has fewer side effects. To make farm management practices, more effective scholars recommend the incorporation of IK into modern farming approaches to protect African agriculture systems from climate shocks and improve productivity [94–96]. Mugwisi [57] reports the use of IK in different aspect of agriculture: animal science, fisheries, soil science, crop science, and postharvest storage. For instance, IK is used in animal husbandry and crop science to manage pest and diseases. Soil fertility and soil water conservation methods (such as mixed cropping, mulching with livestock droppings fallen leaves, etc.), seed preservation, and weed control methods of indigenous people all stem from IK. Kwoyiga and Stefan [97] found that IK also helps farmers to locate groundwater points and determine the source and timing of groundwater recharge for irrigation. For instance, they use the presence of shrubs, broom plants, trees (*Ficus gnaphalocarpa*), thorns/thorn grasses, and black ants to indicate groundwater availability. In some cases and based on farmers IK, indigenous people classify soils into agricultural and nonagricultural purposes based on soil physical properties. Napogbong *et al.* [86] studied indigenous adaptation strategies of Fulani herders in North-Western Ghana and found that cattle herders use different strategies including cattle stress management (siting kraals near or under trees, building bigger kraals, and formatting sub-herds for differential stress management), mobility (linear but unidirectional movement, nonlinear/irregular movement, circular movement, and migratory movement), different sources feed (pruned branches and leaves of tree, crop residue, and sprout grasses), and division of labor (among members of household based on gender and due to increased workload resulting from drought induced food shortage) to address the vulnerabilities of their livestock to climate change. In Ethiopia, Mancini *et al.* [55] understudy several traits farmers use to select better wheat varieties based on their IK. Combining farmers identified traits (seed color, weight and size, tillering capacity, spike quality, amount of flour seed produce, etc.) with metric traits, researchers were able to improve the selection of improved wheat varieties.

For early warning systems, farmers have developed special techniques for gathering, predicting, and interpreting certain indicators to anticipate the weather or seasonal climatic conditions for farm decision-making [10, 51, 98–105]. The long-term experiences of indigenous communities in Africa through the interaction with their immediate environment have enabled them to identify certain indigenous ecological indicators that are explored to predict the weather and seasonal climate. Research has revealed that indigenous people have a more favorable perception about the reliability of IK in weather and seasonal climate for local decision-making and are more inclined to use it rather than scientific meteorological forecasts [11, 78]. In general terms, African indigenous people rely on behavior and appearances of certain insects, animals, and plants, meteorological indicators and astrological bodies for forecasting the occurrence of daily rains, and at a seasonal level, the onset, cessation, intensity, and distribution of the rains. While the interpretation of certain indicators is the same across several communities, others remain peculiar to a particular locality. For instance, the use of dark clouds to predict heavy rainfall few hours before they occur is the universally held knowledge also used by indigenous communities. In addition, the appearance of ants and rapidly increasing size and quantity of ant mounds to predict good rainy season are common in most communities. Meanwhile, using *Turbid color inside the intestine of an animal* to predict above normal rain/flooding and *cow returning home after grazing refusing to go close to its calf* to predict drought is only identified with indigenous pastoralists in southern Ethiopia [84, 88, 91]. Also, Nyadzi *et al.* [75] found that the same indigenous ecological indicators are used for both weather and seasonal predictions, depending on the signals they exhibit. However, dogs (*Canis lupus familiaris*), reptiles (such as snakes—family colubridae), stars, and trees (such as baobab trees—*Adansonia digitate*) are used only for seasonal climate forecast, while soil texture, for example, is used for short-term weather forecast only. There is also evidence in the literature that suggests that the skill to forecast depends on age and personal experiences [64, 94, 106]. Given the overwhelming evidence on the efficacy of these indicators, researchers and policymakers have begun to embrace IK in weather and seasonal forecasting at the local level [33, 53–55, 74].

An important well-documented benefit of IK is the management of risk and disasters. Results show that indigenous communities in different parts of Africa have explored their IK in diverse ways to design disaster management strategies [42, 46, 72, 107–113]. Indigenous communities have coped with extreme weather conditions and natural hazards that result in droughts, floods, and storm damages by fortifying or building appropriate homestead fences and walls for protection. In an attempt to document the role of disaster risk reduction in South Africa, Muyambo *et al.* [114] conclude that IK remains an essential part of adapting local agriculture and contributes to resilience against disasters. Worth mentioning is the use of IK for climate risk assessment. IK has proven relevant for vulnerability assessment and reinforces the need for adaptation in the face of climate-related disasters [115]. For example, File and Derbile [115] utilized participatory approaches to gather perception data that allow analysis of changes in how the past and present generations are at risk to sunshine, temperature, and wind. The use of IK alongside SK in improving early warning systems to make decisions that reduce climate risk and disaster is increasingly gaining momentum. Masinde [116] reported that the need to integrate IK into disaster management systems has been seen as relevant yet to achieve this remains a question unanswered. Building upon this knowledge gap, the authors developed and tested an innovative drought early warning system for sub-Saharan Africa where IK and SK are integrated [72].

Promoting and conserving IK for climate change management

The trend as identified in the literature indicates that IK remains a significant source of resources for responding to climate variability and change especially at the local level. Despite its benefits, the future of IK remains critical in the sense that it faces apathy among young people and more so by scientists and policymakers [85, 88, 117]. Critical factors that inherently drive IK loss in indigenous communities in Africa include (i) modernization and rural-urban migration [82, 85, 98, 118]; (ii) changing landscape due to climate change and land use [88, 117]; and (iii) shifting religious beliefs [39, 119]. Continuous erosion of IK threatens the ability of indigenous people to respond to climate variability and change.

Although the literature on IK is continuously growing, much work is still required to provide insight into the relevance of IK in responding to climate variability and change [71, 118, 120]. Throughout the literature, it is noticeable that IK is still handled in general terms with limited effort to go beyond identifying existing IK and its uses in indigenous communities. Studies that critically engage the complexities of the subject are often absent. Ford *et al.* [121] evaluated how IK is included and captured in the IPCC assessment and observed that although reference to IK has increased from the AR4 to AR5, the subject remained generally limited in scope and length.

IK in Africa, generally, lacks organized documentation. The mode for transmitting IK to the next generation in Africa is still orally performed without proper records and storage. This causes a challenge of losing IK since the older generation is unable to pass on this rather important knowledge to their young ones in a formally documented format for easy access in the future. Without proper documentation, it will be difficult to make a case for IK mainstreaming into the development of climate adaptation strategies [85]. To ameliorate this problem, Tanyanyiwa [122] for instance advocate for the inclusion of IK into teaching curriculum of schools. The author argues that shifting the existing teaching/learning curriculum based on western science to include IK will result in an education that offers a holistic understanding of all knowledge systems and allows young people to perceive IK as a legitimate source of knowledge that is complementary to SK. Orlove *et al.* [30] already identified the openness to incorporate IK into formal education in southern Uganda. The authors observed that certain terminologies (such as "nimbus" meaning rain-bearing clouds) used my indigenous people were as well thought in schools. In studying the extent of IK in extension services delivery in Nigeria and South Africa, Kolawole [96] observe that despite the abundance of IK in both countries, there were low level of IK used by the extension services and therefore suggest that extension services delivery should explore and include more of IK to improve agriculture productivity.

The qualitative nature and the presence of presumed spirituality of IK that is absent in SK have created a bad reputation among policymakers and scientists who view IK with much skepticism. Meanwhile, despite the interest in SK, indigenous farmers have difficulties embracing it because of the absence of a sense of ownership and lack of trust due to unreliability in the information provided and inability to meet needs. The cynicism of climatologists and meteorologists toward farmers' IK and vice versa limits the opportunity for integration. Scholarly works on the subject mainly focus on identifying existing IK used by indigenous people and how they are utilized for building resilience. Studies that attempt to evaluate IK used a rather social qualitative approach to solicit farmers' opinion about the quality of IK [63, 76, 77, 85]. In a recent study, Nyadzi [64, 65] utilized a binary forecast verification method (World Meteorological organization's acceptable forecast verification measure) to quantitatively determine the accuracy or skills of indigenous forecast in Ghana. The author also proposed and tested an Integrated Forecast Probability (IPF) method that quantitatively combined indigenous and scientific forecast (at both daily and seasonal timescale) into a single objective and improved forecast that is more reliable. The author concludes that there is the need to develop methodologies that collect indigenous forecast in a manner that can be analyzed quantitatively and when this is achieved there is the likelihood to improve the perception of IK in the scientific community. The question that remains unanswered is whether the attempt to re-contextualized IK might not result in the loss of its intrinsic value.

Conclusion and recommendation

This study systematically draws from the existing literature to provide insight into the discourse on the role of indigenous knowledge (IK) in managing climate variability and change in Africa. In general, findings show that indigenous communities in Africa possess unique knowledge for managing climate variability and change. Although this knowledge is perceived as complex and sophisticated and often overlooked by scientist and policymakers, it has helped in building the resilience of indigenous people against disasters for several generations. Following the examining themes and emerging issues across the literature, the study prioritizes five main areas structured into research questions as elaborated in section "Review protocol and research questions." Several concluding points and recommendations are derived from this research:

There is no agreement on how IK is defined and it has been referred to using different terminologies. Lack of consensus about what IK meant to different people of the different scholarly background has limited its applications. For instance, Ford *et al.* [121] examined the inclusion of indigenous knowledge and experience in IPCC assessment reports, and argue that reviewing and assessing the state of knowledge for the report is not a value-neutral role despite the moderation by external reviewers. The process is influenced by some factors including the author's disciplinary background. This affects what is included or excluded, how knowledge is framed and argued as well as the amount of space allocated to each topic and the style of writing. A critical look at the available definitions suggests that certain elements remain valid when conceptualizing IK. First, IK originates from indigenous people who live close and interact with nature. Second, IK stems from past observations and experiences accumulated by indigenous people over several years. Third, it is largely preserved by oral transmission from older to younger generation. Therefore, instead of pushing for a single established definition of IK, we should focus on the common elements that offer an opportunity for mutual grounds to develop an elaborated context that builds on the unique features of IK.

Indigenous people in Africa should be viewed as agents of climate change adaptation rather than only victims of climate change. Researchers who focused on climate change adaptation in Africa have shifted their attention to indigenous knowledge as a haven to developing effective climate change adaptation strategies. IK plays a fundamental role in the climate change adaptation space in Africa. IK is very relevant for confirming the occurrence, causes, and impact of climate change among indigenous people. Indigenous people are aware of climate change and its consequences although may not be able to explain directly what the scientific terminologies meant. In some cases, indigenous people have heard of the concept via radios and from extension officers with whom they regularly interact. The perception of indigenous farmers, pastoralist, and fishermen concerning climate change is consistent with scientific meteorological knowledge offering confidence in IK for the formulation of adaptation practices. Results also show that IK plays a central role in the formulation of different climate change adaptation strategies. IK has been applied in three main ways: farm management practices, early warning, and risk and disaster management. Indigenous people are known to depend on their knowledge, because the use of IK is relatively at low cost, relying on indigenous materials and varieties that have low (if at all) effect on their livelihood compared to modern scientific approaches.

The growing advocacy for knowledge co-production has directed attention to IK. Several scholars have suggested that integrating IK and SK offers a great opportunity for improving the efficiency of adaptation measures and the empowerment of indigenous people. One area where the call for integration is gaining momentum is for the development of early warning systems such as climate information services. The logic behind the call to combine IK with SK is that indigenous people know their environment better and have a deeper understanding of their problems. Moreover, for several years, indigenous people have adapted well to their environmental and climatic challenges. Also, integrating IK with SK will establish a level of trust and ownership that will improve the uptake of climate services. Therefore, to ensure effective development of climate change adaptation interventions, the underlying knowledge must be based on multiple sources including indigenous people through the principle of co-production. Additionally, proponents of IK have argued that IK provides insight into understanding the contexts and needs of indigenous people and therefore should be included throughout the process of developing adaptation strategies.

Finally, regardless of its enormous value, IK is endangered by several drivers including modernization and rural-urban migration; increasing population pressure and changes in demographic structure in rural communities, and changing landscape due to climate change and land use; and shifting religious beliefs. Given that the loss of IK will exacerbate the negative impact of climate change among indigenous people, scholars have suggested the need to study its complexity, proper documentation and storage of IK, and developing effective approaches to better understand IK such that its potential to improve climate adaptation planning and implementation in the continent is well appreciated among researchers and policymakers. Therefore, there is a need for more research, proper documentation, and effective methodology to handle IK in a way that makes it appealing for the scientific community. While attempting to achieve this, we suggest that the process should ensure that the unique features that make IK valuable are not lost.

Appendix

List of 77 articles reviewed linked to the five research themes.
Theme 1: Characterization of IK
Theme 2: Potential of IK for knowledge co-production
Theme 3: IK for climate change causes and impact identification
Theme 4: IK for formulating and implementing climate change interventions
Theme 5: Documentation and conservation of IK as a resource for climate change adaptation

No.	Title	Author(s)	Themes
1	A Framework For Integrating Scientific Forecasts With Indigenous Systems Of Weather Forecasting In Southern Nigeria	Ebhuoma, 2020	2
2	Adaptation To Climate Change Using Indigenous Weather Forecasting Systems In Borana Pastoralists Of Southern Ethiopia	Iticha and Husen, 2019	3 and 4
3	Adapting To Climate Change In Shifting Landscapes Of Belief	Murphy *et al.*, 2016	5
4	An Effective Drought Early Warning System For Sub- Saharan Africa: Integrating Modern And Indigenous Approaches	Masinde, 2014	4
5	An Innovative Drought Early Warning System For Sub-Saharan Africa: Integrating Modern And Indigenous Approaches	Masinde, 2015	2 and 4
6	Applying Indigenous Knowledge In Agricultural Extension In Zimbabwe	Mugwisi, 2016	1, 3 and 4
7	Characterizing Local Knowledge Across The Flood Risk Management Cycle: A Case Study Of Southern Malawi	Šakić Trogrlić *et al.*, 2019	1 and 2
8	Climate Change Adaptation In Rwanda Through Indigenous Knowledge Practice	Taremwa *et al.*, 2016	4
9	Climate Change Adaptation: Linking Indigenous Knowledge With Western Science For Effective Adaptation	Makondo and Thomas,2018	3

Continued

No.	Title	Author(s)	Themes
10	Climate Change And Variability In Semiarid Palapye, Eastern Botswana: An Assessment From Smallholder Farmers' Perspective	Akinyemi, 2017	3 and 5
11	Climate Change, Local Knowledge And Climate Change Adaptation In Ghana	Derbile *et al.*, 2016	1 and 4
12	Climate Trends And Farmers' Perceptions Of Climate Change In Zambia	Mulenga *et al.*, 2017	5
13	Climate Variability And Rural Livelihoods: How Households Perceive And Adapt To Climatic Shocks In The Okavango Delta, Botswana	Kolawole *et al.*, 2016	3 and 4
14	Community-Based Environmental Resource Management Systems For Sustainable Livelihood And Climate Change Adaptation: A Review Of Best Practices In Africa	Kaya and Chinsamy, 2016	1
15	Conceptualizing The Knowledge Of Traditional And Indigenous Communities Using Informetrics Approaches	Ngulube and Onyancha, 2020	1
16	Coverage Of Indigenous Knowledge System In Extension Services Delivery In Two Regions Of Nigeria And South Africa: A Content Analysis.	Kolawole, 2013	4 and 5
17	Fulani Herders And Indigenous Strategies Of Climate Change Adaptation In Kpongu Community, North-Western Ghana: Implications For Adaptation Planning	Napogbong *et al.*, 2020	3 and 4
18	Groundwater Development For Dry Season Irrigation In North East Ghana: The Place Of Local Knowledge	Kwoyiga Stefan, 2018	4
19	Cultural Values And African Indigenous Knowledge Systems In Climate Change Adaptation	Kaya, 2016	4
20	Dealing With Uncertainty: Integrating Local And Scientific Knowledge Of The Climate And Weather	Kniveton *et al.*, 2015	1 and 4
21	Diagnosing The Potential Of Hydro-Climatic Information Services To Support Rice Farming In Northern Ghana	Nyadzi *et al.*, 2018	2 and 4
22	Do Indigenous Forecasts And Scientific Forecasts Influence Arable Farmers' And Agro-Pastoralists' Estimation Of Onset And Cessation Of Rains? Empirical Evidence From Rwenzori Region, Western Uganda	Nkuba *et al.*, 2019	3
23	Downscaling Africa's Drought Forecasts Through Integration Of Indigenous And Scientific Drought Forecasts Using Fuzzy Cognitive Maps	Masinde *et al.*, 2018	4
24	Framework For Integrating Indigenous And Scientific Knowledge For Disaster Risk Reduction	Mercer *et al.*, 2010	1 and 2
25	Local Knowledge In Climate Adaptation Research: Moving Knowledge Frameworks From Extraction To Co-Production	Klenk *et al.*, 2017	2
26	Indigenous Climate Information And Modern Meteorological Records In Sinazongwe District, Southern Province, Zambia	Kanno *et al.*, 2013	3
27	Indigenous Climate Knowledge In Southern Uganda: The Multiple Components Of A Dynamic Regional System	Orlove *et al.*, 2010	5
28	Indigenous Knowledge And Farmer Perceptions Of Climate And Ecological Changes In The Bamenda Highlands Of Cameroon: Insights From The Bui Plateau	Tume *et al.*, 2019	3 and 5
29	Indigenous Knowledge Approach In Maintaining A Livelihood In The Face Of Disastrous Climate Change: Case Of Drought In Msinga Villages, Kwazulu-Natal	Rukema and Umubyeyi, 2019	3 and 4
30	Indigenous Knowledge For Seasonal Weather And Climate Forecasting Across East Africa	Radeny *et al.*, 2019	3, 4 and 5
31	Indigenous Knowledge Indicators In Determining Climate Variability In Rural Ghana	Sulloa *et al.*, 2020	4
32	Indigenous Knowledge Of Rural Communities For Combating Climate Change Impacts In West Central Ethiopia	Amare, 2018	3
33	Indigenous Knowledge Related To Climate Variability And Change: Insights From Droughts In Semi-Arid Areas Of Former Makueni District, Kenya	Speranza *et al.*, 2010	3 and 5
34	Indigenous Knowledge Systems And Indicators Of Rain: Evidence From Rwenzori Region, Western Uganda	Nkuba *et al.*, 2020	4
35	Indigenous Knowledge Systems And The Teaching Of Climate Change In Zimbabwean Secondary Schools	Tanyanyiwa, 2019	4 and 5
36	Indigenous Knowledge, Global Ignorance? Insights From An Eastern Cape Climate Change Study	Apraku *et al.*, 2018	2
37	Indigenous Knowledge, Livelihoods And Government Policy In The Okavango Delta, Botswana	Cassidy *et al.*, 2011	3 and 5
38	Indigenous Strategies Used By Selected Farming Communities In Kwazulu Natal, South Africa, To Manage Soil, Water, And Climate Extremes And To Make Weather Predictions	Vilakazi *et al.*, 2019	3 and 4

Continued

No.	Title	Author(s)	Themes
39	Indigenous Weather Forecasting Systems: A Case Study Of The Biotic Weather Forecasting Indicators For Wards 12 And 13 In Mberengwa District Zimbabwe	Shoko and Shoko, 2013	4
40	Integrating Indigenous And Scientific Knowledge Systems For Climate Change Adaptation In Zambia	Kasali, 2011	1 and 2
41	Integrating Indigenous Knowledge With Conventional Science: Enhancing Localized Climate And Weather Forecasts In Nessa, Mulanje, Malaw	Kalanda-Joshua *et al.*, 2011	1, 2, 4, 5
42	Integration Of Indigenous Knowledge Systems Into Climate Change Adaptation And Enhancing Food Security In Nandi And Keiyo Districts, Kenya	Songok *et al.*, 2011	2, 4, 5
43	ITIKI Plus: A Mobile Based Application For Integrating Indigenous Knowledge And Scientific Agro-Climate Decision Support For Africa's Small-Scale Farmers	Masinde and Thothela 2019	2
44	Joining Smallholder Farmers' Traditional Knowledge With Metric Traits To Select Better Varieties Of Ethiopian Wheat	Mancini *et al.*, 2017	1 and 4
45	Local And Indigenous Knowledge Systems In Subsistence Agriculture, Climate Risk Management, And Mitigation Of Community Vulnerability In Changing Climate, Lake Victoria Basin: A Case Study Of Rakai And Isingiro Districts, Uganda	Tolo *et al.*, 2014	4
46	Local Institutions And Indigenous Knowledge In Adoption And Scaling Of Climate-Smart Agricultural Innovations Among Sub-Saharan Smallholder Farmers	Makate, 2019	2
47	Mainstreaming Indigenous Knowledge In Climate Change Response: Traditional 'Rainmaking' In Kenya	Kwanya, 2014	4
48	Phenological Cues Intrinsic In Indigenous Knowledge Systems For Forecasting Seasonal Climate In The Delta State Of Niger	Fitchett and Ebhuoma, 2018	3
49	Reducing Vulnerability Of Rain-Fed Agriculture To Drought Through Indigenous Knowledge Systems In North-Eastern Ghana	Derbile, 2013	3 and 4
50	Resilience Of Informal Settlements To Climate Change In The Mountainous Areas Of Konso, Ethiopia And Qwaqwa, South Africa	Melore and Nel, 2020	2
51	Resilience Of The Poorest: Coping Strategies And Indigenous Knowledge Of Living With The Floods In Northern Namibia	Hooli, 2016	4
52	Role Of Indigenous Knowledge In Climate Change Adaptation: A Case Study Of The Teso Sub-Region, Eastern Uganda	Egeru, 2012	1 and 3
53	Sunshine, Temperature And Wind Community Risk Assessment Of Climate Change, Indigenous Knowledge And Climate Change Adaptation Planning In Ghana	File and Derbile, 2020	4
54	The Best Of Both Worlds: A Decision-Making Framework For Combining Traditional And Contemporary Forecast Systems	Plotz *et al.*, 2017	1 and 2
55	The Contribution Of Indigenous Knowledge To Disaster Risk Reduction Activities In Zimbabwe: A Big Call To Practitioners	Dube and Munsaka, 2018	4
56	The Role Of Indigenous Knowledge (IK) In Adaptation To Drought By Agropastoral Smallholder Farmers In Uganda	Barasa *et al.*, 2020	3
57	The Role Of Indigenous Knowledge In Drought Risk Reduction: A Case Of Communal Farmers In South Africa	Muyambo *et al.*, 2017	4
58	The Role Of Local Knowledge In Adaptation To Climate Change	Naess, 2013	1, 2 and 5
59	The Use Of Indigenous Knowledge Systems For Short And Long Range Rainfall Prediction And Farmers' Perceptions Of Science-Based Seasonal Forecasts In Zimbabwe	Gwenzi *et al.*, 2016	3
60	Seasonal Climate Prediction And Adaptation Using Indigenous Knowledge Systems In Agriculture Systems In Southern Africa: A Review	Jiri *et al.*, 2016	4
61	The Value Of Indigenous Knowledge In Climate Change Mitigation And Adaptation Strategies In The African Sahel	Nyong *et al.*, 2007	4
62	The Values Of Traditional Ecological Knowledge	Reyes-García 2015	5
63	Towards A Methodological Approach To Document And Analyze Local Knowledge Of Climate Change: With Evidence From Rift Valley And Blue Nile Basins, Ethiopia	Mekuriaw, 2017	3
64	Traditional And Local Knowledge Practices For Disaster Risk Reduction In Northern Ghana	Macnight *et al.*, 2018	4
65	Traditional Ecological Knowledge And Flood Risk Management: A Preliminary Case Study Of The Rwenzori	Bwambale *et al.*, 2018	4
66	Useful Traditional Knowledge Indicators For Drought Forecasting In The Mzingwane Catchment Area Of Zimbabwe	Chisadza *et al.*, 2013	4
67	Using Traditional Knowledge To Cope With Climate Change In Rural Ghana	Gyampoh *et al.*, 2009	3

Continued

No.	Title	Author(s)	Themes
68	Using Indigenous Knowledge To Enhance Rainfall Forecasts Among Smallholder Farmers In Mt. Elgon Region, Eastern Uganda	Kyazze *et al.*, 2019	4
69	Validation Of Local Knowledge Drought Forecasting Systems In The Limpopo River Basin In Southern Africa	Chisadza *et al.*, 2014	4
70	We Know Our Terrain': Indigenous Knowledge Preferred To Scientific Systems Of Weather Forecasting In The Delta State Of Nigeria	Ebhuoma and Simatele, 2019	1 and 4
71	Weather Forecasting Using Local Traditional Knowledge (LTK) In The Midst Of Climate Change In Domboshawa, Zimbabwe	Tanyanyiwa, 2018	4
72	Women's Use Of Indigenous Knowledge For Environmental Security And Sustainable Development In Southwest Nigeria	Yetunde Adebunmi Aluko	3
73	Coping With Climate Variability And Non-Climate Stressors In The West African Oyster (Crassostrea Tulipa) Fishery In Coastal Ghana	Atindana *et al.*, 2020	3
74	A Deeper Meaning Of Sustainability: Insights From Indigenous Knowledge	Mazzocchi, 2020	1
75	Climate Variability Since 1970 And Farmers' Observations In Northern Ghana	Nyadzi, 2016	3
76	Indigenous Knowledge Systems And Climate Change Management In Africa	Mafongoya and Ajayi, 2017	1 and 4
77	Best Of Both Worlds: Co-Producing Climate Services That Integrate Scientific And Indigenous Weather And Seasonal Climate Forecast For Water Management And Food Production In Ghana	Nyadzi, 2020	1, 2 and 4

References

1. Wani KA, Ariana L. Impact of climate change on indigenous people and adaptive capacity of bajo tribe, Indonesia. Environmental Claims Journal 2018;30:302–13.
2. WB - world Bank. Indigenous peoples 2019. Retrieved from: URL: https://www.worldbank.org/en/topic/indigenouspeoples
3. UN. Indigenous Peoples in the African region. Twelfth Session of the UN Permanent Forum on Indigenous Issues Discussion on Thursday, 23 May 2013, 3 – 6 p.m 2013. Available from: URL: https://www.un.org/esa/socdev/unpfii/documents/2013/Media/Fact%20Sheet_Africa_%20UNPFII-12.pdf
4. Mohamed Shaffril HA, Ahmad N, Samsuddin SF, Samah AA, Hamdan ME. Systematic literature review on adaptation towards climate change impacts among indigenous people in the Asia Pacific regions. Journal of Cleaner Production 2020;258:120595.
5. IPCC. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. In: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press; 2014.
6. Chanza N, Mafongoya PL. Indigenous-based climate science from the Zimbabwean experience: from impact identification, mitigation and adaptation. In: Indigenous knowledge systems and climate change management in Africa. Wageningen, The Netherlands: CTA; 2017. p. 67.
7. Alexander C, Bynum N, Johnson E, King U, Mustonen T, Neofotis P, et al. Linking indigenous and scientific knowledge of climate change. BioScience 2011;61:477–84.
8. Ajibade L, Eche J. Indigenous knowledge for climate change adaptation in Nigeria. In: Indigenous knowledge systems and climate change management in Africa. Wageningen, The Netherlands: CTA; 2017. p. 219.
9. Sheffield J, Wood EF, Chaney N, Guan K, Sadri S, Yuan X, et al. A drought monitoring and forecasting system for sub-sahara african water resources and food security. Bulletin of the American Meteorological Society 2014;95:861–82.
10. Nyadzi E, Nyamekye AB, Werners SE, Biesbroek RG, Dewulf A, Slobbe E Van, et al. Diagnosing the potential of hydro-climatic information services to support rice farming in northern Ghana. NJAS - Wageningen Journal of Life Sciences 2018;86–87:51–63.
11. Ebhuoma EE, Simatele DM. 'We know our Terrain': indigenous knowledge preferred to scientific systems of weather forecasting in the Delta State of Nigeria. Climate and Development 2019;11:112–23.
12. Makwara EC. Indigenous knowledge systems and modern weather forecasting: exploring the linkages. Journal of Sustainable Agriculture 2013;2:98–141.
13. Plotz RD, Chambers LE, Finn CK. The best of both worlds: a decision-making framework for combining traditional and contemporary forecast systems. Journal of Applied Meteorology and Climatology 2017;56:2377–92.
14. Smit B, Burton I, Klein RJT, Wandel J. An anatomy of adaptation to climate change and variability. In: Societal adaptation to climate variability and change. The Netherlands: Springer; 2000. p. 223–51.
15. Tambo JA. Adaptation and resilience to climate change and variability in north-east Ghana. International Journal of Disaster Risk Reduction 2016;17:85–94.
16. Mugambiwa SS. Adaptation measures to sustain indigenous practices and the use of indigenous knowledge systems to adapt to climate change in Mutoko Rural District of Zimbabwe. Jàmbá: Journal of Disaster Risk Studies 2018;10(1):1–9.
17. FAO. Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities. Rome, Italy: Food and Agriculture Organization of the United Nations; 2007.
18. Feola G, Lerner AM, Jain M, Montefrio MJF, Nicholas KA. Researching farmer behaviour in climate change adaptation and sustainable agriculture: lessons learned

from five case studies. Journal of Rural Studies 2015;39:74–84.

19. Belfer E, Ford JD, Maillet M. Representation of indigenous peoples in climate change reporting. Climatic Change 2017;145:57–70.
20. Fairhead J, Fraser J, Amanor K, Solomon D, Lehmann J, Leach M. Indigenous soil enrichment for food security and climate change in Africa and Asia: a review. In: Indigenous knowledge: enhancing its contribution to natural resources management. UK: CABI; 2017. p. 99–115.
21. Makondo CC, Thomas DSG. Climate change adaptation: linking indigenous knowledge with western science for effective adaptation. Environmental Science & Policy 2018;88:83–91.
22. Salick J, Fang Z, Byg A. Eastern Himalayan alpine plant ecology, Tibetan ethnobotany, and climate change. Global Environmental Change 2009;19:147–55.
23. Naess LO. The role of local knowledge in adaptation to climate change. Wiley Interdisciplinary Reviews: Climate Change 2013;4:99–106.
24. Ngodigha SA, Abowei JFN, Ogamba EN. The role of indigenous knowledge in fisheries research in Ogbia Creek, Niger Delta. International Journal of Novel Research in Life Science 2015;2(5):41–49.
25. David W, Ploeger A. Indigenous knowledge (IK) of water resources management in West Sumatra, Indonesia. Future of Food: Journal on Food, Agriculture and Society 2014;2(1):40–44.
26. Cabrera VE, Letson D, Podestá G. The value of climate information when farm programs matter. Agricultural Systems 2007;93:25–42.
27. Desbiez A, Matthews R, Tripathi B, Ellis-Jones J. Perceptions and assessment of soil fertility by farmers in the mid-hills of Nepal. Agriculture, Ecosystems and Environment 2004;103:191–206.
28. Gray LC, Morant P. Reconciling indigenous knowledge with scientific assessment of soil fertility changes in southwestern Burkina Faso. Geoderma 2003;111:425–37.
29. Zuma-Netshiukhwi G, Stigter K, Walker S. Use of traditional weather/climate knowledge by farmers in the South-Western free State of South Africa: agrometeorological learning by scientists. Atmosphere (Basel) 2013;4:383–410.
30. Orlove B, Roncoli C, Kabugo M, Majugu A. Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system. Climatic Change 2010;100:243–65.
31. Chang'a LB, Yanda PZ, Ngana J. Indigenous knowledge in seasonal rainfall prediction in Tanzania: a case of the South-western Highland of Tanzania. Journal of Geography and Regional Planning 2010;3:4.
32. Olsson P, Folke C, Berkes F. Adaptive comanagement for building resilience in social -ecological systems. Environmental Management 2004;34(1):75–90.
33. Mafongoya PL, Ajayi OC. Indigenous knowledge and climate change: overview and basic propositions. In: Indigenous knowledge systems and climate change management in Africa. Wageningen, The Netherlands: CTA; 2017. p. 17–28.
34. Diffenbaugh NS, Pal JS, Giorgi F, Gao X. Heat stress intensification in the Mediterranean climate change hotspot. Geophysical Research Letters 2007;34.
35. Robinson P, Lowe J. Literature reviews vs systematic reviews. Australian and New Zealand Journal of Public Health 2015;39:103.
36. Martín-Martín A, Costas R, van Leeuwen T, López-Cózar ED. Evidence of open access of scientific publications in Google Scholar: a large-scale analysis. Journal of Informetrics 2018;12(3):819–41.
37. Klenk N, Fiume A, Meehan K, Gibbes C. Local knowledge in climate adaptation research: moving knowledge frameworks from extraction to co-production. Wiley Interdisciplinary Reviews: Climate Change 2017;8(5):1–15.
38. Ingram KT, Roncoli MC, Kirshen PH. Opportunities and constraints for farmers of west Africa to use seasonal precipitation forecasts with Burkina Faso as a case study. Agricultural Systems 2002;74:331–49.
39. Speranza CI, Kiteme B, Ambenje P, Wiesmann U, Makali S. Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. Climatic Change 2010;100:295–315.
40. Newsham AJ, Thomas DSG. Knowing, farming and climate change adaptation in North-Central Namibia. Global Environmental Change 2011;21:761–70.
41. Chisadza B, Tumbare MJ, Nyabeze WR, Nhapi I. Linkages between local knowledge drought forecasting indicators and scientific drought forecasting parameters in the Limpopo River Basin in Southern Africa. International Journal of Disaster Risk Reduction 2015;12:226–33.
42. Derbile EK. Reducing vulnerability of rain-fed agriculture to drought through indigenous knowledge systems in north-eastern Ghana. International Journal of Climate Change Strategies and Management 2013;5:71–94.
43. Gyampoh BA, Amisah S, Idinoba M, Nkem J. Using traditional knowledge to cope with climate change in rural Ghana. Unasylva 2009;60(281/232):70–4.
44. Kasali G. Integrating Indigenous and scientific knowledge systems for climate change adaptation in Zambia. In: Experiences of climate change adaptation in Africa. Berlin, Heidelberg: Springer; 2011. p. 281–95.
45. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. International Journal of Surgery 2010;8(5):336–41.
46. Chisadza B, Tumbare MJ, Nhapi I, Nyabeze WR. Useful traditional knowledge indicators for drought forecasting in the Mzingwane catchment area of Zimbabwe. Disaster Prevention and Management 2013;22:312–25.
47. Kitchenham B, Charters S. Guidelines for performing systematic literature reviews in software engineering. EBSE Technical Report Version 2.3. UK: EBSE; 2007.
48. Petticrew M, Roberts H. Systematic reviews in the social sciences: a practical guide. John Wiley & Sons; 2008.
49. Egeru A. Role of indigenous knowledge in climate change adaptation: a case study of the teso Subregion, eastern Uganda. Indian Journal of Traditional Knowledge 2012;11:217–24.
50. Mazzocchi F. A deeper meaning of sustainability: insights from indigenous knowledge. Anthropological Review 2020;7:77–93.
51. Kniveton D, Visman E, Tall A, Diop M, Ewbank R, Njoroge E, et al. Dealing with uncertainty: integrating local and scientific

knowledge of the climate and weather. Disasters 2015;39:s35–53.

52. Šakić Trogrlić R, Wright G, Duncan M, van den Homberg M, Adeloye A, Mwale F, et al. Characterising local knowledge across the flood risk management cycle: a case study of Southern Malawi. Sustainability 2019;11:1681.

53. Berkes F, Colding J, Folke C. Rediscovery of traditional ecological knowledge as adaptive management. Ecological Applications 2000;10:1251–62.

54. Derbile EK, Jarawura FX, Dombo MY. Climate change, local knowledge and climate change adaptation in Ghana. In: Adaptation to climate change and variability in rural West Africa. Cham. Switzerland: Springer; 2016. p. 83–102.

55. Mancini C, Kidane YG, Mengistu DK, Pè ME, Fadda C, Dell'Acqua M, et al. Joining smallholder farmers' traditional knowledge with metric traits to select better varieties of Ethiopian wheat. Scientific Reports 2017;7:1–11.

56. Ngulube P, Onyancha OB. What's in a name? Using informetric techniques to conceptualize the knowledge of traditional and indigenous communities. Indilinga: African Journal of Indigenous Knowledge Systems 2011;10(2):129–52.

57. Mugwisi T. Applying indigenous knowledge in agricultural extension in Zimbabwe. In: Handbook of research on social, cultural, and educational considerations of indigenous knowledge in developing countries. Hershey, Pennsylvania: IGI Global; 2016. p. 303–23.

58. Boven K, Morohashi J. Best practices using indigenous knowledge. The Hague: Nuffic; 2002.

59. Field CB, Barros V, Stocker TF, Dahe Q, Jon Dokken D, Ebi KL, et al. Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change. UK: Cambridge University Press; 2012.

60. Chanza N, De Wit A. Enhancing climate governance through indigenous knowledge: case in sustainability science. South African Journal of Science 2016;112.

61. Kaya HO, Chinsamy M. Community-based environmental resource management systems for sustainable livelihood and climate change adaptation: a review of best practices in Africa. Journal of Social Sciences 2016;46:123–9.

62. Mercer J, Kelman I, Taranis L, Suchet-Pearson S. Framework for integrating indigenous and scientific knowledge for disaster risk reduction. Disasters 2010;34:214–39.

63. Kalanda-Joshua M, Ngongondo C, Chipeta L, Mpembeka F. Integrating indigenous knowledge with conventional science: enhancing localised climate and weather forecasts in Nessa, Mulanje, Malawi. Physics and Chemistry of the Earth, Parts A/B/C 2011;36:996–1003.

64. Nyadzi E. Best of Both Worlds: co-producing climate services that integrate scientific and indigenous weather and seasonal climate forecast for water management and food production in Ghana [PhD thesis]. Wageningen, The Netherlands: Wageningen University & Research; 2020 [date unknown].

65. Nyadzi E, Werners SE, Biesbroek R, Ludwig F. Techniques and skills of indigenous weather and seasonal climate forecast in Northern Ghana. Climate and Development 2020:1–12.

66. Gbangou T, Van Slobbe E, Ludwig F, Gordana K-B, Paparrizos S. Harnessing local forecasting knowledge on weather and climate in Ghana: documentation, skills and integration with scientific forecasting knowledge. Weather, Climate, and Society 2020;13:23–37.

67. Makate C. Local institutions and indigenous knowledge in adoption and scaling of climate-smart agricultural innovations among sub-Saharan smallholder farmers. International Journal of Climate Change Strategies and Management 2019;12:270–87.

68. Melore TW, Nel V. Resilience of informal settlements to climate change in the mountainous areas of Konso, Ethiopia and QwaQwa, South Africa. Jamba J Disaster Risk Stud 2020;12.

69. Ebhuoma EE. A framework for integrating scientific forecasts with indigenous systems of weather forecasting in southern Nigeria. Development in Practice 2020;30:472–84.

70. Apraku A, Akpan W, Moyo P. Indigenous knowledge, global ignorance? Insights from an Eastern Cape climate change study. South African Review of Sociology 2018;49:1–21.

71. Songok CK, Kipkorir EC, Mugalavai EM. Integration of indigenous knowledge systems into climate change adaptation and enhancing food security in Nandi and Keiyo districts, Kenya. In: Experiences of climate change adaptation in Africa. Berlin, Heidelberg: Springer; 2011. p. 69–95.

72. Masinde M. An innovative drought early warning system for sub-Saharan Africa: integrating modern and indigenous approaches. African Journal of Science, Technology, Innovation and Development 2015;7:8–25.

73. Masinde M, Thothela PN. ITIKI plus: a mobile based application for integrating indigenous knowledge and scientific agro-climate decision support for Africa's small-scale farmers. In: 2019 IEEE 2nd International Conference on Information and Computer Technologies, ICICT 2019. New York, US: Institute of Electrical and Electronics Engineers Inc.; 2019. p. 303–9.

74. Kwanya T. Mainstreaming indigenous knowledge in climate change response: traditional 'rainmaking' in Kenya. In: Springer Proceedings in Complexity. Dordrecht: Springer; 2014. p. 603–15.

75. Gwenzi J, Mashonjowa E, Mafongoya PL, Rwasoka DT, Stigter K. The use of indigenous knowledge systems for short and long range rainfall prediction and farmers' perceptions of science-based seasonal forecasts in Zimbabwe. International Journal of Climate Change Strategies and Management 2016;8:440–62.

76. Akinyemi FO. Climate change and variability in semiarid palapye, eastern Botswana: an assessment from smallholder farmers' perspective. Weather, Climate, and Society 2017;9:349–65.

77. Mulenga BP, Wineman A, Sitko NJ. Climate trends and farmers' perceptions of climate change in Zambia. Environmental Management 2017;59:291–306.

78. Kolawole OD, Motsholapheko MR, Ngwenya BN, Thakadu O, Mmopelwa G, Kgathi DL. Climate variability and rural livelihoods: how households perceive and adapt to climatic shocks in the Okavango Delta, Botswana. Weather, Climate, and Society 2016;8:131–45.

79. Nyadzi E. Climate variability since 1970 and farmers' observations in Northern Ghana. Sustainable Agriculture Research 2016;5(2):41–56. doi: 10.5539/sar.v5n2p41.

80. Kanno H, Sakurai T, Shinjo H, Miyazaki H, Ishimoto Y, Saeki T, et al. indigenous climate information and modern

meteorological records in Sinazongwe District, Southern Province, Zambia. Japan Agricultural Research Quarterly (JARQ) 2013;47:191–201.

81. Rukema JR, Umubyeyi BS. Indigenous knowledge approach in maintaining a livelihood in the face of disastrous climate change: Case of drought in Msinga villages, KwaZulu-Natal. Jàmbá: Journal of Disaster Risk Studies 2019;11(1):1–10.

82. Cassidy L, Wilk J, Kgathi DL, Bendsen H, Ngwenya BN, Mosepele K. Indigenous knowledge, livelihoods and government policy in the Okavango Delta, Botswana. In: Kgathi DL, Ngwenya BN, Wilk J, editors. Rural livelihoods and political economy. Hauppauge, New York: Nova Science Publishers, Inc.; 2011. p. 7597.

83. Mekuriaw A. Assessing the effectiveness of land resource management practices on erosion and vegetative cover using GIS and remote sensing techniques in Melaka watershed, Ethiopia. Environmental Systems Research 2017;6:1–10.

84. Vilakazi BS, Zengeni R, Mafongoya P. Indigenous strategies used by selected farming communities in KwaZulu Natal, South Africa, to manage soil, water, and climate extremes and to make weather predictions. Land Degradation & Development 2019;30:1999–2008.

85. Tume SJP, Kimengsi JN, Fogwe ZN. Indigenous knowledge and farmer perceptions of climate and ecological changes in the Bamenda Highlands of Cameroon: insights from the Bui Plateau. Climate 2019;7:138.

86. Napogbong LA, Ahmed A, Derbile EK. Fulani herders and indigenous strategies of climate change adaptation in Kpongu community, North-Western Ghana: implications for adaptation planning. Climate and Development 2020;25:1–4. doi: 10.1080/17565529.2020.1746231.

87. Nkuba MR, Chanda R, Mmopelwa G, Adedoyin A, Mangheni MN, Lesolle D, et al. Do indigenous forecasts and scientific forecasts influence arable farmers' and agro-pastoralists' estimation of onset and cessation of rains? Empirical evidence from Rwenzori region, Western Uganda. Agricultural and Forest Meteorology 2019;278:107667.

88. Radeny M, Desalegn A, Mubiru D, Kyazze F, Mahoo H, Recha J, et al. Indigenous knowledge for seasonal weather and climate forecasting across East Africa. Climatic Change 2019;156:509–26.

89. Bernard B, David M, Anthony E, Michael MS, James W, Andrew A, et al. The role of indigenous knowledge (IK) in adaptation to drought by agropastoral smallholder farmers in Uganda. Indian Journal of Traditional Knowledge 2019;19:44–52.

90. Atindana SA, Fagbola O, Ajani E, Alhassan EH, Ampofo-Yeboah A. Coping with climate variability and non-climate stressors in the West African Oyster (*Crassostrea tulipa*) fishery in coastal Ghana. Marit StudScience 2020;19:81–92.

91. Iticha B, Husen A. Adaptation to climate change using indigenous weather forecasting systems in Borana pastoralists of southern Ethiopia. Climate and Development 2019;11:564–73.

92. Amare ZY. Indigenous knowledge of rural communities for combating climate change impacts in west central Ethiopia. Journal of Agricultural Extension 2018;22:181–95.

93. Nyong A, Adesina F, Osman Elasha B. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation Strategies for Global Change 2007;12:787–97.

94. Taremwa NK, Gashumba D, Butera A, Ranganathan T. Climate change adaptation in Rwanda through indigenous knowledge practice. Journal of Social Sciences 2016;46:165–75.

95. Tolo CU, Majule EA, Lejju JB. Local and indigenous knowledge systems in subsistence agriculture, climate risk management, and mitigation of community vulnerability in changing climate, Lake Victoria Basin: a case study of Rakai and Isingiro Districts, Uganda. In: Nile River Basin: ecohydrological challenges, climate change and hydropolitics. Switzerland: Springer International Publishing; 2014. p. 451–73.

96. Kolawole AE. Coverage of indigenous knowledge system in extension services delivery in two regions of Nigeria and South Africa: a content analysis. Life Science Journal. 2013;10(3):2573–8.

97. Kwoyiga L, Stefan C. Groundwater development for dry season irrigation in North East Ghana: the place of local knowledge. Water 2018;10:1724.

98. Tanyanyiwa VI. Weather forecasting using local traditional knowledge (LTK) in the midst of climate change in Domboshawa, Zimbabwe. In: Climate change management. Cham, Switzerland: Springer; 2018:1–20.

99. Fitchett JM, Ebhuoma E. Phenological cues intrinsic in indigenous knowledge systems for forecasting seasonal climate in the Delta State of Nigeria. International Journal of Biometeorology 2018;62:1115–9.

100. Chisadza B, Tumbare MJ, Nyabeze WR, Nhapi I. Validation of local knowledge drought forecasting systems in the Limpopo River Basin in Southern Africa. Disaster Prevention and Management 2014;23:551–66.

101. Kyazze FB, Mubangizi N, Mukwaya PII, Kyamanywa S. Using indigenous knowledge to enhance rainfall forecasts among smallholder farmers in Mt. Elgon Region, Eastern Uganda. In: Climate change management. Cham, Switzerland: Springer; 2019:691–713.

102. Jiri O, Mafongoya PL, Mubaya C, Mafongoya O. Seasonal climate prediction and adaptation using indigenous knowledge systems in agriculture systems in Southern Africa: a review. The Journal of Agricultural Science 2016;8:156.

103. Nkuba MR, Chanda R, Mmopelwa G, Mangheni MN, Lesolle D, Kato E. Indigenous knowledge systems and indicators of rain: evidence from rwenzori region, Western Uganda. Weather, Climate, and Society 2020;12:213–34.

104. Sullo C, King RS, Yiridomoh GY, Doghle K. Indigenous knowledge indicators in determining climate variability in rural Ghana. Rural Society 2020;29:59–74.

105. Aluko YA. Women's use of indigenous knowledge for environmental security and sustainable development in Southwest Nigeria. . International Indigenous Policy Journal. 2018;9(3). Available from: URL: https://ir.lib.uwo.ca/iipj:https://ir.lib.uwo.ca/iipj/vol9/iss3/2

106. Shoko K, Shoko N. Indigenous weather forecasting systems: a case study of the abiotic weather forecasting indicators for wards 12 and 13 in Mberengwa District Zimbabwe. Asian Social Science 2013;9:285–97.

107. Rukema JR, Umubyeyi BS. Indigenous knowledge approach in maintaining a livelihood in the face of disastrous climate change: Case of drought in Msinga villages, KwaZulu-Natal. Jàmbá: Journal of Disaster Risk Studies. 2019;11(1):1–10.

108. Kaya HO. Cultural values and African indigenous knowledge systems in climate change adaptation. Journal of Social Sciences 2016;46:130–36.

109. Masinde M, Mwagha M, Tadesse T. Downscaling Africa's drought forecasts through integration of indigenous and scientific drought forecasts using fuzzy cognitive maps. Geosciences 2018;8:135.

110. Bwambale B, Muhumuza M, Nyeko M. Traditional ecological knowledge and flood risk management: A preliminary case study of the Rwenzori. Jàmbá: Journal of Disaster Risk Studies. 2018;10(1):1–10.

111. Macnight Ngwese N, Saito O, Sato A, Agyeman Boafo Y, Jasaw G. Traditional and local knowledge practices for disaster risk reduction in Northern Ghana. Sustainability 2018;10:825.

112. Dube E, Munsaka E. The contribution of indigenous knowledge to disaster risk reduction activities in Zimbabwe: a big call to practitioners. Cape Town, South Africa: Jamba; 2018. p. 10.

113. Hooli LJ. Resilience of the poorest: coping strategies and indigenous knowledge of living with the floods in Northern Namibia. Regional Environmental Change 2016;16:695–707.

114. Muyambo F, Bahta YT, Jordaan AJ. The role of indigenous knowledge in drought risk reduction: a case of communal farmers in South Africa. Cape Town, South Africa: Jamba; 2017. p. 9.

115. File DJM, Derbile EK. Sunshine, temperature and wind: community risk assessment of climate change, indigenous knowledge and climate change adaptation planning in Ghana. International Journal of Climate Change Strategies and Management 2020;12:22–38.

116. Masinde M. An effective drought early warning system for sub-Saharan Africa: integrating modern and indigenous approaches. In: ACM International Conference Proceeding Series. New York, United States: Association for Computing Machinery; 2014. p. 60–9.

117. Reyes-García V: The values of traditional ecological knowledge. In: Handbook of ecological economics. Cheltenham, United Kingdom: Edward Elgar Publishing; 2015.

118. Kilemba LM, Mafongoya PL. The challenges of documentation and conservation of indigenous knowledge for natural resources management. In: Indigenous knowledge systems and climate change management in Africa. Wageningen, The Netherlands: CTA; 2017. p. 139.

119. Murphy C, Tembo M, Phiri A, Yerokun O, Grummell B. Adapting to climate change in shifting landscapes of belief. Climatic Change 2016;134:101–14.

120. Joshua M, Ngongondo C, Monjerezi M, Chipungu F, Malidadi C. Relevance of indigenous knowledge in weather and climate forecasts for agricultural adaptation to climate variability and change in Malawi. In: Indigenous knowledge systems and climate change management in Africa. Wageningen, The Netherlands: CTA; 2017. p. 185–218.

121. Ford JD, Cameron L, Rubis J, Maillet M, Nakashima D, Willox AC, et al. Including indigenous knowledge and experience in IPCC assessment reports. Nature Climate Change 2016;6:349–353.

122. Tanyanyiwa VI. Indigenous knowledge systems and the teaching of climate change in Zimbabwean secondary schools. SAGE Open 2019;9:215824401988514.