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Multi-level Analysis of Climate Knowledge Management in Tanzania

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Abstract

Climate change governance is highly knowledge intensive. Knowledge from both natural and social sciences has been fundamental in climate change decision-making globally. However, climate knowledge management has not been systematically analyzed in many countries, thus creating gaps in terms of knowledge production and use at various levels. This paper is framed to understand climate knowledge management at multiple levels in Tanzania. First, the paper identifies gaps and needs in climate knowledge; then, it conducts a multiple-level analysis for climate knowledge management. To accomplish this, the paper applies a combination of knowledge management theories to analyze data from the literature and interviews. Results show there are critical knowledge gaps and needs in Tanzania in terms of localized climate change science; sectoral vulnerability; sectoral greenhouse gas emissions management; socio-economic climate resilience data; localized climatic and weather information; and knowledge on disaster risk reduction. Fundamentally, climate knowledge is not fully mainstreamed into the sectoral knowledge management frameworks and is less prioritized in sectoral planning processes. Lack of climate change policy, lack of a climate change unit with a specialized focus on climate change research, inadequate specialized climate change expertise, financial constraints, and inadequate adoption of ICT are some of the barriers blocking climate knowledge management at multiple levels. Due to this, the formulation and implementation of climate change policies, strategies, plans, programs, and projects in Tanzania are faced with scarcity, uncertainty and unreliability of climate knowledge making it particularly difficult for the country to effectively address climate change challenges. The paper serves as input for actions to improve climate knowledge management to strengthen climate change governance in Tanzania.

Keywords: *Knowledge Management; Climate Change Governance; Multiple Levels; Gaps; Needs*

1. Introduction

Climate change creates uncertainty for the future, particularly in vulnerable countries like Tanzania where the economy and livelihoods largely depend on climate-sensitive sectors such as agriculture (URT, 2021). Knowledge about scientific and social dimensions of climate change is critical in creating an understanding of the situations, capacity, perceptions, and interests of various stakeholders in making

informed decisions to address climate change impacts at all levels (Meinke et al., 2006; IPCC, 2014). Scores of studies have emphasized the importance of climate knowledge in climate change governance (Wiig, 1993; Eliasson, 2000; Dillinga and Lemos, 2010; Hofmann and Wrobel, 2011; Finnis et al., 2014; IPCC 2014; Kamarudin et al. 2015). To be effective, climate change knowledge needs to be systematically managed so that interventions and learning processes can produce the intended results (Schut et al., 2014; Takeuchi, 1995; Alavi and Leidner, 2001). Effective knowledge management entails having an effective framework for generating, analyzing, storing, sharing, and disseminating knowledge at multiple levels. A comprehensive approach is critical in understanding gaps, needs and functioning in knowledge through knowledge audits (Brockhaus et al., 2019).

In Tanzania, climate knowledge is based on international knowledge sources, specifically, the Inter-governmental Panel for Climate Change (IPCC) and the United Nations Framework Convention for Climate Change (UNFCCC) reports. Other sources include specialized agencies such as World Meteorological Organization, agencies (e.g., UNDP, UN Environment, FAO, WB). Localized climate knowledge is inadequate, which creates a vacuum in understanding both the scientific and socio-economic dimensions of climate change to guide policy design and implementation at multiple levels. The existing knowledge stock is limited in terms of coverage, focus, accessibility, and quantity, and due to a deficit in local expertise, climate change knowledge is highly fragmented and potentially low in quality. This paper is aimed to analyze gaps and needs in climate knowledge management in Tanzania. Essentially, the paper provides key insights on strengthening climate knowledge production, storage, accessibility, and the country's institutional framework for climate knowledge management. Using a combination of knowledge management theories, the main objective of this paper is to analyze the role of knowledge management in climate change governance in Tanzania, to be achieved by responding to the following research question:

"How is climate change knowledge mainstreamed into knowledge management systems at multiple levels in Tanzania?"

This paper has six sections. Section 2 presents the theoretical framework, section 3 methodology, section 4 results, section 5 discusses the results, and section 6 presents a conclusion.

The Concepts of Knowledge and Knowledge Management

Generally, there is no consensus on the definition of "knowledge." Most scholars emphasized the growing importance of knowledge in socio-economic development, but the majority concluded that the whole concept of knowledge is slippery and very difficult to define (Davenport and Prusak, 1998; Qvortrup, 2007). Other scholars have defined knowledge as a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information (Nonaka and Toyama, 2015; Polanyi and Sen, 2009; Woods and Cortada, 2000). In organizations, knowledge is often embedded in documents and organizational routines, processes, practices, and norms (Davenport and Prusak, 1998). In business, knowledge is a mixture of insight, perception, experience, and foresight. It is a special blend of intellect and intuition that enables someone to do something to determine the most appropriate action (Jennex, 2008). Knowledge can be described in various forms based on circumstances. The two most preferred forms are explicit and tacit knowledge (Polanyi, 1966; Nonaka and Takeuchi, 1995). Explicit knowledge (knowing that) implies knowledge that can be codified and digitized from intangible forms such as books, newspapers, scholarly articles, documents, reports, and memos. The tacit (knowing-how) implies knowledge that is embedded in the human mind through experience and learning, such as wisdom, insights, and intuitions; this form of knowledge is hard to capture in a tangible form (ibid.). Others refer to declarative, procedural, causal, and relational knowledge, and some refer to the core, advanced, and innovative knowledge (Zack, 1999). Others distinguished between human, social, and structured knowledge (DeLong and Fahey, 2000). Aguayo (2004) distinguishes between substantive and entrepreneurial knowledge.

The concept of knowledge management has been described as the production, representation, storage, transfer, transformation, application, embedding, and protection of knowledge (Dalkir, 2005). It is also the deliberate and systematic coordination of people, technology, processes, and structure to add value through reuse and innovation (ibid.). This coordination is achieved through creating, sharing, and applying knowledge, as well as feeding the valuable lessons learned and best practices to foster continued organizational learning. Generally, there are at least three distinct perspectives on knowledge management: a business perspective, a cognitive science or knowledge science perspective, and a process or technology perspective (Anand and Singh, 2011). As a business activity, knowledge management reflects strategy, policy, and practice at all levels of the organization to use the enterprise's intellectual assets to achieve positive business results (ibid.). From a cognitive/knowledge science perspective, knowledge management is a fundamental resource that allows us to function intelligently (ibid.). From a process and technology perspective, it is the processes and technology that facilitate the transformation of information into actionable knowledge (Dalkir, 2015; Anand and Singh, 2011).

In the context of climate change, knowledge management is a critical aspect of climate change governance (Bremer and Meisch, 2017). Importantly, for policies, strategies, and plans to be effective, they must be informed by knowledgeable (Bremer and Meisch, 2017). Importantly, for policies, strategies, and plans to be effective, they must be informed by knowledge. The relevance of knowledge in climate change governance has been challenged due to perceptions related to political, socioeconomic, and cultural settings, which are in most cases interconnected. Effective decision-making in addressing climate change requires integrated approaches to adequately mainstream these perceptions (Cranston and Jackson, 2013). More meaningful decisions can likely be taken in the context of a wide range of stakeholders participating in the acquisition and sharing of climate knowledge. Broadly speaking, two schools of thought exist about climate knowledge management. First, scientific knowledge about climate change, when effectively produced and disseminated to the end users, including policymakers, will result in effective decision-making to address climate change (ibid.). Second, the decisions taken will be translated into actions, whereby activities to reduce emissions of greenhouse gases or adapt to the impacts will be implemented (ibid.). However, various forms of knowledge have different impacts on people's concerns about climate change and their willingness to change behaviors (Anable et al., 2006; Kenis and Mathijs, 2010; Milfont, 2012). Knowledge about climate change can be acquired through formal and informal means. The formal approach involves the integration of aspects of climate change into the formal education systems. Informal evolves from exposure to knowledge from sources such as the media or first-hand experience from the surrounding environment. In both cases, it is expected that an increase in knowledge about climate change will likely increase overall concern about climate risks, which would lead to enhanced public responsibility to act to tackle the climate change challenge (Milfont, 2012).

Important as well is understanding the proper framework for knowledge management. In this, all necessary knowledge management enablers, such as people, processes, technologies, and governance, are in place and interlinked to allow a seamless flow of knowledge within the organization or system (Pawlowski and Bick, 2015). A strong knowledge management framework is fundamental for effective climate knowledge management, as it provides a guiding structure for understanding, gathering, organizing, retaining, and sharing climate knowledge to enable the effective development and implementation of key climate change decisions and initiatives. In developing a climate knowledge framework, a climate knowledge audit can be conducted to analyze a country’s climate knowledge management status in terms of the existence of knowledge assets, knowledge flow at various levels, and the extent to which people, processes, and technology support or hamper effective knowledge management (Lauer and Tanniru, 2001; Antonova et al., 2009). The climate knowledge audit reveals the country’s climate knowledge management needs, strengths, weaknesses, and opportunities. It also provides an evidence-based assessment of where the country needs to focus its climate knowledge management efforts (ibid.).

Dimensions of Climate Change Knowledge

The most reliable way to learn about climate is from the IPCC reports, which are based on scientific research. Other sources mostly measure the causes and impacts of climate change (Bråten and Strømsø, 2010; Sundblad et al., 2008), and some assess whether anthropogenic activities represent the main cause of changing climate. Though the trend is changing, very few sources address other dimensions of climate knowledge, such as individual and societal dimensions. (Hoppe et al. 2018) distinguish four types of climate knowledge, each with its own set of functions. The first is orientation knowledge, which serves to enable people to orient themselves with basic climate change knowledge such as understanding the causes and impacts of climate change. The second is knowledge explanation and interpretation, which occur when people are aware of climate change, its causes, and various aspects of it, including models (Hoppe et al., 2018). The third is action-related knowledge, which relates to people's actions, practices, methods, and strategies regarding climate change (Kaiser and Fuhrer, 2003; Tobler et al., 2012). Fourth is source knowledge, which refers to the origins of knowledge and where it can be found. It is about how people perceive climate science, which produces knowledge about climate change and is thus the central 'knowledge source'. It comprises knowledge about the process of gaining knowledge (ibid.)

Climate Change Knowledge Gaps and Needs

There is overwhelming evidence that climate change exerts continuous pressure on development, particularly livelihoods (IPCC, 2014; Connolly-Boutin and Smit, 2016; Nhemachena et al., 2020). Due to this, the need for effective climate knowledge management is critical to inform effective policy decision-making for climate change governance. Furthermore, responsive planning requires appropriate climate risk analysis across sectors and regions, which involves the development and implementation of policies, strategies, and plans that define measures aimed at building climate resilience. Vulnerability assessments and early warning systems are thus critical for both decision-making and responsive planning, and these include hazard mapping, forecasting systems, data interpretation, processing, and dissemination, information usability, and capacity building for effective response (Naumann et al., 2013; Zommers and Singh, 2014). The optimal responsive planning includes localized information on a natural dimension (environmental information, topography, and disasters); a social dimension (people: health status, social capital, education, and awareness); an economic dimension (livelihoods: employment, income, assets, etc.); a physical dimension (infrastructure: road network, warning system, housing, and land use); and an institutional dimension (organizations: institutional coordination, development plans) (ibid.).

The traditional reductionist approach to science has been focused on producing scientific knowledge rather than the synthesis of socially relevant outcomes (Meinke et al., 2006). This might be the key reason for the failure of policymakers and communities to embrace the knowledge offered by climate researchers. Essentially, the translation of climate knowledge into adaptation or mitigation actions requires three critical components: salience (the perceived relevance of the knowledge), credibility (the perceived technical quality of the knowledge), and legitimacy (the perceived objectivity of the process by which the knowledge is shared) (ibid.). Four different frameworks can be used to understand climate knowledge gaps. The first view sees knowledge as progressing in a linear fashion (Hulme, 2018). Knowledge here is progressive, ignorance is finite, and discovery leads to ever more complete understanding to reduce the uncertainties in predictions (ibid.). A second view conceives knowledge gaps as the result of poor connectivity, whereby integrating different knowledge is expected to fill the knowledge gaps, as even more comprehensive and faithful replicas of reality are built in our minds or our models (ibid.). A third view of knowledge gaps is that they are socially contingent, in which knowledge is constructed because of social norms and processes. A final view of gaps in knowledge is to see them as places of brittleness or weakness. This heuristic requires knowledge to be thickened by adding layers of meaning and significance to our experience and understanding of reality (ibid.).

2. Knowledge Management Theories

Recently, knowledge management has evolved as a formal scientific discipline supported by scholars in academia, practitioners in corporate environments, and consultants. There are several theoretical approaches to analyzing knowledge management, depending on the application. The central knowledge management theories are categorized as organizational, where the focus is on how institutions are designed culturally and hierarchically to manage knowledge processes (Durst and Edvardsson, 2012; Grant, 1996); ecological, in which the focus is on people, relationships, and learning communities, including interactions among individuals and organizations and institutions and the internal and external factors that draw people together to share knowledge (Grant, 1996); and techno-centric, which talks about technologies and the technological processes that facilitate seamless flow and storage of knowledge and information, which includes the adoption and use of ICT methods, tools, and techniques (Omona et al., 2010a). Regardless of which theoretical approach is adopted, knowledge management includes the impacts of people, processes, and technology on knowledge sharing (Ferreira and Mueller, 2020; Omona et al., 2010b). While knowledge management theories are still evolving, the existing approaches can still be used in the context of analyzing climate change knowledge management, including in Tanzania.

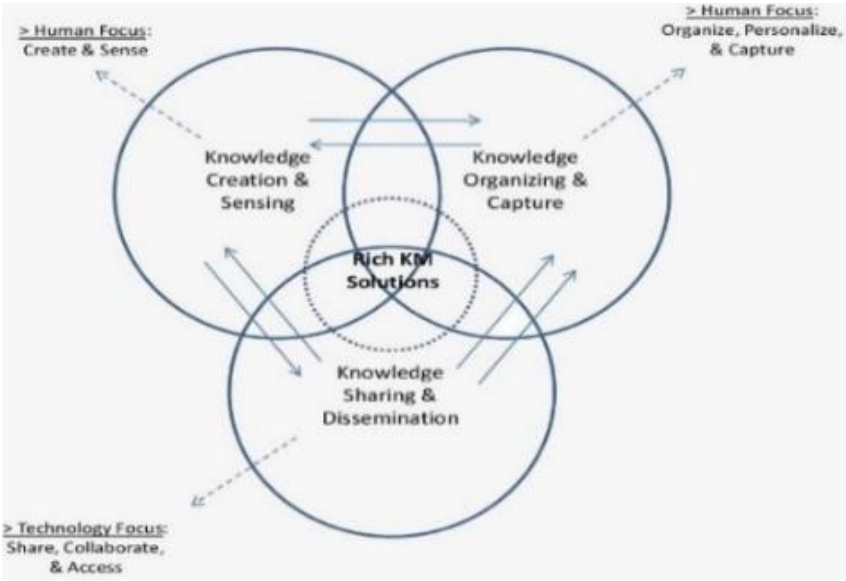

Figure 1: Knowledge management process. **Source:** Botha *et al*, 2008.

In complementing the above theoretical approach, the study also makes use of the knowledge deficit theory, especially in analyzing the climate change knowledge deficit in Tanzania. The knowledge deficit theory attributes public skepticism of science to a lack of knowledge resulting from a lack of information. The theory suggests that there are knowledge deficits to fill by giving the public relevant knowledge. It implies that communication should focus on improving the transfer of knowledge to fill the knowledge gap (Botha et al., 2008). Regarding climate change, the theory suggests that if the public is not concerned about climate change, it is because there is a deficit in their knowledge of climate change. It argues that by providing them with adequate knowledge, their perception will change toward pro-climate actions (Allum et al., 2008; Roser-Renouf and Nisbet, 2008; Arlt et al., 2011; Taddicken, 2013). Both theoretical concepts are applied in Section 6 of this paper to analyze key results for this study, which focuses on the analysis of climate knowledge needs and gaps as well as the examination of climate knowledge management at multiple governance levels.

3. Data Collection and Analysis

To generate and analyze data, the study used a variety of methods. A review of the literature on climate change governance was done to note specific references to climate knowledge management. This was followed by 40 key informant interviews to document the knowledge management gaps and needs at multiple levels in Tanzania. The interviews were conducted by engaging a wide range of respondents representing the relevant government ministries and authorities, with a special focus on the 13 sectors prioritized in Tanzania's Nationally Determined Contribution (NDC). These sectors include agriculture; livestock; forestry; energy; water; tourism; human settlements; health; infrastructure; transport; waste; disaster risk reduction; and the coastal, marine, environmental, and fisheries industries. Further, respondents from the academia include mainly universities (University of Dar es Salaam, the University of Dodoma, and the Sokoine University of Agriculture), the National Carbon Monitoring Centre, which is responsible for GHG emission data management, umbrella CSOs (the Forum for Climate Change and the Climate Action Network), selected members of the DPGE and EDPG, selected private sector establishments (two cement factories, two independent power generation companies, one sugar factory, and one financial institution), two research institutions (REPOA and ESRF), the media (journalists from the Journalists Environmental Association), two members of parliament from the Parliament of Tanzania, and four independent climate change researchers. The criteria for the selection of the respondents included actors engaged in environmental and climate change issues, professionals involved in climate services information, environmental officers representing MDAs and LGAs, and experts in knowledge management processes at multiple governance levels. The interview guide consisted of 20 open-ended questions, and the interviews were conducted in Swahili and English, lasting 45–60 minutes. Information was recorded and transcribed for analysis using NVivo 11 software. The analyses consisted of thematic coding, including contextual nodes to map responses to the questions and eight research nodes around the use of climate information in decision-making and planning. The data were analyzed using Content Analysis (CA) applying both manifest and latent analyses. The analysis focused on two aspects of climate knowledge management: climate change knowledge gaps and needs, and multilevel climate knowledge management.

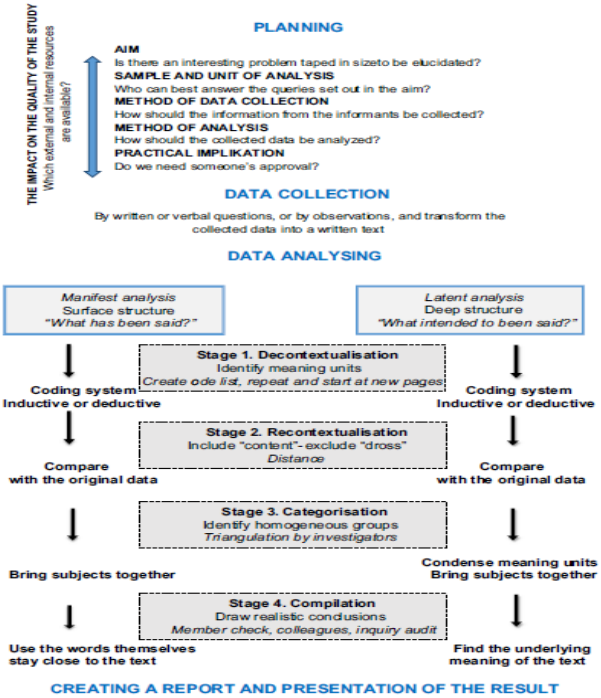

Figure 2: An overview of the process of qualitative content analysis. **Source:** Bengtsson, 2016

4. Results

Overall, the results point to a significant knowledge gap in Tanzania regarding several aspects of climate change. These results support the applicability of the knowledge management and knowledge deficit theories in this study, and a discussion based on these theories is presented in the following section. The results are grouped into two levels; climate change knowledge gaps and needs, which focus on climate change science, climate change vulnerability, and climate change governance; and multilevel climate knowledge management, which identifies knowledge deficits and needs at the multiple governance levels (i.e., MDAs and LGAs, education, research, development partners, CSOs, the private sector, and media).

4.1 Climate Knowledge Gaps and Needs

Climate Change Science

This study has revealed a critical knowledge deficit in terms of climate change science in Tanzania, which can be categorized into three thematic areas: historical climate variations and GHG emissions, meteorological and hydro-met aspects of climate change, and local emission scenarios and climate change models.

In terms of historical climate variations and GHG emissions**,** the National Carbon Monitoring Centre (NCMC), which is hosted by the Sokoine University of Agriculture (SUA), is responsible for collecting, monitoring, and reporting on GHG emissions in the country. The Center primarily focused on the forestry sector alone, for which a forestry land use and land cover database were developed, which also included basic information on forestry carbon emissions. Data is being collected and compiled using Remote Sensing and Global Information Systems analyzed and stored online. Over time, additional sectors were introduced in the Centre's portfolio following the successful launch of the National GHG and MRV inventory systems, hosted by the Center. However, with inadequate expertise in these sectors, a significant knowledge gap exists. A respondent from NCMC highlighted this knowledge gap:

> "…. NCMC has been mandated by the government to manage GHG emission inventories for all sectors prioritized in the country's Nationally Determined Contribution…"However, due to limited technical capacity, we are facing a huge knowledge gap, especially in non-forestry sectors.…" (Male, 35 years old).

Another respondent said that the lack of a sustainable framework to make it easier to collect emission data from the right data sources is a problem. This has a big effect on both the amount and quality of the data:

> "…. The fact that we must update and collect new GHG data means that we need to have an effective framework to ensure systematic access to and sharing of data from the sources…. this system is not currently in place…" We have started to train some stakeholders to facilitate data collection, but we are facing both financial and technological limitations.…" (Male, 42 years old).

Further, legal constraints limit the capacity of the Centre to establish and operate the country's GHG Registry. To play this role, a review of the Environmental Management Act of 2004 will be needed. A respondent from the Centre noted this limitation.

> "…. The existing Environment Management Act, 2004 does not give us the mandate to establish and operate the GHG Registry…this is a critical limitation to our work in managing the GHG emission in the country…." (Male, 35 years old).

Apart from the capacity gap at the NCMC, critical limitations can also be observed in other relevant institutions. These include the relevant academic and research institutions, the private sector operations, and the public institutions. These are expected to play a critical role in producing, storing, and reporting GHG emission data to the NCMC. A researcher familiar with GHG inventories highlighted these critical challenges in Tanzania:

> "…. Potential GHG emitters do not have the technical capacity to manage and report GHG data…many are not even aware of the need to report their emissions…I can cite examples of cement factories, power plants, or public institutions such as prisons and universities…." (Male, 42 years old).

The table below shows knowledge sources and gaps on historical climate variations and GHG emissions knowledge sources in Tanzania.

Table 1: *Knowledge sources for GHGs emission in Tanzania*

Knowledge product	Type	Source	Knowledge gap
Greenhouse Gas Emissions in Tanzania	Document	https://www.climatelinks.org/sites/default/files/asset/document/Tanzania%20GHG%20Emissions%20Factsheet%20Final.pdf	Limited certainties due to dependence on outdated data sources.
CEEST (1994)," Sources and Sinks of Greenhouse Gases in Tanzania," Draft Final Report, CEEST Report No. 5/1994, Dar es Salaam.	Document	http://www.tzonline.org/pdf/sourcesandsinksofgreenhousegasesintanzania6.pdf	Highly outdated, bypassed by events.
Tanzania GHG Inventory, Projections and National System (MRV Portal), 2018	Online database	https://www.aether-uk.com/Case-studies/Tanzania-GHG-Inventory-MRV-System	Provides recent data using IPCC methodologies. However, the development of the database applie to tier 1 (default values) due to a lack of verifiable data.
A national forestry resources monitoring and assessment of Tanzania (NA FORMA)	Online database	http://www.suaire.suanet.ac.tz8080/xmlui/handle/123456789/1287	Provide good data on forestry but with limitations on forestry emissions. The database is outdated

In terms of meteorological and hydrometeorological knowledge, the study identified critical gaps related to the capacity of the Tanzania Meteorological Authority (TMA) in producing, analyzing, storing, and disseminating data to the end-users. TMA has institutional responsibility for this, but inadequate infrastructure, technology, staff, and funding affect knowledge generation on climatic and weather variabilities. A TMA respondent revealed this during the interview.

> "…. Despite some improvement in the weather and climate forecasting, we are still facing limitations in infrastructure in terms of fulfilling the required number of automated weather stations to be installed in many parts of the country…but also ICT equipment useful in the analysis, storage, and dissemination of the data…." (Female, 48 years old).

For hydromet data, there are huge capacity gaps within the Ministry of Water, which is responsible for the management of water basin authorities across the country. Out of nine water basins, only two basins have hydro-met equipment installed to support data generation, and even these basins face several operational challenges. A respondent from the Ministry of Water raised this concern and expressed the need for increased procurement and installation of hydromet equipment in the remaining seven water basins.:

"…. Only two water basins which are Pangani, and Ruvuma and Southern Coast, have automated weather stations and hydro-met systems installed through support from various development partners…despite operational challenges, these systems have improved data collection…which improved early warning systems in the two basins…. this need to be done in the remaining seven water basins…." (Female, 49 years old).

For both, meteorological and hydro-met data, and information management, this research has revealed a capacity gap in how the information is centrally managed to support the country in addressing climatic disasters such as floods and droughts at the local levels. This is attributed to the non-functioning of the national Emergence and Communication Centre (ECC), which is managed by the Disaster Management Department in the Prime Minister's Office. The table below summarizes knowledge types and knowledge gaps for both meteorology and hydro-met in Tanzania.

Table 2: *Meteorological and hydro-met knowledge gaps*

Knowledge type	Knowledge gap
Meteorological	Data production and processing • Insufficient weather stations to meet the country's demand • Insufficient staff at the local levels to support data collection and reporting. • Limited capacity in producing long-term climate forecasts • Inadequate technologies for data processing (hardware and software) • Insufficient expertise in the packaging of climate information • Inadequate capacity to downscale weather forecasts to meet user requirements. Data storage • Insufficient technologies for data rescuing and archiving. • Poor data integration between hosting institutions through the National Database for climate and hydrology. Data dissemination • Inadequate dissemination of localized weather forecasts. • Climate information product is too general and not specific. • Inadequate knowledge in the use of climate information for stakeholders. • Bureaucratic barriers in disseminating weather information that limits end users' access to information. SOPs are not regularly reviewed and applied. • Lack of platforms for sharing climate information and feedback with stakeholders.
Hydro-met data	• Inadequate flood and drought forecasting systems that cut across all sectors including in urban areas. Flood monitoring is done manually in most cases. • No early warning for floods exists. • Lack of capacity of issuing flood forecasts. • Data security does not exist, backup is made manually using flash discs. • Most of the data are stored manually in files. • Inadequate expertise in data collection, analysis, assimilation, and quality and control check. • Inadequate budget to support operations and maintenance costs.

As for the climate impact models, gaps in the application of the global climate models at the local level were identified. Local experts' ability to downscale these general circulation models or global climate models (GCMs) is limited. This has implications in terms of generating climate change knowledge that humans are causing global climate change, or "global warming. Global climate is used to plan local mitigation and adaptation policies, strategies, and plans. Cognizant of the limitations of global climate

change models, especially in terms of their inability to reproduce important atmospheric phenomena, and inaccurate representations of the complex natural interconnections (Legates, 2002; Wilby et al., 2004; Christensen et al., 2007), which create difficulties for local experts to interpret and extrapolate, the need to build local expertise to develop and apply localized climate models is critical. The global models are generally insufficient for the analysis of many regional and local climate aspects, such as extremes (Christensen et al., 2007). The respondent from one of the research institutions referred to this as a challenge, referring to the limited availability of local data on GHG emissions, and uncertainty in climate variability projections:

> "…. The limited knowledge in developing and applying climate models is a critical challenge for local experts in producing GHG emission data and producing climate variability projection within the local context…. this incapacity forces experts to rely on global models, which are practically complex and not necessarily accurate …." (Male, 57 years old).

Climate Change Vulnerability

A knowledge deficit related to how societal change affects local climate change risks has been identified in terms of scientific knowledge on human vulnerability and contribution to climate change. There is also a very limited understanding of the socio-economic consequences of climate change amongst the relevant institutions and experts, and the existing literature lacks adequate information on socio-economic scenarios and models and how they include climate change vulnerabilities, exposure, and risks to communities in Tanzania. The sectoral vulnerability assessments are also lacking in providing specific knowledge on the level of effort required to address the impacts. Attempts have been made to conduct vulnerability assessments in the agriculture and health sectors, but due to the capacity and data challenges, the coverage and quality of these assessments are questionable. Although the study was conducted on the economic impacts of climate change in Tanzania (Watkis et al., 2011), there is still a lack of spatially disaggregated data on the climate change impacts. Generally, for all sectors and geographical scales, there is a capacity gap in analyzing the role of intersecting vulnerabilities (along the lines of gender, age distribution, social class; cultural group, economic activities, and geographical location—rural or urban, or based on ecological zones), and response capacities for diverse communities whose livelihoods are already compromised by the impacts of climate change. A respondent representing one of the research institutions identified the lack of sectoral vulnerability assessments as one of the key limitations in developing and implementing policies, plans, and strategies to build climate resilience.

> "…. Absence of sectoral vulnerability assessments creates a significant knowledge gap for policymakers and climate change stakeholders…." (Male, 43 years old).

Table 3: *Sectoral climate change vulnerability assessments*

Sector	Vulnerability assessment	Source	Gap
General	Tanzania Country Climate Change Risk Assessment Report	Irish Aid 2018:	Report prepared based on existing information.
Agriculture	Tanzania Agriculture Climate Resilience Plan, 2014–2019	Ministry of Agriculture	Outdated
Water	Resource vulnerability and adaptation in the Mara River basin	Climate.org	The donor-led initiative, not a government-owned document is outdated and has narrow coverage.
Health	2006. Climate Change Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region.	The International START Secretariat, Washington, DC.	Highly outdated.

Regarding disaster/hazard mapping, which also includes climate-induced disasters (floods and droughts), a strong knowledge gap exists. The Tanzania Disaster Risk Profile was updated in 2019 and

serves to provide key disaster risk information at the country level. Localized disaster profiles are, however, lacking. Local technical expertise to conduct such profiles is inadequate, leaving no option but to depend on international expertise provided by consultants. A respondent from the government ministry responsible for disaster management pointed out this as a gap:

> "…. Locally we don't have the expertise to conduct hazard mapping…this is a critical challenge since depending on international expertise is costly and we normally do not have budget allocated for this kind of activity…." (Male, 41 years old).

Further, gaps were identified in terms of the capacity of the country in conducting pre- and post-disaster needs assessments and disaster recovery frameworks. The same respondent above expressed limitations in data availability and accessibility, especially at the local levels:

> "…. Like disaster maps, the department has very limited capacity to undertake pre- and post-disaster needs assessments, which normally requires extensive experience and huge resources …. availability of data especially at the local levels is also a challenge when conducting these exercises …." (Male, 41 years old).

Climate Change Governance

Analysis of the country's climate change governance knowledge framework revealed a lack of coordinated systems for climate knowledge management at multiple levels. The absence of a dedicated climate change policy has been repeatedly cited by stakeholders as being attributable to the lack of policy guidance for climate knowledge management. The reliance on the existing Environment Management Act of 2004 does not provide the required framework for climate knowledge management since climate change is not fully mainstreamed in the Act. Though climate change is mainstreamed in the new Environmental Policy, 2022, the policy lacks updated legal backing to facilitate its implementation and support climate knowledge management in the country. A representative from the CSO noted this limitation during one of the focus group discussions:

> "…. The Environment Management Act is highly outdated and cannot provide a strong legal framework to the new Environmental Policy to support climate knowledge management …" (Female 38 years old).

Tanzania developed various climate change knowledge documents in terms of climate change strategies. However, many of these documents are outdated, and others are missing the required information due to data challenges. The National Climate Change Response Strategy has been prepared, but its implementation will remain a challenge due to the lack of a sustainable climate change financing framework. This will have negative implications for climate knowledge management due to difficulties in accessing the required financing for various climate knowledge management initiatives. A respondent from one of the development partners familiar with the climate change strategies highlighted the role of an effective financing framework to support climate knowledge management at multiple levels:

> "…. Based on experience from many countries including Rwanda through their Environment Fund, effective climate knowledge management at multiple levels needs having in place effective financing mechanism to facilitate resource mobilization to finance various knowledge management activities…." (Male, 43 years old).

Available national climate knowledge documents in terms of climate change governance (including policies, strategies, and plans) are listed in Table 4 below.

Table 4: *Climate change governance knowledge sources and gaps*

Knowledge document	Type	Source	Gaps
National Climate Change Response Strategy	Strategy	VPO, 2021	Data limitations
National Environmental Management Master Plan, 2022-2032	Plan	VPO, 2022	Implementation lacks a financing framework
Climate Change Communication Strategy	Strategy	VPO, 2013	Outdated
National REDD+ Strategy and Action Plan	Strategy	VPO, 2012c	Outdated
Nationally Determined Contributions	Plan	VPO, 2019	Data limitations.
Guideline for Mainstreaming Climate Change Adaptation into National Sectoral Policies, Plans and Programmes in Tanzania	Guidelines	VPO, 2012a	Outdated
National Adaptation Programme of Action	Plan	VPO, 2007	Highly outdated
2nd National Communication under the UNFCCC	Report	VPO, 2004a	Highly outdated
1st National Communication under the UNFCCC	Report	VPO, 2003	Highly outdated

4.2 Multi-level Climate Knowledge Management

MDAs and LGAs

In Tanzania, climate change governance is placed at the Vice President's Office (VPO), which also coordinates the functioning of the two climate change committees, the National Climate Change Steering Committee, and the National Climate Change Technical Committee. VPO is also a focal point for the NDC, GEF, GCF, the carbon market, and other multilateral environment agreements, including those related to climate change. This role gives the VPO the mandate of coordinating knowledge management as stipulated in the Environmental Policy, 2022. Under the Section, which is responsible for climate change governance, the Deputy Director of Environment, who is the Head of the Section, is required to facilitate and coordinate climate change knowledge management in collaboration with other relevant stakeholders. However, due to funding constraints, frequent staff shifting, limited access to ICT, and inadequate collaboration with relevant sectors and other climate change stakeholders, the institution is struggling to deliver its mandate, which also includes climate knowledge management. There is also a shortage of well-trained experts at the VPO with advanced knowledge of climate science and the dynamics of climate systems, which demand a high level of professional proficiency in theory and practice. In addition, knowledge, and expertise in mathematical modeling are lacking, thus limiting the capacity to use in-house expertise to carry out complex climate change studies and assessments. The capacity challenge was singled out by many respondents, including the representative from one of the ministries:

> "…. There is limited capacity within the VPO in terms of well-trained staff on advanced climate change mathematical modelling and complex climate change systems … There is also very limited application of ICT at the VPO to help in developing and dissemination climate change data and information, for example, the existing VPO website was not designed to provide integrated data and information on climate change issues …." (Male, 46 years old).

The issue of poor coordination between relevant ministries and levels of government also has an impact on the government's capacity to manage climate knowledge. This challenge is common at both national and sub-national levels, particularly at the district level down to the village level. Some sectoral ministries have established environment desks to facilitate the mainstreaming of the environment in sectoral plans, but due to limited expertise and budget constraints, these desks have been largely non-functional. This was highlighted by an officer responsible for environmental management:

> "…. Inadequate financing and expertise are the key major blockages for sectoral environmental officers to perform their duties that also involve developing climate change knowledge at the

sectoral levels…. And the fact that climate change is not fully mainstreamed in many ministries it is even more difficult to address these challenges at the sectoral levels….” (Female, 40 years old).

Furthermore, some available climate change information and data are highly fragmented and inadequately mainstreamed in national systems. There is a shared perception among the respondents interviewed that this fragmentation deeply affects climate knowledge management in the country. Further, due to the lack of an appropriate framework for climate knowledge management, the roles and responsibilities of institutions are not very clear. There are also no active platforms that pull together stakeholders to exchange knowledge about various aspects of climate change. A CSO representative confirmed these as potential blockages:

“…. Data availability and accessibility in Tanzania is limited since we do not have effective platforms for knowledge exchange … the available knowledge materials are also highly fragmented.….” (Male, 49 years old).

Table 5 provides a summary of climate knowledge gaps for selected sector ministries based on the analysis conducted in this study.

Table 5: *Selected sectoral climate change knowledge gaps*

Sector ministry	Knowledge gap
Water	• Inadequate expertise in the generation, processing, and general management of climatic and hydro-met data • Inadequate capacity in the dissemination of hydro-met forecasts • Lack of appropriate technologies and equipment • Weak collaboration with relevant institutions in terms of climate knowledge management • Absence of sectoral framework for climate knowledge management
Livestock	• Lack of expertise in the generation, processing, and general management of climatic data and analysis of the climate impacts on the sector • Climate knowledge is not mainstreamed in the livestock management training colleges • No guiding framework for climate knowledge management • Inadequate climate services, some pastoralists depend on climate services from neighbouring countries
Agriculture	• Inadequate capacity in generating and disseminating climate information to end-users and provision of specific weather information • No funds allocated to manage agrometeorological stations • Insufficient and outdated equipment and technologies • No collaboration exists with the climate service providers • Relying only on climate information from TMA • No funds for expansion of crop monitoring and early warning stations, at least one station per ward is needed • Outdated agriculture resilience plan • Poor implementation of climate-smart agriculture practices
Natural resources management	• No formal mechanism for generating, receiving, and disseminating climate information and weather forecasts • Weather forecasts provided by TMA are too general to fit specific sectoral needs • No guideline for climate knowledge management within the sector • Climate change is not mainstreamed in the protected areas’ management plans

Education System

Higher education institutions can play a critical role in enabling Tanzania to achieve a low-emission development pathway by providing the required climate change knowledge through degree programs and specialized courses. They are also well-positioned to provide enabling platforms for climate change dialogues and knowledge development. A lecturer from the University of Dar es Salaam was on point to identify the role of universities in the provision of formal climate change knowledge in the country:

> "…. Our universities could be an entry point for the provision of formal climate change knowledge to produce professionals in climate change and green development …. This will go a long way to addressing climate knowledge gaps since the graduates will be pioneers in training more professionals and potentially invest in green sustainable investments …." (Male, 53 years old).

This study has shown that Tanzania's colleges and universities don't do a good job of managing climate knowledge. The gaps are linked to the fact that climate change is not fully mainstreamed in the country's education system. Though some universities, such as the University of Dar es Salaam, the Open University of Tanzania, and the Eastern and Southern African Management Institute, host degree programs and specialized courses that include climate change, gaps related to an inadequate budget and limited access to specialized research tools affect the quality of the knowledge delivered. Generally, there are currently very few climate change professionals at the levels of master's and a doctorate in the country. Even these, are the result of isolated programs supported by donors at the University of Dar es Salaam and the Sokoine University of Agriculture. Table 6 below summarizes the list of universities that provide degrees and courses that include climate change in Tanzania.

Table 6: *Climate change degree programs and courses in the universities in Tanzania*

Name of institution	Programme/Course
University of Dar es Salaam	• BSc in Meteorology (elective course in Climate Change) • BA in Geography and Environmental Studies (elective course in Climatology) • PhD Environmental Science (elective course in Climatic Change and the Environment)
Centre for Climate Change Studies (CCCS), University of Dar es Salaam	• Master of Science in Climate Change and Sustainable Development • PhD in Climate Change and Sustainable Development
Sokoine University of Agriculture (SUA)	• MSc in Environmental Sciences, Management and Technology (with a course in Climate Change Science) • BSc in Environmental Sciences and Management (with courses in Air Pollution, Prevention and Control; Global Climate Change; and Disaster Management) • BSc in Forestry (with an elective course in Climate Change) • BSc in Agriculture General (with an elective course in Global Climate Change and Disaster Management)
Open University of Tanzania	• BA in Natural Resources Management (with elective courses in Climate Variability and Climatology) • MSc Environmental Studies (with an elective course in Environmental Pollution)
Mzumbe University	• MSC in Environment Management (with a course in Climate Change Science)
University of Dodoma	• BA in Geography and Environmental Studies (elective course in Climatology) • BSc in Environmental Science (with a course in Climate Change Science)
The Eastern and Southern African Management Institute (ESAMI)	• Short course: Africa Climate Finance Leadership Programme • Short course: Africa Climate Finance Course: Unlocking Public Climate Finance for Sustainable Business Transformation

Research

The capacity for climate change research in Tanzania is generally weak. The existing research activities are limited to very few institutions and mainly focus on studying the general impacts of climate change on isolated geographical areas or sectoral components, but not much on scientific climatic data, or long-term climatic modeling and forecasting. There has been very little focus on the effects of localized climate variability on ecosystems and biodiversity (including in protected areas), as well as the assessment of disaggregated costs of climate change impacts and adaptation. The study revealed that the management of climate change knowledge in the research environment lacks policy and political guidance, and that climate change is inadequately mainstreamed into research policies and operational frameworks. A representative from one of the research institutions noted the inadequate mainstreaming of climate change as a critical challenge for the research institutions:

> "…. Many research institutions in Tanzania haven't yet mainstreamed climate change into research activities …. Only a few of them have conducted some isolated research …but this research is largely incidental based on donor funding …." (Female, 54 years old).

There is also very limited research attention to the process of decision-making and response to climate variability at multiple levels. In addition, there is very limited interdisciplinary adaptation research that integrates analytical perspectives across the social and natural sciences. While there is relatively good progress in terms of experimental research on agricultural techniques due to the extent of climate impacts on the sector in the country, there has been less attention paid to long-term research on farmers' behaviour, particularly as economic factors change (relative factor prices, resource availability, accessibility, and markets). A researcher from one of the research institutions revealed this fact during the interview session:

> "…. The few research that is available mainly focus on the agricultural sector due to the pressure exerted by the climate change impacts on the sector…but the challenge is that most of this research is limited in scope …." (Male, 42 years old).

Other gaps relate to inadequate coordination between research institutions that leads to duplication of efforts and low-quality research outputs due to limitations in sharing of expertise and experience. The lack of policy guidelines on climate research, and inadequate technical and financial capacity at the VPO to manage climate change research activities in the country are also critical gaps. Table 7 below summarized a list of research institutions and the gaps in climate change knowledge.

Table 7: *Selected research institutions and gaps in climate change knowledge*

Research institution	Climate knowledge gap
Research on Poverty Alleviation (REPOA)	Research is based on existing information on climate change policy frameworks such a NDC and climate change strategies. *https://www.repoa.or.tz/?publication=climate-finance-availability-and-access-in-tanzania* *https://www.repoa.or.tz/?publication=tanzanias-nationally-determined-contribution-ndc-an-overview-of-progress-opportunities-and-prospects*
Economic and Social Research Foundation (ESRF)	Research is narrow in scope and incidental. *https://esrf.or.tz/wp-content/uploads/2021/05/CUTS_PB3.pdf* *https://esrf.or.tz/wp-content/uploads/2021/05/CUTS_PB2.pdf* *https://esrf.or.tz/wp-content/uploads/2021/05/EACCCF7-Tanzania.pdf* *https://esrf.or.tz/wp-content/uploads/2021/05/EACCCF5-Tanzania.pdf* *https://esrf.or.tz/wp-content/uploads/2021/05/EACCCF3-Tanzania.pdf* *https://esrf.or.tz/wp-content/uploads/2021/05/EACCCF1-Tanzania.pdf* *https://esrf.or.tz/wp-content/uploads/2021/05/Climate-change-as-a-silent-disaster.pdf* *https://esrf.or.tz/wp-content/uploads/2020/06/GreenEconomic-Growth.pdf*

	https://esrf.or.tz/wp-content/uploads/2020/06/climate_change_affects.pdf https://esrf.or.tz/wp-content/uploads/2020/06/EACCCF2-Tanzania.pdf https://esrf.or.tz/wp-content/uploads/2020/06/EACCCF3-Tanzania.pdf https://esrf.or.tz/wp-content/uploads/2020/06/CUTS_PB3.pdf
Tanzania Wildlife Research Institute	Climate research is not integrated.
National Institute for Medical Research	Climate research is not integrated.
Selian Agricultural Research Institute (TARI)	Climate research is not integrated.
Tanzania Coffee Research Institute (TaCRI)	Climate research is not integrated.
Tanzania Forestry Research Institute (TAFORI)	Climate research is not integrated.
Tanzania Livestock Research Institute (TALIRI)	Climate research is not integrated.
Tea Research Institute of Tanzania (TRIT)	Climate research is not integrated.
Tropical Pesticides Research Institute (TPRI)	Climate research is not integrated.

Development Partners

This study has revealed that many development partners are increasingly integrating climate change into their multi-year strategic plans, with budget allocations. A review of the project portfolios of the development partner groups on the environment (DPGE) and energy (EDPG), complemented with interviews with some of the DPs, revealed an increasing interest in national climate change processes, especially in terms of key national climate change policy documents such as the National Climate Change Response Strategy, Nationally Determined Contribution, and the National Adaptation Plan. However, little has been invested in developing knowledge capacity, especially in climate change science and adaptation. Some isolated efforts can be documented, but the challenge of continuity and fragmentation is cited. There is an apparent lack of jointness and collaboration among the DPs in climate knowledge management initiatives, resulting in disconnected efforts by the DPs to address the country's climate knowledge deficit. A DP representative highlighted the challenge of collaboration between DPs in climate knowledge management:

> "…. Developing climate change knowledge is important in building the capacity of the country in climate change adaptation and mitigation…and we development partners here in Tanzania have a key role to support the VPO and other partners including CSOs and education institutions in climate change knowledge development…however, we are facing the challenge of collaboration between ourselves …" (Male, 49 years old).

A representative from an academic institution which implements a climate change project supported by one of the DPs expressed the challenge of sustainability and continuity of climate knowledge initiatives in academic institutions:

> "…. Due to multiple challenges, we normally depend on donor support to pursue climate change projects in our university…however, these programs are only short-lived, and many are project-based, thus time bound…" (Male, 51 years old).

Civil Society Organizations

This study has revealed a lack of an effective framework for CSOs' engagement in climate knowledge management in Tanzania. CSOs that were consulted in this study cited an ineffective involvement by the government in the preparation of key national climate change frameworks as a critical gap. A key observation here is that the usual approach for developing these frameworks is mostly top-down, where CSOs and communities are largely sidelined. While the active participation of CSOs is recognized as necessary for the successful implementation of these frameworks, including in creating awareness of climate change at the local level, little has been done to develop an effective framework to build their capacity in terms of training and financing. A CSO representative highlighted the limited involvement as a critical gap:

> "…. Although the government is aware of our role in climate change knowledge generation and dissemination including awareness creation at the community levels, we CSOs have not been consistently engaged in key climate change processes …." (Male, 43 years old).

For CSOs, most climate change initiatives are donor-supported, unpredictable, unsustainable, and result-determined. The complexity of climate change knowledge means that CSOs' participation in climate knowledge management requires a supportive policy framework to mitigate existing gaps, including financing. This study has identified two CSOs that are relatively active in climate knowledge management, i.e., the Forum for Climate Change (Forum CC) and the Climate Action Network Tanzania (CANT). The two institutions have been proactive in climate change knowledge co-production and dissemination, working in collaboration with other stakeholders. However, most of the interventions implemented by these CSOs are limited in terms of coverage and scale due to funding and technical limitations. Further, there has been a rising tendency for donors to discourage training and knowledge generation activities at the expense of activities that have tangible impacts on communities, such as borehole drilling or solar PV installations.

Private Sector

The private sector's engagement is linked to the availability and accessibility of data and information on climate change, as this will inform business decision-making. Lack of knowledge and awareness is a critical challenge limiting the private sector's participation in adopting climate-friendly practices. Generally, many in the private sector are still unclear about the opportunities that are available around climate change mitigation and adaptation, and how they would meaningfully participate in generating and applying climate change knowledge. This study has found a lack of a collaborative approach to climate change by the private sector in Tanzania, which affects their engagement in climate knowledge management. An environmental officer representing a cement factory noted the technical challenge in generating, analyzing, storing, and sharing climate information:

> "…. We have not yet started to systematically collect, analyze and record GHG emission and other climate change data emanating from our operation…it is a challenge for us as we don't have the required technology and technical capacity…. Further, this is not a requirement, meaning climate change data collection is not mainstreamed in our day-to-day operation…" (Female, 44 years old).

Media

Media has a key role in climate knowledge management by acting as a medium of knowledge exchange between the researchers, who produce the knowledge, and the public/policymakers, who are the ultimate users of the knowledge. Figure 3 shows the role of media in climate change knowledge management in many contexts.

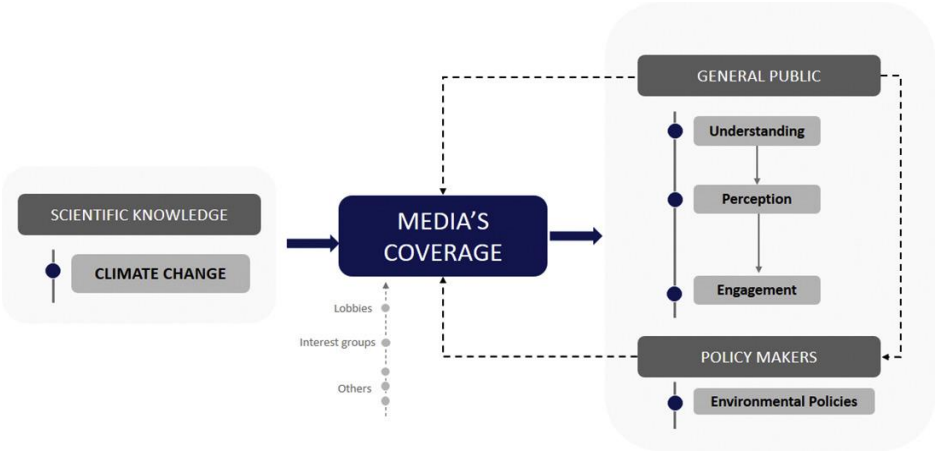

Figure 3**:** Role of media in climate change knowledge management. **Source**: Areia *et al*, 2019

Previous studies have attempted to understand the level of climate change information and knowledge coverage in the Tanzanian media, with a special focus on local newspapers. Generally, the studies have found very low levels of coverage and prominence of climate change information in the Tanzanian newspapers in the past 10 years (Elia, 2017). There has been some improvement since then, but gaps still exist. The findings of this study confirmed the existence of gaps in terms of weak technical knowledge of climate change among media stakeholders. The gaps are related to the general lack of prioritization of climate change knowledge and information by the local media outlets vis-à-vis other issues, the high cost of media fees, and the few specialized environmental and climate change journalists. Media stakeholders confirmed these limitations in the media focus group discussion:

> "…. For now, climate change and general environmental issues are only beginning to gain attention by media companies including newspapers … but more should be done to create awareness to the media to improve reporting on climate change issues …." (Female, 48 years old).

Discussions with journalists revealed the capacity gap in preparing and presenting climate change news, which was mainly attributed to the journalists' limited knowledge of climate change sources, risks, vulnerabilities, and opportunities. Journalists are expected to create stories about climate justice issues by analyzing local contexts and multiple social factors. This type of reporting can inform the public about practices that can foster climate resilience, trigger the formulation of climate policies and plans, and empower people to benefit from opportunities such as carbon trading or green investments. A representative from the environment journalists' association linked the capacity challenge to the lack of training on climate change issues for the local media:

> "…. It is also important to build the capacity of journalists to develop a specialization in climate change reporting …." (Male, 43 years old).

The study has also found that the main sources of climate change information for local journalists are largely the proceedings of climate change events organized locally, and random searches on the internet. This restricts the ability of local journalists to generate localized climate change knowledge through other means, such as investigative journalism or engagement journalism, which places communities at the center of the action.

Political Level

The collaborative framework for climate knowledge generation and use between scientists and policymakers is, in most cases, fragile. Practically, there is an imbalanced science-policy interface in

Tanzania due to the lack of a platform for engaging politicians in general climate change issues. Politicians are engaged on an ad hoc basis when the need for parliamentary approval of certain climate change frameworks arises. And even in these instances, only a handful of politicians seem to have a good understanding of the climate change issues brought forward. According to one of the CSO, respondents interviewed for this study, the delay in approving several key climate change frameworks (including the Kyoto Protocol, Paris Agreement, and NDC) by decision-makers, including the Parliament, was caused in part by a lack of knowledge about climate change:

> "…. Our politicians lack adequate knowledge on climate change aspects due to lack of awareness raising programs focusing the parliament …." (Male, 63 years old).

5. Discussions

According to the knowledge-deficit theory, a lack of understanding about climate change—or a failure to fully understand the scientific consensus—is to blame for people's or institutions' lack of concern or actions to combat climate change impacts (Cornforth, 2011). Arguably, people or institutions without or with limited knowledge of climate change do not have high levels of concern about climate change compared to those with high knowledge of climate change. This study has identified several climate knowledge deficits at multiple levels through the analysis of the information obtained from a wide range of climate change stakeholders in Tanzania. The results of this study conform with the argument of the knowledge-deficit theory for climate knowledge management. The study also follows the three pillars of the knowledge management theory, which focus on the organizational, ecological, and techno-centric aspects of managing knowledge and stress the roles of institutions, interactions, and technology (Grant, 1996).

Regarding climate change science, the knowledge deficit was examined in terms of the limited country's capacity in the areas of historical climate variations and GHG emissions, meteorological and hydro-met aspects of climate change, and local emission scenarios and climate change models. Examination of various institutions, including the National Carbon Monitoring Centre, TMA, sectoral ministries, and several education and research institutions, showed an expertise deficit in producing, analyzing, storing, and disseminating localized scientific and social climate change information and data. This shortfall may limit the country's ability to manage climate change in areas such as policy development and implementation.

Climate knowledge management is linked to institutional capacity at all levels of governance. The fact that VPO is responsible for climate change knowledge management and can coordinate with other institutions and stakeholders is critical. The lack of a climate change unit, and specifically the absence of a specialized climate change research unit at the VPO to facilitate knowledge generation, has been a barrier. This study has identified further institutional barriers at VPO in terms of staff deficiency, frequent staff relocation, budgetary constraints, and dependency on external support. Further, the inadequacy of climate change focal points in the sectoral ministries, compounded with low technical and financial capacities in these ministries, is seen to contribute to the inadequate participation of these ministries in generating and disseminating knowledge and information about climate change. For example, in all the ministries consulted in this study, the respondents couldn't confirm budget allocation for climate change research from any source.

According to the organizational aspect of knowledge management theory, it is paramount to have a proper institutional framework to achieve effective knowledge management (Grant, 1996). In this situation, the need for improved capacity at VPO and other sectoral ministries cannot be underestimated. The challenge of inadequate collaboration within the government's institutions needs to be addressed in this case. This barrier was also seen across other stakeholders, including CSOs, research institutions, education institutions, the private sector, and the media. Essentially, Tanzania lacks a multi-stakeholder and multi-

sectoral platform for climate change knowledge sharing. The proposal to hold an Annual Climate Change Forum in the new climate change strategy is seen as a good approach to addressing this barrier, but its implementation remains a challenge. At the DP's level, the absence of a systematic coordination framework for climate knowledge management is also a barrier. The existing DPs' platforms (such as DPGE and EDPG) are not designed to explicitly generate knowledge but largely share information among the stakeholders.

As it was observed, the VPO cannot adequately use the ICT system to effectively coordinate climate knowledge management due to several challenges. This conforms with the techno-centric aspect of the knowledge management theory, which talks about the effective use of technologies in generating, analyzing, storing, and disseminating knowledge in a particular institutional or societal setting (Grant, 1996). For example, the existing VPO website lacks the functions and contents required to promote knowledge production and dissemination. The ineffective application of the ICT systems at the National Carbon Monitoring Centre to facilitate the generation of the required GHG emission data, especially in the non-forestry sectors, also conforms with the techno-centric aspect of the knowledge management theory. The same situation was observed in the case of other sectoral ministries, including the ministry of water, which is responsible for the management of the water basins in the country. The application of the ICT system in this case entails expanding the coverage of the hydromet systems to all water basins in the country. This is expected to strengthen the country's capacity for collecting, analyzing, and disseminating hydro-meteorological data to improve climate change adaptation. The incapacity of TMA to deploy ICT can be discussed based on its inability to expand the coverage of automated weather stations to capture localized weather and climatic data. Regarding the Prime Minister's Office, which is responsible for disaster management in Tanzania, ICT application can be discussed in terms of the incapacity of the ministry to produce the required reports and information on climate-related disasters, and the incapacity to effectively disseminate the information to the intended users.

Being one of the sources of knowledge gathered from various sources, the media in Tanzania is well-positioned to address gaps in climate change knowledge. The role of the media is discussed using the knowledge deficit theory, which tries to link the public's action and response to climate change with the level of public knowledge about climate change. In general, the media are crucial in facilitating the public's access to climate knowledge based on their direct link with the producers of the knowledge and the user, which is the public. This study has found the inadequate capacity of knowledge producers to communicate climate knowledge to the media, and the incapacity of the media to source, prepare and communicate localized climate change information. This has resulted in inadequate coverage of climate change in the local media, thus depriving the public of crucial climate change information. All of this corresponds to the ecological aspect of knowledge management theory, which emphasizes the role of interactions and relationships between people and learning communities, as well as the interaction of internal and external factors in knowledge sharing (Grant, 1996).

So far, the role of the education system in managing climate knowledge has been limited to figuring out how well higher education institutions can learn about climate change. The study has found gaps in knowledge at this level since only a few programmes and courses are offered at the university level. This fact conforms with the knowledge deficit theory explained above, where the need for improved engagement of the education system in generating knowledge about climate change can be justified. This is expected to reduce the knowledge deficit since universities are positioned to offer specialized knowledge that can address societal challenges, including climate change. Like the research institutions, where a knowledge deficit was identified in terms of the focus and type of climate change research conducted by the research institutions in the country.

This study has also analyzed the role of the private sector in climate knowledge management and found a deficit in knowledge for most of the private sector stakeholders since climate change is not fully

mainstreamed in their operations' plans and strategies. Private sector establishments, as potential sources of GHG emissions, have the potential to be a very good source of localized GHG emission data and information. The low level of awareness and inadequate climate change expertise need to be addressed to create entry points for the participation of the private sector in climate change knowledge management in the country.

Finally, this study identified a strong knowledge gap at the political level, especially in the Parliament. Because the Parliament approves all policies for the country, including those concerning climate change, it is critical that members of parliament, including standing committees on environmental issues, are empowered to understand climate change issues and fully integrate them into their operational processes. The role of politicians will be crucial as well in promoting the development and implementation of a stand-alone climate change policy in Tanzania, which is expected to also guide climate knowledge management at multiple levels.

Conclusion

As knowledge about climate change spreads through society, people become aware of its causes and effects and take action to mitigate its effects. Similarly, decision-makers become increasingly conscious of their responsibility to develop the required policies, strategies, and plans as well as to support the execution of various climate change projects and programs by increasing overall funding allocations. Therefore, a comprehensive assessment of climate knowledge management in Tanzania is essential to ensuring that gaps and needs for climate knowledge are identified and appropriate actions are taken to address them. The multi-level analysis of climate knowledge management using both the knowledge deficit theory and the knowledge management theory provided an opportunity to analyze the climate knowledge management framework at multiple levels (MDA and LGAs, education, research, the private sector, CSO, DP, political, and media levels) in Tanzania. In general, Tanzania lacks knowledge in several areas, including localized climate change science, sectoral vulnerability, sectoral greenhouse gas emissions management, socio-economic data for purposes of enhancing climate resilience, localized climatic and weather information, and disaster risk reduction. Fundamentally, the sectoral knowledge management frameworks do not consistently mainstream climate knowledge, making it less relevant and less important in planning procedures. Lack of supportive policies, inadequate specialized expertise, staff relocation, financial constraints, an inadequate collaboration between stakeholders, poor adoption of ICT, and a lack of knowledge-sharing platforms, are some of the barriers identified as contributing to inadequate climate knowledge management at multiple levels. Due to this, the formulation and implementation of policies, plans, strategies, programs, and projects in Tanzania are faced with scarcity, uncertainty, and the unreliability of climate knowledge, making it particularly difficult for the country to effectively address climate change challenges. Stakeholders identified the need for an improved institutional framework at the VPO level to address the existing gaps, which include the establishment of a functional climate change unit and a dedicated research unit. The paper serves as input for actions for improved climate knowledge management to strengthen climate change governance in Tanzania. In this context, the findings in this paper can be adopted by decision-makers and other stakeholders to support climate knowledge management in Tanzania. Likewise, the common patterns and challenges identified also highlight the possibilities for learning among the key stakeholders to strengthen the interface between knowledge and policy in climate change governance.

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