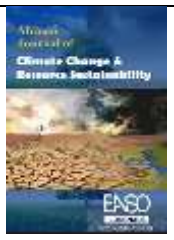
Article DOI : https://doi.org/10.37284/ajccrs.3.1.2160



African Journal of Climate Change and Resource Sustainability
ajccrs.eanso.org
Volume 3, Issue 1, 2024
Print ISSN: 790-962X | Online ISSN: 790-9638
Title DOI: https://doi.org/10.37284/2790-9638

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Assessing The Resilience of Adaptation Measures: Conceptual Frameworks for A Case Study of Ghana's Keta Sea Defense System

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Article DOI: https://doi.org/10.37284/ajccrs.3.1.2160

Date Published: *30 August 2024*

Keywords: *Adaptation, Climate Change, Coast, Conceptual, Framework, Keta, Sea Defense.*

ABSTRACT

The consequences of rising sea levels caused by climate change have been detrimental to the residents living along the coast of Keta in Ghana. The construction of the Keta Sea defense system as an adaptation measure designed to alleviate the situation appears to have had little impact. Despite the development of various climate change adaptation frameworks to help enhance the resilience of adaptation measures, the outcome of these adaptation measures remain uncertain until another climate change related event occurs that may disrupt socio-economic life. To mitigate this, adaptation measures ought to be assessed using a rigorous assessment-based adaptation framework. This study proposed two of such frameworks, that is, conceptual adaptation framework of interaction and conceptual adaptation framework of outcomes. The two conceptual frameworks are to be used concurrently and can be applied in assessing and implementing other environmental measures within a specific environmental context.

APA CITATION

Acquaah, E. K., Mearns, K. & Agyepong, A. (2024). Assessing The Resilience of Adaptation Measures: Conceptual Frameworks for A Case Study of Ghana's Keta Sea Defense System *African Journal of Climate Change and Resource Sustainability*, *3*(1), 259-271. https://doi.org/10.37284/ajccrs.3.1.2160.

CHICAGO CITATION

Acquaah, Ezekiel Kojo, Kevin Mearns and Adelaide Agyepong. 2024. "Assessing The Resilience of Adaptation Measures: Conceptual Frameworks for A Case Study of Ghana's Keta Sea Defense System", *African Journal of Climate Change and Resource Sustainability* 3 (1), 259-271. https://doi.org/10.37284/ajccrs.3.1.2160.

HARVARD CITATION

Acquaah, E. K., Mearns, K. & Agyepong, A. (2024) "Assessing The Resilience of Adaptation Measures: Conceptual Frameworks for A Case Study of Ghana's Keta Sea Defense System", *African Journal of Climate Change and Resource Sustainability*, 3(1), pp. 259-271. Doi: 10.37284/ajccrs.3.1.2160.

IEEE CITATION

E. K. Acquaah, K. Mearns & A. Agyepong "Assessing The Resilience of Adaptation Measures: Conceptual Frameworks for A Case Study of Ghana's Keta Sea Defense System", AJCCRS, vol. 3, no. 1, pp. 259-271, Aug. 2160.

MLA CITATION

Acquaah, Ezekiel Kojo, Kevin Mearns & Adelaide Agyepong. "Assessing The Resilience of Adaptation Measures: Conceptual Frameworks for A Case Study of Ghana's Keta Sea Defense System". *African Journal of Climate Change and Resource Sustainability*, Vol. 3, no. 1, Aug. 2024, pp. 259-271, doi:10.37284/ajccrs.3.2160.

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INTRODUCTION

One of the significant consequences of climate change that disrupts socio-economic life is the increasing sea levels. This has garnered considerable attention from governments across the globe, particularly those situated along the coast. A multitude of coastal regions are under threat from sea-level rise, which has the potential to provoke considerable socio-economic change. According to the Intergovernmental Panel on Climate Change (IPCC), global sea levels are anticipated to rise in the years to come (IPCC, 2019). By the year 2050, it is estimated that approximately one billion individuals worldwide will be at risk of rising sea levels (IPCC, 2019). Although the rate of global sea-level rise was 1.7 millimeters per year between 1901 and 2010, it is projected to increase to 8 millimeters per year between 2081 and 2100 (Pachauri et al., 2014). This projected increase is supported by the findings that the rate of sea level rise has already shown signs of acceleration in recent decades (Church & White, 2006; Schultz, 2011). The acceleration is attributed to anthropogenic climate change, which is expected to continue influencing sea level rise through thermal expansion of seawater and the melting of glaciers and ice sheets (Mengel et al., 2016; Tokarska et al., 2019).

Regional variations in sea level rise are also noted, with some areas experiencing rates that deviate from the global average due to local factors such as land uplift or subsidence, and regional climate variability (Tseng et al., 2014; Frederikse et al., 2021). The extent of the impact of rising sea levels varies depending on the adaptation measures used to moderate the impact and the mitigation measures taken to reduce carbon emissions (Priestley, 2021). The consequences of rising sea levels are substantial, particularly for those living along the coast. This may include coastal erosion and flooding, which have the potential to cause significant socio-economic change, particularly in the lives of those living and working along the coast. Along with intense precipitation, sea-level projections indicate an increase in floods and landslides, the frequency of tropical cyclones, and the intensity of wind (Tapan & Luna, 2017). Coastal erosion and flooding result in the destruction of properties including homes, intrusion of agricultural land, reduction of coastal lands, more frequent and intense storms, saltwater intrusion into freshwater sources and unemployment for farmers whose land is affected (Codjoe et al., 2017), and in some cases, climate-induced relocation, which negatively impacts human settlements (Salifu, 2021).

Other studies over the past years indicated a growing concern over the impact of climate change in the lives of people, especially those along the coastline (Addo, 2013; Bettini, 2017; Cinner et al., 2018). These impacts not only threaten the livelihoods of people who depend on coastal resources, but also pose significant challenges to the overall sustainability of these communities (Hoegh-Guldberg et al., 2019). In addition, climate change is also expected to exacerbate existing social and economic inequalities, with vulnerable populations being disproportionately affected by the consequences of climate change (Adger et al., 2009).

Therefore, it is imperative that policymakers and stakeholders take urgent action to address the impacts of climate change on coastal communities and promote sustainable and equitable approaches to managing these areas. In addressing the impacts of climate change on coastal communities in Ghana, the Government of Ghana conducted geophysical investigations to determine the underlying causes of coastal erosion and flooding particularly within the Keta and Ada coastline. Following these investigations, the government implemented various measures, including the construction of sea defense system (an adaptation measure) along the south-eastern coast of Ghana in 2000. The sea defense system was specifically built in the Keta and Ada coastlines, but this study focused on the Keta coastline due to the frequent occurrence of

Article DOI : https://doi.org/10.37284/ajccrs.3.1.2160

ocean surge and the fact that lessons learnt from the Keta coastline can be applied to the Ada coastline because of their similar geographical characteristics. The construction of the sea defense system by the Government did not produce the desired outcomes. This is not surprising because actual outcomes of implemented adaptation measures remain uncertain until subsequent climate change events occur which may lead to loss of lives and properties.

In November 2021, a storm-related ocean surge in the coastal district of Keta displaced nearly 4,000 people, causing water to infiltrate homes and soak residents' belongings and beds while they slept (Osisiadan, 2021). This occurred despite the presence of the Keta Sea defense system and other efforts by the local inhabitants which include adaptation techniques such as filling beaches with sand and elevating building foundations to protect against sea erosion (Gbedemah, 2023). Literature search shows that there is no established connection between the outcomes of a sea defense-related adaptation measure and any of the existing conceptual frameworks, resulting in a knowledge gap. Predictions by the Intergovernmental Panel on Climate Change indicate that climate change and its consequences will worsen in the coming decades (IPCC, 2019), this makes it crucial to take proactive measures to ensure that existing climate change adaptation measures are more resilient.

It is for these reasons (the knowledge gap and the IPCC predictions) that this study proposes two frameworks: the conceptual adaptation framework of interaction and the conceptual adaptation framework of outcomes as dual assessment tools for assessing climate change adaptation measures including the Keta Sea defense system. Another reason why the two adaptation frameworks have become necessary to be used for the assessment of sea defense-related adaptation measures is the fact that other conceptual frameworks have been devised for various sectors, but none was mentioned specifically for related sea defense systems. Some of closest available frameworks include frameworks for water management (Johnson & Weaver 2009), frameworks for tourism (Simpson et al., 2008), frameworks for community sustainability (Snover et al., 2007), frameworks for natural resource management (Cross et al., 2012) and frameworks for the cross-border impacts of climate change (Carter et al., 2021).

In the review on the impact of urbanization and climate change on urban flooding and urban water quality by Miller and Hutchins (2017), the majority of the literature these authors reviewed lacked conceptual frameworks for assessing the effectiveness of related sea defense adaptation measures. Similarly, as indicated by Hunt and Watkiss (2011) in their review on rising sea levels and their resulting floods that are becoming increasingly common due to climate change, they indicate that it has become necessary to develop appropriate tools for assessing the measures put in place to mitigate the impact of rising sea levels. Klopfer et al., (2021), proposed that a framework would be essential for assessing climate change adaptation measures because a framework provides a high-level overview of the system's sub-concepts, which can be used to evaluate vulnerability, risk, sensitivity, resilience, and other adaptation-related factors. Tapan and Luna (2017), recommended a framework for adaptation measures because climate change and its socio-economic consequences may be unavoidable, and the impacts may be more severe and rapid than current estimates suggest. Beatley, (2014) and Salehi et al., (2019) also indicated that the use of a climate change adaptation framework can promote resilience, sustainable development, positive social change, creativity, innovation, flexibility, reduce vulnerability, and enhance effective management. All these underscores the importance of the proposed conceptual adaptation framework of interaction and the conceptual adaptation framework of outcomes from this study.

MATERIALS AND METHODS

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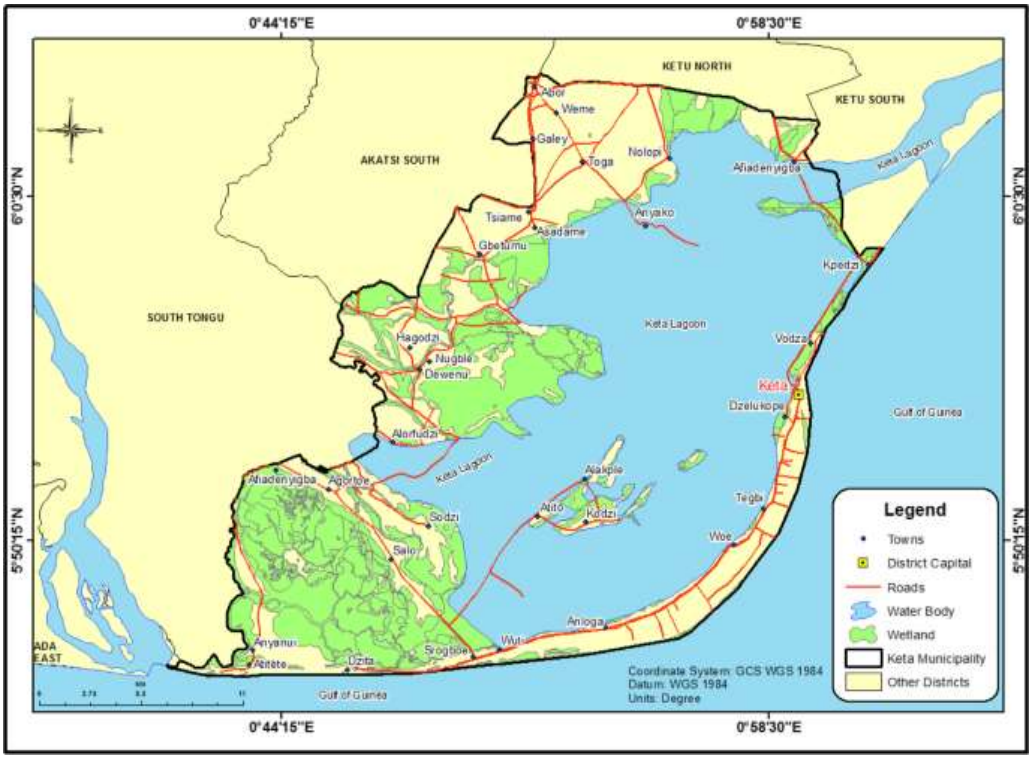
Study area

The study area encompasses the Keta municipal, which is one of the 261 metropolitan, municipal, and district assemblies in Ghana and constitutes one of the eighteen districts in the Volta Region of Ghana. Originally established as an ordinary district assembly in 1988, known as the Keta District, it was carved out of the former Anlo District Council until it attained municipal district assembly status, which took effect from February 29, 2008. The Keta municipality serves as the capital town of the municipality and is located in the southeast part of the Volta Region of Ghana, (Mahu, et al., 2023). It lies within Longitudes 0.30E and 1.05E and Latitudes 5.45N and 6.005N, situated east of the Volta estuary, approximately 160km east of Accra, off the Accra-Aflao main road. Out of the total surface area of 1,086km^2, roughly 30% (approximately 362km^2) is covered by water bodies, with the largest being Keta Lagoon, which spans approximately 12km at its widest section and 32km in length. Consequently, the remaining land area comprises 446 km^2 (Lamptey et al., 2014). This situation presents significant constraints on access to land, but fishing and water transportation potential exists. The municipality's boundaries are demarcated by Akatsi South Municipal to the north, Ketu South Municipal to the east, South Tongu District to the west, and the Gulf of Guinea to the south. The municipality is a low-lying coastal plain, with the highest point standing at 53 meters above sea level and the lowest point ranging from 1 to 3.5 meters below sea level, making it vulnerable to tidal waves and sea erosion, (Peters & Kumisi, 2023). Consequently, certain coastal communities experienced sea erosion, necessitating the construction of a sea defense system to safeguard the remaining land. The municipality comprises three primary geographic regions: the narrow coastal strip, the middle belt's lagoon basin, and the plains of the north.

Fig 1. Map showing the location of Keta and its boundaries. (Source: Peters & Kusimi, 2023).



The population of the Keta Municipality, according to the 2021 Ghana Statistical Service population and housing census, is 78,862 individuals. This figure consists of 36,986 males and 41,876 females. The

Article DOI : https://doi.org/10.37284/ajccrs.3.1.2160

climate in Keta is characterized as a tropical savanna, with monthly mean temperatures above 18°C throughout the year. Additionally, the municipality experiences a pronounced dry season, with the driest month having precipitation levels below 60mm.

Data sources

The study used primary and secondary data that were gathered from governmental institutions whose work is connected to climate change and water resources management in Ghana. The study refers to these institutions as climate change actors and they comprise the Ghana Meteorological Agency, Water Research Institute, Energy Commission, Volta River Authority, and the Ministry of Environment, Science, Technology, and Innovation (MESTI). There are other governmental institutions whose duties intersect with climate and water bodies, but the duties of the aforementioned five institutions are more closely aligned with climate change and water resources management in Ghana hence choosing them for this study. The secondary data was mainly sourced from the Ministry of Environment, Science, Technology, and Innovation and information from the literature review. For the primary data, the study engaged and interviewed three senior and two middle-level officials from the Ghana Meteorological Agency, Water Research Institute, Energy Commission and the Volta River Authority. Senior management staff were targeted for interview to give more insight into issues related to climate change policies, whiles the middle management staff were also interviewed to provide insight into practices and practical issues related to climate change management in Ghana. Table 1 shows the interview structure that illustrates the number of intended respondents to be interviewed, the actual number of respondents who were interviewed, the mode of engagement and the descriptive statistics (total, mean, median, range, variance and the standard deviation). Table 2 shows the sources of the secondary data gathered mainly from the MESTI. They included climate change related policy documents, legislative documents, and reports.

Table 1: Interview structure

Agency	No. of intended senior level staff to be engaged	No. of senior level staff actually engaged	Mode of engagement	No. of intended middle level staff to be engaged	No. of middle level staff actually engaged	Mode of engagement
Volta River Authority	3	3	Email	2	1	Email
Energy Commission	3	1	Face-to-face interaction	2	0	None applicable
Water Research Institute	3	3	Face-to-face interaction	2	1	Face-to-face interaction
Ghana Meteorological Agency	3	2	Face-to-face interaction	2	2	Face-to-face interaction
Total	12	9		8	4	
Mean	3	2.25		2	1	
Median	3	2.5		2	1	
Range	0	2		0	2	
Variance	0	0.917		0	0.667	
Standard Dev.	0	0.9157		0	0.816	

Source: Authors compilation 2023

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Table 2: List of policy, legislative and report documents consulted

No.	Document	Document Type
1	Ghana National Climate Change Policy	Policy document
2	Ghana National Climate Change Master Plan Action Programmes for Implementation: 2015 – 2020	Policy document
3	National Environmental Policy	Policy document
4	Ghana Climate Change Legislation	Legislative document
5	ODI Report on Climate Change Finance in Ghana,	Report

Source: Authors compilation 2023 from MESTI

A key policy within the space of climate change is the Ghana National Climate Change Policy framework (Government of Ghana, 2013). The framework guides the development, coordination and implementation of climate change management processes in Ghana. Broadly, the aim of the framework is to ensure a climate resilient and climate compatible economy while achieving sustainable development and equitable low carbon economic growth for Ghana. It outlines three major objectives to attain: (i) low carbon growth, (ii) social development and (iii) effective adaptation to climate change. Activities resulting in low carbon growth could lead to less emission of GHGs and subsequently mitigate global warming and climate change. Ghana National Climate Change Master Plan Action Programmes for Implementation: 2015 – 2020 serves as a guide to future national development planning framework to ensure that Ghana has a climate-resilient economy to ensure low carbon development. It has ten policy focus areas, but relevant to our work is policy focus number two which focuses on building climate resilient infrastructure. Specifically, under programme 2.7, under policy focus two, the documents detailed all the activities and investment made in protecting coastal resources and communities (Government of Ghana 2020). The National Environmental Policy attempts to restructure and redirect Ghana's climate change and environmental implementation strategy to achieve the desired results (Government of Ghana 2012). Ghana draws its Climate Change Legislation from the Environmental Protection Agency Act, 1994 (Act 490) to regulate climate change matters. Act 490 and Legislative Instrument 1652 of 1999, indicates that any adverse effect on the environment tends to affect other areas including health, socio-economic and cultural sectors, making the effects of climate change multi-sectorial (Government of Ghana, 1999). According to the ODI Report on Climate Change Finance in Ghana Climate change relevant expenditure is approximately two percent of government expenditure and 0.5 percent of GDP (Asante et al., 2015). This is deemed to be very low base upon which the National Climate Change Policy has to build over the next five years to accomplish its policy objectives

RESULTS

The framework development process

The process of building a sea defense or any other related adaptation measure starts with the climate change actors and the beneficiary community; thus, making interaction and cooperation among the climate change actors and the community members very essential. Complete cooperation between the climate change actors and the communities ensures the buy-in of the beneficiary communities and the success of implementing adaptation measures. The study discovered a lack of coordination and collaboration among climate change actors. This was evidenced in statements such as: *"Our work schedule is to analyse and test water bodies to monitor how is being affected by climate change among other things, but our activities hardly interact with other agencies who are also involved in climate change-related activities but in relation to hydropower generation"*. Again, a statement such as "*We know the Meteorological Agency*

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generates temperature readings, but we take our own temperature readings to monitor the water levels" shows lack of coordination and collaboration. A respondent even called for a concerted effort to tackle the issue of climate change stating that *"Climate change is an escalating threat with the potential to cause significant disruption and this calls for concerted effort to tackle the situation as individual institutional effort will not yield much results".* Table 3 shows summary of other extracts from the interview section.

Table 3: Summary of other extracts from the interview section with the government institutions

1	Sometimes there are cases of very intense rainfall that sometimes distracts our intervention and adaptation activities in the communities. .
2	Most of the times we experience the intense rainfall in June, but this period seems to be changing where we now witness intense rainfall in some unexpected months.
3	There are times we also experience prolong high temperatures that results in low water levels leading to the shutdown of some of the turbines. This subsequently leads to suboptimal operation of the dam.
4	Water in the fishponds we monitor is drying up gradually because the rains are not falling as expected these days.
5	One of the worst performances of the Akosombo dam occurred around 2010. The energy production of dam was reduced to 175MW per day instead of the expected 1020MW per day.
6	The surrounding rivers and other sources of water used for irrigation are drying up. This is negatively affecting livelihood.
7	There seems to be a lot of drying up of our water bodies which must be tackled swiftly otherwise there would be dire consequences on hydropower production and other sectors of the economy.
8	The dam has been experiencing some sort of climate change-linked water shortages leading to fluctuating water levels particularly in-between the rain and dry season

Source: Authors compilation 2023

The interview results show the need to create a channel of collaboration among the climate change actors. To also ensure successful implementation of adaptation measures, it is critical for the climate change actors to collaborate and cooperate efficiently in managing the implementation process of the adaptation measures. Again, to have an effective adaptation measure, it is crucial that the climate change actors understand the factors that impact having successful adaptation measures within the climate change settings. Based on the interaction and information from the climate change actors the study developed an initial framework that bring together the climate change actors and harnesses the available adaptation options, adaptation opportunities and constraints, and some possible adaptation measures or activities that can be carried out. This led to the development of the conceptual adaptation framework of interaction shown in Figure 2.

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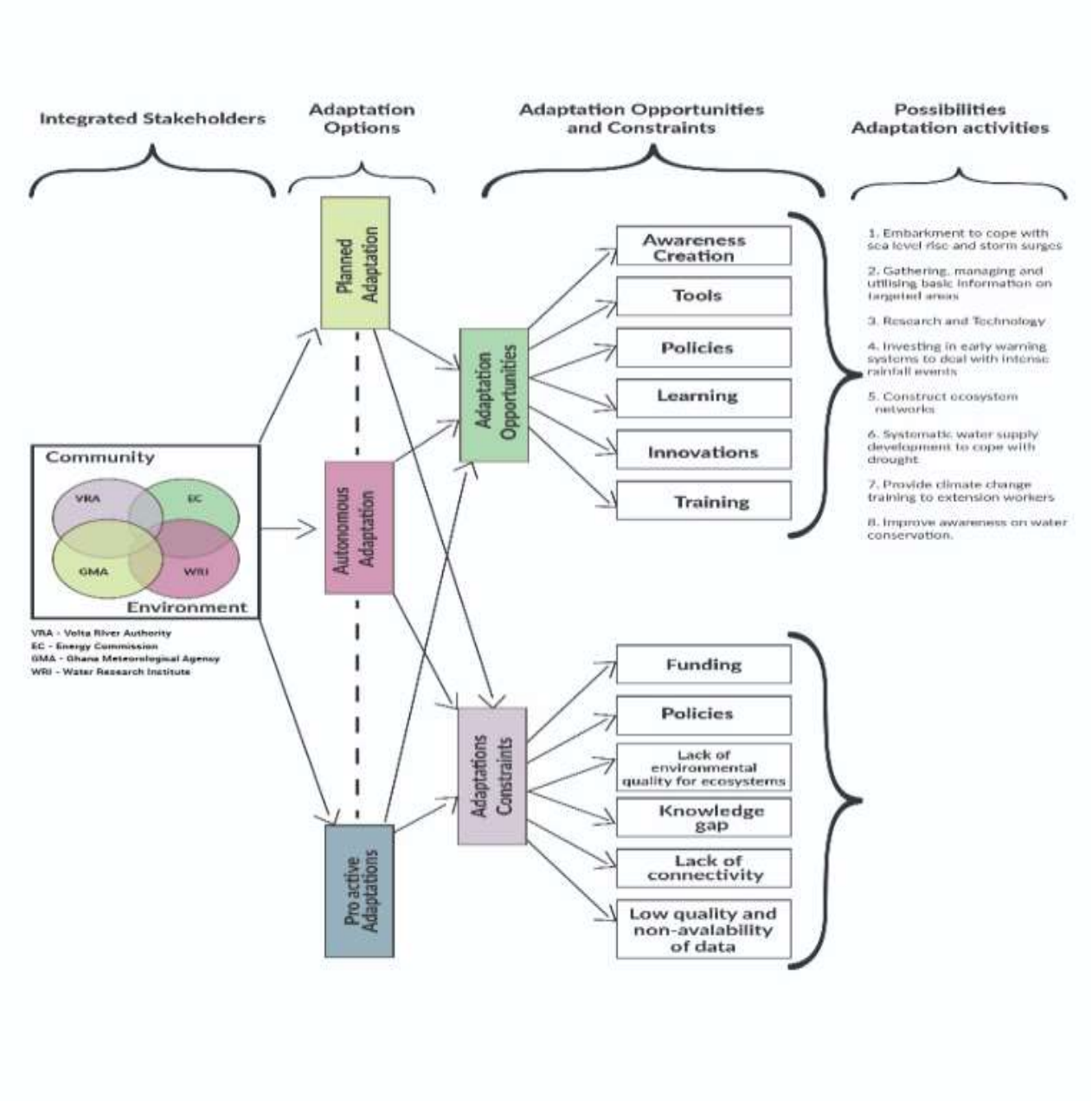
Figure 2: Conceptual adaptation framework of interaction



Source: Authors, 2023

The framework as illustrated in Figure 2, is known as the conceptual adaptation framework of interaction. It comprises four columns that have been integrated; the first column consists of the integrated stakeholders, the second column presents the three types of adaptation options: planned adaptation, autonomous adaptation, and proactive adaptation, the third column outlines possible adaptation opportunities and constraints with examples for each, while the fourth column indicates some examples of potential adaptation activities that can be undertaken. The column of integrated stakeholders highlights the climate actors who collaborate to evaluate and choose the type of adaptation options that may be suitable under the circumstances; for instance, under the circumstance of rising sea level, this may call for a sea defense system or any other adaptation measure. It is worthy

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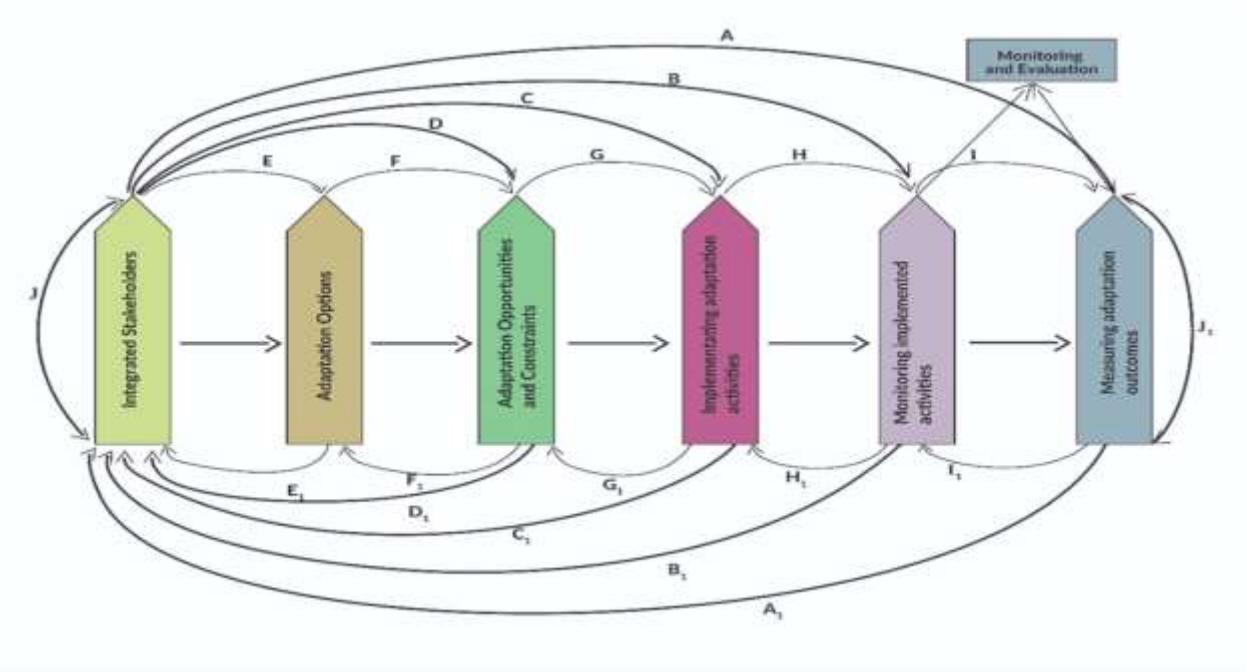
to note that the adaptation framework of interaction can be applied to the implementation of any other adaptation measure apart from the sea defense system.

The IPCC (2022) mentioned the three types of adaptation option, that is the proactive adaptation, planned adaptation and autonomous adaptation as shown in Figure 2. The proactive adaptation involves taking action before climate change impacts occur to avoid high costs, planned adaptation involves deliberate policy decisions based on awareness of changing conditions whiles the autonomous adaptation refers to natural and human systems reacting to changes in their environment. To apply these adaptation options, the integrated stakeholders would need to identify who or what is adapting, what they are adapting to, and the adaptation process. It is also crucial for the integrated stakeholders to identify the possible constraints to the adaptation measures to deal with it before forging ahead and identify possible opportunities that can advance the adaptation measures to capitalize on it to advance the implementation process.

Thorough and rigorous assessment is necessary at every stage of the implementation process to enhance the success rate of the desired outcome by examining all available options for a specific adaptation measure. Due to this, the study further developed an assessment instrument known as the conceptual adaptation framework of outcomes as shown in Figure 3. The conceptual adaptation framework of outcomes is subsequently used to assess the outcome of the adaptation measure after using the conceptual adaptation framework of interaction to begin the process of undertaking the adaptation measure.

Figure 3: Conceptual Adaptation Framework of Outcomes



Source: Authors, 2023

The conceptual adaptation framework of outcomes emphasizes the importance of rigorous assessment at every step of the implementation process before moving to the next step. It has some components of the conceptual adaptation framework of interaction within it, that is the integrated stakeholders,

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adaptation options, adaptation opportunities and constraints and the implementing adaptation activities. The arrows labeled "A" to "J" show the various directional signs that point to the activities to be carried out. The activities to be carried out and by who are summarized in the boxes labeled as integrated stakeholders, adaptation options, adaptation opportunities and constraints, implementing adaptation activities, monitoring implemented activities and measuring adaptation outcomes. The integrated stakeholders are those who would consider the various adaptation options available, bearing in mind the possible adaptation opportunities and constraints. This is followed by implementing the adaptation activities, and then monitoring the implemented activities to assess progress or otherwise and finally measuring the adaptation outcomes. The integrated stakeholders are expected to use a monitoring and evaluation tool at the last two stages, that is the monitoring implemented activities and the measuring adaptation outcome stages (hence the monitoring and evaluation above the monitoring implemented activities and the measuring adaptation outcome) to assess the final outcome of the adaptation measure.

Incorporating robust monitoring and evaluation within the framework strengthens the entire adaptation process and enhances the success rate. In the case of the arrows, the activities to be carried out under arrow "A" are indicated by arrows "B," "C," and "D". Arrow "B" shows the summation of activities to be carried out, which is indicated by "E," "F," "G," and "H." Arrow "C" gives the summation of activities to be carried out, which is indicated by "E," "F," and "G," while arrow "D" also gives the summation of activities to be carried out, which is "E" and "F." The conceptual adaptation framework of outcomes depicts a cyclical nature and illustrates the stage-by-stage activities (indicated by EFGHIJ and $E_1F_1G_1H_1I_1J_1$) to be undertaken by the integrated stakeholders. Again, letters (A to J) and the corresponding letters with subscripts (A_1 to J_1) demonstrate the cyclical and an evolving process of the framework.

The cyclical nature of the framework gives opportunity for the integrated stakeholder (climate change actors) to reassess every stage of the process (from EE_1 to $I\ I_1$) so that objectives that are not met at any stage will be determined and worked on even before reaching the final stage of measuring the adaptation outcomes. It also helps the integrated stakeholders to assess the functionality and efficiency of the implemented adaptation activities at every stage. Assessing the objective at every stage of the implementation of any adaptation measure is essential for the entire adaptation endeavor because it can help reduce costs by minimizing the likelihood of having to implement another adaptation measure at a new cost if the initial measure fails at the end of the process. It also saves time, as implementers of the adaptation measure would not need to spend extra time planning another measure if the initial one does not work, it ensures productivity as implementers can focus on other productive sectors and also increase the adaptive capacity of the community while reducing its vulnerability to the impacts of climate change. The novelty in this study is the development of the two frameworks, that is the conceptual adaptation framework of interaction and the Conceptual Adaptation Framework of Outcomes with its peculiar monitoring and evaluation feature. These frameworks would be needed because they can enhance the success rate of any adaptation measure.

CONCLUSION

This study has demonstrated the utility of conceptual adaptation frameworks for moderating the implementation of adaptation measures. The two frameworks (conceptual adaptation framework of interaction and the conceptual adaptation framework of outcomes) are adaptable, and its usage can be tailored to suit any other adaptation measure within a specific environmental context. The two frameworks are used together, that is the conceptual adaptation framework of outcomes is subsequently used to assess the outcome of the

Article DOI : https://doi.org/10.37284/ajccrs.3.1.2160

adaptation measure after beginning the implementation process of the adaptation measure with the conceptual adaptation framework of interaction. It is crucial to involve all stakeholders, that is all national climate change actors and the community, to ensure the successful implementation and buy-in of relevant adaptation measures. This study recommends incorporation of the usage of the frameworks into national policy especially for coastal areas to increase the success rate and effectiveness of implemented adaptation measures in such areas. The applicability of the frameworks is highly dependent on the environmental context. The flexibility of the conceptual adaptation framework of outcomes contributes to ensuring a high success rate and ease of use under different environmental conditions.

Declaration of conflict of interest

The authors declare that there is no conflict of interest with respect to the research, authorship and/or publication of this article.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

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