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Climate change impacts and adaptation strategies for Ghana's coastal population: A qualitative inquiry

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ABSTRACT

The study explored the multifaceted effects of climate change on seafront communities in Ghana, revealing a cascade of challenges spanning livelihood disruptions, environmental degradation, health, social disruption, and species extinction. Through interviews and focus group discussions, it demonstrates how changing weather patterns disrupt fishing and farming industries, leading to economic hardship and food insecurity. Environmental degradation, exacerbated by extreme weather events, threatens homes and infrastructure, displacing populations. Health issues arise from intense heat and vector-borne diseases, while social and cultural disruptions strain community cohesion and identity. Additionally, climate change threatens aquatic species' survival, impacting food security and ecological balance. Yet, amidst these adversities, a glimmer of hope is found in the adaptation strategies employed by these communities. The study highlights adaptation strategies adopted by communities, including agricultural diversification, relocation, housing adaptation, flood management, and marine safety practices, as indispensable in mitigating climate adversities and fortifying the resilience of Ghana's coastal communities. Yet, such efforts cannot stand alone; concerted efforts at local, national, and global levels are imperative to safeguard the future of Ghana's coastal communities and, indeed, those worldwide. We can only confront the daunting reality of climate change and chart a sustainable path forward for all through collaborative action.

Keywords: Climate change, impact, adaptation strategies, livelihood, coastal community

1. INTRODUCTION

Coastal regions in Ghana are integral to the country's economy, with significant contributions from sectors such as fisheries, tourism, and shipping. However, these areas are also at the frontline of climate change impacts, experiencing rising sea levels, coastal degradation and severe weather incidents with greater frequency and

intensity. Research has demonstrated that the rate of sea-level rise along the West African coast is accelerating, with projections indicating further increases in the coming decades (Nicholls et al., 2008). The rise in sea levels, caused by the thermal expansion of seawater, and the melting of polar ice, presents a severe risk to low-lying coastal areas, leading to the inundation of land and displacement of populations (Appeaning-Addo et al., 2011). In Ghana, this trend translates into the encroachment of seawater into low-lying areas, leading to the displacement of communities and the loss of agricultural land.

For instance, Keta in the Volta Region has witnessed significant land loss over the years, forcing residents to abandon their homes and relocate. Coastal erosion exacerbates the issue, as the gradual loss of land diminishes habitable and arable areas, threatening the livelihoods of coastal communities (Boateng, 2012). According to Boateng, (2009), approximately 70% of Ghana's coastline is experiencing varying degrees of erosion. This has profound implications for coastal settlements, infrastructure, and ecosystems. In communities such as Ada and Ningo-Prampram, the receding shoreline has destroyed property and essential infrastructure, including roads and schools, thus disrupting daily life and economic activities. The phenomenon is not different from the Western coast of Ghana. In communities like Akwidaa and Anlo Beach, the risks of climatic change are threatening, with houses submerged under wave action and wave erosion.

Severe weather conditions, such as intense storms and flooding, are becoming more frequent and fierce due to climate change (IPCC, 2014). These impacts are not sparing coastal communities in Ghana, as seawater intrudes into schools, and flooding destroys farmland and properties. In addition to physical changes, climate change also affects the socioeconomic fabric of coastal communities. Fishermen, who heavily depend on predictable weather patterns and healthy marine ecosystems, are encountering declining fish stocks and altered marine habitats due to changing ocean temperatures and conditions, which further strains their economic viability (Nunoo et al., 2014). These changes not only impact food security but also threaten the financial stability of households that depend on fishing as their primary source of income.

Similarly, the tourism industry suffers from the degradation of coastal attractions and increased frequency of adverse weather events. Additionally, the destruction of mangroves and other protective natural barriers increases the vulnerability of these communities to future climatic events. Previous research has often emphasized the physical and economic impacts of climate change on coastal areas (Boateng, 2009). However, there is a growing recognition of the need to understand the social dimensions of these changes. Understanding how climate change affects coastal communities in Ghana requires a qualitative approach delving into residents' lived experiences.

This study aims to explore how climate change is reshaping the lives, economies, and cultural identities of these communities. By using qualitative methods such as in-depth interviews and group discussions, this study aims to capture the perspectives of those most impacted by environmental changes. Such an approach is essential for understanding the complex interplay between ecological changes and social dynamics, which quantitative methods alone may not fully elucidate. By emphasizing human experiences rather than statistics, this study aims to provide insights to guide policymakers, development practitioners, and local leaders in creating more responsive and sustainable adaptation measures.

Relevant Literature

Human as an Agent of Climate Change

Global warming is now a fact, with its consequences manifesting across numerous world regions (Islam et al., 2021). There is no gainsaying that human activities are changing the climate (Hasan, 2015; Nwankwoala, 2015). With substantial certainty, current climate research assigns human activity as the dominant source of warming witnessed during the past century (Leggett, 2018). Climate change results from man's activities, including socioeconomic growth and the effort to limit GHG (Chadwick, 2017; Leggett, 2018; Walsh et al., 2014). Combustion of fossil fuels, deforestation, and livestock farming are all contributing to the progressive alteration of the Earth's atmosphere and warming rate (Jackson, 2021).

These actions release vast amounts of carbon emissions into the sky, magnifying the greenhouse effect and adding to global warming (Hansen et al., 2013; Onoja et al., 2011). When fossil fuels are burned, carbon dioxide, a greenhouse gas, is emitted (Siddik et al., 2021). Deforestation releases carbon that hitherto has been removed back into the atmosphere. Africa's deforestation rate is about double that of the rest of the world, with the continent losing approximately 4 million hectares of forest annually (AfDB, 2012). Farming and road construction can change the earth's reflectivity, resulting in localized heating and cooling (Golden, 2004).

Natural Causes of Climate Change

Natural phenomena like fluctuations in volcanism, insolation, and the Earth's revolution around the sun may all influence the atmospheric temperature of the planet (Onoja et al., 2011). However, the two most significant factors influencing current climate change time frames are variations in volcanic activity and changes in solar radiation. Seismic activity has been documented to discharge sulfur dioxide (SO2), moisture, particles, and ash into the air as byproducts. Large amounts of gases and ash can have long-term effects on Earth's climate by increasing terrestrial albedo and causing atmospheric condensation (Jackson, 2021; Onoja et al., 2011). Eruptive volcanoes, however, are sporadic and have only a temporary effect on the climate (Stenchikov, 2021).

Although the sun's energy output seems to be steady from a daily point of view, tiny fluctuations over time can cause climate change (Onoja et al., 2011). Again, variations in solar output have influenced climate patterns over the past centuries, but they are insignificant compared to artificial carbon emission contributions (Stenchikov, 2021). Furthermore, variations in the axial tilt of the planet can cause minor but significant changes in the severity of the seasons (Onoja et al., 2011). The movement of the Earth's crust has changed the shape, structure, and topography of the continents, as well as the ocean floor. Topographic and bathymetric changes, in turn, have had a tremendous influence on the flow of the air and the oceans, affecting the climate of the Earth (Jackson, 2021).

Impacts of Climate Change

Climate change has sparked global debate owing to its adverse effects on humanity's living conditions. Climate change presents a considerable threat to Africa's long-term development and prosperity (Asante and Amuakwa-Mensah, 2015). Changes in rainfall patterns, which reduce agriculture productivity and food security, are among the long-term consequences of climate change (Abrams et al., 2017; Carmin, 2012), deteriorating water security Müller-Kuckelberg, (2012), Tadesse, (2010), dwindling fish supplies in huge lakes as temperatures rise UNDP and GEF, (2018), Wondimagegn and Lemma, (2016), and changes in vector-borne illnesses (Mattah et al., 2018). The Arctic is heating at a rate double that of the rest of the planet. As ice caps thaw into the water, our oceans will rise, putting coastal habitats and low-lying communities at risk (Anne et al., 2018). Coastal erosion exacerbates the issue, as the gradual loss of land diminishes habitable and arable areas, threatening the livelihoods of coastal communities Boateng, (2012), and leading to the displacement of populations (Appeaning-Addo et al., 2011).

Furthermore, coastal erosion exacerbated by increasing sea levels devastates a large section of Ghana's east coast, jeopardizing millions of dollars invested in infrastructure. Torrential rains are severely impacting road networks, resulting in astronomical yearly road maintenance costs that hinder the necessary extension of road infrastructure to improve accessibility (UNEP and UNDP, 2013). Climate change has several effects on human health (Muller-Kuckelberg, 2012). Severe weather catastrophes like tornadoes and floods can inflict wounds, tainted potable water, and storm surges, all of which might imperil critical property or force population relocation. Relocation comes with new sets of health hazards, such as congestion, trauma, social unrest, a lack of safe water, and the transmission of contagious diseases (Bartlett, 2008). Climate change affects coastal communities and fishery supplies, vital to the indigenous industry, thereby devastating their living conditions and putting these communities on the verge of economic collapse.

Adaptation Strategies to Climate Change

Climate change presents considerable threats to beachfront communities, significantly impacting fishing and agricultural livelihoods. Adaptation mechanisms are essential to mitigate these effects and ensure the sustainability of these vital sectors. In fishing communities, adaptation strategies include the development of more resilient fishing practices, such as adjusting fishing seasons and diversifying target species to reduce dependency on vulnerable fish stocks (Cinner et al., 2018). Additionally, implementing marine protected areas can help restore fish populations and ecosystems, providing long-term benefits for fishers. Farmers are adopting salt-tolerant crop varieties and employing improved irrigation techniques to manage water resources more effectively by combating soil salinization and water scarcity, which are exacerbated by rising sea levels and increased evaporation rates (Rasul and Sharma, 2016).

These practices not only increase crop yields but also improve food security in vulnerable regions. Agroforestry and integrated farming systems are promoted to enhance resilience, combining crop production with aquaculture and livestock to diversify income sources and reduce risk. Many coastal communities are shifting from traditional fishing and farming to alternative income-generating activities such as aquaculture and ecotourism. Aquaculture, for example, offers a viable alternative by reducing the pressure on wild fish stocks and providing a stable income source (Klinger and Naylor, 2012). In Bangladesh, small-scale aquaculture projects have significantly improved the economic resilience of coastal households by offering a buffer against the uncertainties of climate change

(Ahmed and Glaser, 2016). Similarly, promoting ecotourism leverages the natural beauty and biodiversity of coastal areas to create sustainable economic opportunities while fostering environmental conservation (Martínez et al., 2007).

Additionally, coastal communities are investing in infrastructure improvements, such as the erection of sea walls and the rehabilitation of mangroves, acting as natural defences to storm surges and beach erosion (Menéndez et al., 2018; Narayan et al., 2016; Nicholls et al., 2008). Mangroves, in particular, act as natural protection against storm surges and coastal erosion while providing critical habitats for fish and other marine life (Alongi, 2008). These ecosystems also offer additional benefits such as preserving biodiversity and capturing carbon. These natural defences, in combination with engineered solutions, can significantly decrease the physical and economic vulnerabilities of coastal regions. Moreover, early warning systems and community education programs are critical in enhancing preparedness and response capabilities. For instance, establishing efficient evacuation routes and emergency shelters can save lives during disasters (IPCC, 2014).

Education and training programs equip communities with the knowledge and skills needed to adapt to changing environmental conditions and to adopt sustainable practices Adger et al., (2005) to proactively manage resources (Armitage et al., 2010). Developing community-based disaster risk management improves preparedness and resilience (O'Brien and Selboe, 2015). Another crucial adaptation mechanism is the implementation of sustainable land-use planning. By restricting development in high-risk areas and promoting flood-resistant building materials and elevated structures, communities can reduce vulnerability to extreme weather events (Hinkel et al., 2014). Joint initiatives involving local governments, non-governmental organizations, and community members are crucial for the success of adaptation strategies. Participatory approaches ensure that the needs and knowledge of local populations are integrated into planning and implementation processes.

2. DATA AND STUDY METHOD

The research was conducted in Anlo Beach (5.0252°N, -1.6144°W), Akwidaa (4.7603°N, -2.0341°W), Ampenyi (5.0667°N, -1.4333°W), and Gomoa Fetteh (5.4200°N, -0.4738°W), in Ghana's Western and Central Regions (Figure 1). Except for Gomoa Fetteh, these communities have similar geographical characteristics in that they are sandwiched between two water bodies. Anlo Beach is located at the Pra River estuary, Akwidaa at the Ezile River estuary, and Ampenyi is situated at the Brenu Lagoon. These communities were selected due to their high exposure to the impacts of climate change. Their proximity to the coast subject them to coastal inundations. Climate change impacts such as sea level rise that drives coastal flooding, coastal erosion, and storm surges are common in these communities, with Akwidaa and Anlo Beach impacted heavily.

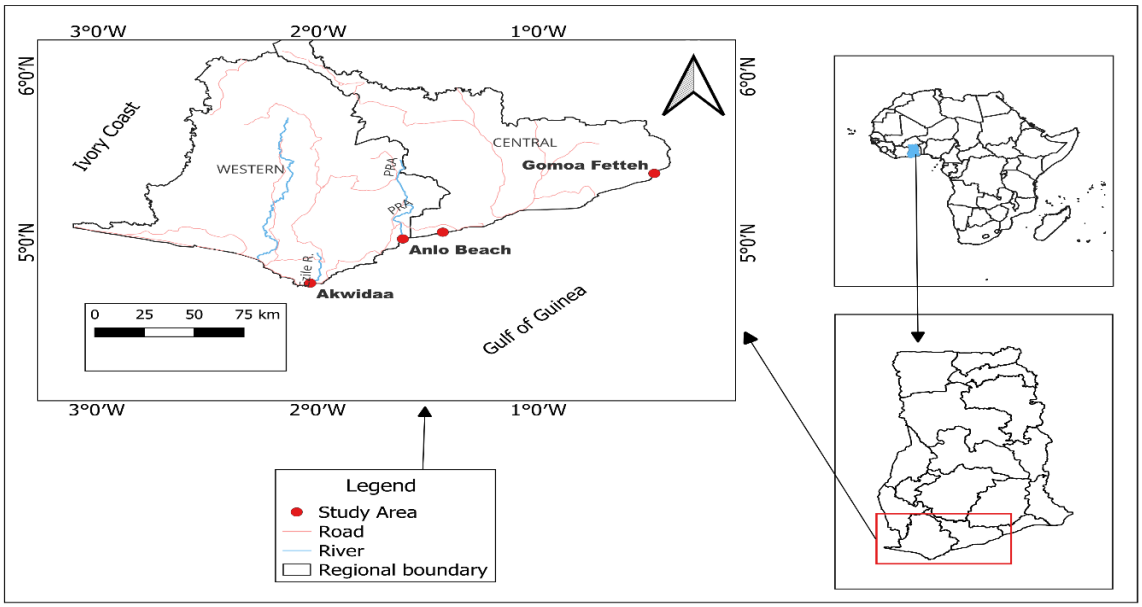

Figure 1 Study area map showing the four sampling communities.
Source: Author (2023)

Data were collected from twenty in-depth interviews (five in each community) and eight focus groups (two in each community) from July to August 2022. In-depth interviews involved diverse stakeholders, including assembly members, chief fishermen and fishmongers, unit committee members, and teachers. The focus group discussion involved eight (8) to ten (10) members with gender balance. This information is depicted in (Tables 1 and 2).

Table 1 Demographic information of focus groups

Location	Group Discussion	No of Participants
Akwidaa	Men	10
Anlo Beach	Men	8
Ampenyi	Men	8
Gomoa Fetteh	Men	10
Akwidaa	Women	10
Anlo Beach	Women	10
Ampenyi	Women	9
Gomoa Fetteh	Women	8

Source: Field Data (2022)

Table 2 Demographic information of focal interviewees

Interviewee	Gender	Age	Occupation	Location
Joseph	Male	50-55	Fishing	Akwidaa
Ekrah	Male	55-60	Fishing	Akwidaa
Osofo	Male	40-45	Fishing	Akwidaa
Amega	Male	45-50	Fishing	Anlo Beach
Bani	Male	50-55	Fishing	Anlo Beach
Evelyn	Female	55-60	Fish processing	Anlo Beach
Ackon	Male	45-55	Farming	Ampenyi
Esi	Female	60-65	Fish processing	Ampenyi
Martha	Female	40-45	Farming	Ampenyi
Egyir	Male	60-65	Teaching	Gomoa Fetteh
Rose	Female	55-60	Farming	Gomoa Fetteh
Dadzie	Male	45-50	Fishing	Gomoa Fetteh

Source: Field Data (2022)

The researcher administered a standardized interview and discussion guides. Interviews and focus groups were conducted in person, lasting 30-35 minutes for interviews and 45 minutes to one hour for focus groups. The researcher collected data on the causes, impacts, and adaptation to climate change. The investigator posed the subsequent questions to the interviewees and discussants: What cause (s) of climate change? How has climate change impacted the way you live? Or In what way(s) has climate change impacted your life? What strategies do you employ in adapting to climate change impact? It was imperative, at this stage, to consider the ethics governing social research. The researcher acquired ethical approval from the 'University of Cape Coast's IRB'. Participants provided their consent by signing the informed consent forms during the data collection process. Additionally, the researcher obtained consent from the participants before recording the proceedings of the interviews and group interactions in audio format.

To maintain anonymity and confidentiality for the study participants, the researcher carefully used pseudonyms. The interviews and the focus group discussions were transcribed verbatim. All forms of repetition, such as questions and responses, from both the interviewer and interviewees, as well as circumlocutions and interruptions, were pruned from the data. The data were, then, coded

following Braun et al., (2016) coding schema. Most of the codes were articulated using gerunds. Employing gerunds in coding is beneficial for researchers as it helps them to achieve a higher level of abstraction, thus avoiding the simple re-description of the data (Charmaz, 2004). By using the constant comparative method, emerging themes were organized. The write-up went beyond merely presenting the information. Incorporating excerpts into the analytical narration convincingly demonstrated the story he was telling about the data.

The analytical narratives went beyond a simple summary of the facts to present a claim in response to the research questions. These data excerpts, obtained from interviews and discussions, best represented a specific trend identified in the investigation. In the main write-up, the extracts were italicized in quotation marks as direct voices from the participants. To ensure data quality, two additional analysts further coded the data to ensure inter-coder reliability. Additionally, the researcher triangulated data from the focus group interactions with data from in-depth interviews to cross-validate the data and minimize bias inherent in any single data collection method. By integrating perspectives from both focus groups and interviews, the research gained a deeper comprehension of the phenomenon. It additionally permitted for the identification of converging or diverging themes across different data sources. Such comprehensive analysis enriches the credibility and robustness of the study's findings, contributing to its overall trustworthiness within the research community.

3. RESULTS AND DISCUSSION

The analysis discussed in this section is structured into two main segments. The first section deals with how climate change impacts and reshapes the lives of coastal communities, and the final part unravels strategies these residents adopt in adapting to threats posed by the changing climate.

Impact of Climate Change on Coastal Communities in Ghana

Research indicates that climate change significantly affects coastal communities in Ghana, disrupting their livelihoods, leading to environmental degradation and infrastructure damage, causing health issues and diseases, disrupting social and cultural practices, and resulting in species extinction.

Impact on Livelihoods

The changing climate has directly affected livelihoods in fishing and farming industries. Fishermen struggle with reduced catches, leading to financial burdens resulting from the rising cost of fuel and inputs that cannot be compensated for due to the decreased fish catch. Ekrah, a fisherman described: “In the fishing industry, high temperatures have reduced the fish population by causing them to move away from our waters. As a result, we don’t catch enough fish when we go to sea. When this happens, our fuel costs become burdensome, making life unbearable for some of us". Ekua, a fish processor, expressed a similar sentiment when she stated, “One of the effects is that we don’t have any job to do. Our work involves smoking fish, but because there is a shortage of fish, we cannot obtain any to sell. Consequently, we are enduring hardship due to the lack of income for our livelihood”.

According to them, the hardship makes it difficult to cater for themselves and their families. Similarly, farmers face challenges with crop failure, altered planting seasons, increased need for chemical inputs, and unpredictable rainfall patterns, resulting in famine, food insecurity and economic hardship, particularly in coastal communities heavily reliant on fishing and farming. This is because the intensity of the sun prevents crops from growing. After all, they wither just after the planting season. Furthermore, the unpredictable nature of rainfall is a severe constraint to agriculture, making farmers alter their planting seasons, decrease crop yields, and lead to food insecurity. Ackon, a resident in Ampenyi, noted: “Today, the rainfall pattern has changed. The months you expect rain have changed. In the olden days, when it was September, October, and November, the rains were heavy and normally fell at night but now do we see that? Now there is no difference between the rainy season and the dry season, likewise between major rainy season and minor rainy seasons”.

The unpredictability nature of the rainfall pattern makes it difficult for farmers to tune their farming activities to the rains, which sometimes results in crop failure. Fishermen, who heavily depend on predictable weather patterns and healthy marine ecosystems, are facing declining fish stocks and altered marine habitats due to changing ocean temperatures and conditions, which further strains their economic viability (Nunoo et al., 2014). These changes not only impact food security but also threaten the financial stability of

households that depend on fishing as their primary source of income. In addition to reducing agriculture productivity and food security, changes in rainfall patterns worsen water security. As climate change affects coastal communities and fishery supply, which are vital to the indigenous industry, it devastates their living conditions and puts these communities on the verge of economic collapse.

Environmental Degradation and Loss of Infrastructure

Adverse weather conditions, like intense storms and flooding, are becoming more common and harsh because of climate change IPCC, (2014), leading to environmental degradation, including deforestation via wildfires, loss of coastal land, and erosion. The sea encroaches on land, destroying homes and infrastructure, while deforestation exacerbates the effects of drastic weather occurrences like storms and floods, sometimes resulting in death. Kpodo, a farmer theorized: "The Anlo Beach you see today as long was not like that some twenty years ago! It was extensive to the extent that the distance from where we are seated to the coast was far away but due to sea level rise, the sea has eaten into (eroded) the land and taken off our buildings. You see, my brother here, the sea has destroyed his house three times, and looking at his age now, where will he get money to build another house?".

Rising sea levels and environmental degradation force communities to relocate, leading to displacement and loss of homes. Coastal erosion and flooding threaten lives and livelihoods, creating a cycle of vulnerability and instability for affected populations. According to the participants, the sea has submerged most of their homes and continues to approach them. Bani, a resident of Anlo Beach, shared his sentiment when he said, "This is the third place I have relocated to. In 1996 and 1997 and September 24, 2007. The first one was in 96-97, I was displaced. On 24th September 2007, I was again displaced, so this is the third place". Climate change claims the lives of coastal residents, especially, fishermen through boat capsizing and drifting.

In the men's focus group interaction at Akwidaa, Joseph, a fisherman, lamented: "I remember some time ago, we went to the sea, and at night when we were coming, a storm blew. In the night, our boat capsized, and the net was in the boat". We didn't know what to do and when it happens like that if you don't know how to swim. It has happened several times and many people have lost their lives due to that". The present study confirms the extant literature that the gradual loss of land diminishes habitable and arable areas, threatening the livelihoods of coastal communities Boateng, (2012), leading to the displacement of populations Appeaning-Addo et al., (2011), jeopardizing millions of dollars invested in coastal infrastructure (UNEP and UNDP, 2013).

Health Impacts and Disease

The escalating heat from climate change has resulted in health issues such as skin burns, headaches, increased susceptibility to diseases like malaria, and challenges in accessing clean water, worsening existing health disparities in affected communities. Variations in precipitation patterns also contribute to the spread of illnesses, further impacting public health. According to coastal residents, the high temperature due to climate change causes headaches and skin diseases like skin burns, chicken pox, and foot swells. In addition, residents explained that in the aftermath of flooding, mainly by heavy rainfall, stagnant waters become breeding grounds for mosquitoes. This was the opinion shared by one of the participants, "For fishing, we drag the nets ashore. We do it in the sand and it is your feet that you use when dragging by standing firm while pulling the net and the sun is also heating you. Sometimes, the sun can burn your feet to develop foot swells".

A similar view was shared by Egyir, a resident in Gomoa Fetteh when he theorized: "The intensity of the sun is too much to the extent that it burns the skin than when we were young". Moreover, higher temperatures pose a significant challenge to water security in coastal communities by lowering the water table, leading to the drying up of wells. It constrains the communities' access to potable water. "Amega, a fisherman at Anlo Beach, reported: "When the temperature is high, many things happen. First, the water level in the well you see here drops. If you go there now, you will see that the water level has decreased. It is the main problem we are facing here". This observation aligns with the existing literature, highlighting the global burden of climatic change on health and well-being.

One pertinent study by Watts et al., (2018) underscores the multifaceted health risks of climate change. The report highlights how rising temperatures exacerbate health disparities by increasing the incidence of heat-related illnesses, and vector-borne diseases, and straining water resources. The report's findings are consistent with the experiences of coastal residents who have noticed increased skin burns and headaches due to prolonged exposure to intense sunlight, as well as a rise in mosquito-borne diseases like malaria after flooding events. As global temperatures increase, the direct impact on human health becomes more pronounced with increased heat exposure and altered disease patterns.

Social and Cultural Disruption

Climate change disrupts social structures and cultural practices integral to coastal communities for generations. Displacement, loss of traditional land, and changes in livelihoods strain social cohesion and threaten cultural identity, leading to community disintegration and loss of heritage. Paraphrasing some of the participants, starting life again in a new place is difficult. It destroys the social networks, family and cultural ties they have built. A story told by Bani at Anlo Beach revealed that the relocation of the community had been difficult. The planned relocation site belonged to another community, leading to conflict and social unrest, further destabilizing the already stressed community. Again, some of the resident's apathy to move was also a cause of the delay in the relocation. He recounted that while some were ready to move, others were unwilling to relocate.

According to him, having stayed in the community passed down by their forefathers as the first settlers, owning their properties, and depending on the sea as their primary source of livelihood, some were reluctant to resettle for fear of losing their livelihoods, properties, social connections, and cultural identity. The study emphasizes that displacement can disrupt the longstanding ties that communities have with their ancestral lands, which are vital to their cultural practices and identities. This finding strongly resonated with (Maldonado et al., 2013). While the Anlo Beach community feared losing their livelihoods and social connections, the Alaskan communities expressed concerns about the loss of traditional knowledge, language, and cultural heritage that are intrinsically tied to their specific geographical locations (Maldonado et al., 2013).

Furthermore, the destruction of cultural heritage sites by extreme weather further exacerbates this loss, erasing physical remnants of history and identity. In Akwidaa, the people agreed that the sea had eroded portions of a sacred grove. The psychological toll of climate anxiety and the loss of place-based cultural ties contribute to a pervasive loss and dislocation. This revelation concurs with Clayton et al., (2014), who investigated the psychological effects of climate change, mainly focusing on eco-anxiety and the sense of loss. Their findings resonate with the experiences in Akwidaa, where the erosion of a sacred grove represents more than just physical loss—it symbolizes a profound cultural and spiritual loss.

Extinction of Aquatic Species

Climate change poses a significant danger to aquatic life, especially in the world's oceans. The escalation of global temperatures results in higher sea temperatures, causing disturbances in marine ecosystems and impacting the survival of many fish species. For instance, herring, a critical species in aquatic food webs, faces the risk of extinction if current trends continue. Joseph, a fisherman in Akwidaa emphasized: “Because if you listen to what we hear about our forests and the sea, if things do not put right, some few years to come, our coming children, won’t see a trace of the fish they call herring”. Warming waters can alter their breeding cycles, reduce the availability of plankton they feed on, and force them to migrate to less hospitable environments. Overfishing compounds these issues, reducing fish populations faster than they can recover.

The loss of biodiversity has profound consequences, not only for aquatic life but also for human communities that depend on fishing for food and livelihood. If we do not act now to address climate change and promote sustainable fishing, future generations might find oceans empty of key species like herring, causing ecological and economic problems. Existing research supports the above finding. For instance, recent studies revealed that by 2070, one-third of all animal and plant species could be at risk of extinction due to the interconnected burdens of climate change, pollution, and deforestation (Rice, 2020; Román-Palacios and Wiens, 2020). Additionally, mammals, fish, birds, reptiles, and other vertebrates are disappearing at an alarming rate, far exceeding natural rates, largely due to these environmental pressures (Rice, 2020). The present study’s outcome implies that the entire ecosystems and the delicate balance of life within them will be disrupted.

Adaptation Strategies Employed

Aside from hard engineering structures such as seawalls, beak waters, etc. that coastal communities are expecting from the government, the study shows that these communities are adapting to climate change shocks with soft adaptation strategies. These include; agricultural and livelihood diversification, relocation, housing adaptation strategies, flood prevention and management, and marine safety practices or measures.

Agriculture and Livelihood Diversification

In response to the impacts of climate change on agriculture, the research revealed that farmers are adopting salt-tolerant crop varieties and using improved irrigation techniques to manage water resources. Sharing the views of some of the participants, this was what Araba, a farmer, noted: "Now we plant crops that can grow even in the seawater and in the dry season when water is scarce, some have reservoirs to store water during the rainy season which they use to water their crops". These practices not only improve crop yields but also enhance food security in these vulnerable regions. In addition, these coastal communities adopt alternative livelihood strategies to adapt to climate change shocks. While most of these residents are primarily fishers and farmers, they engage in other forms of livelihood such as aquaculture. Joe, a resident in Gomoa Fetteh, reported it this way, "Although our main occupation is fishing and farming, some also have fishponds where they rear fishes and sell them".

The study further revealed that sometimes, when the primary occupation is not flourishing, they move into other businesses. According to some of the participants, they possess okada (tricycles), and motors, and others know how to drive. So, when they realize that their farming and fishing occupations are not booming, they switch to these alternatives as a way of diversifying their sources of income. These findings agree with the literature. Agroforestry and integrated farming systems promote resilience, combining crop production with aquaculture and livestock to diversify income sources and reduce risk. For this reason, these coastal communities are shifting from traditional fishing and farming to alternative income-generating activities such as aquaculture. Aquaculture, for example, offers a viable alternative by reducing the pressure on wild fish stocks and providing a stable income source (Klinger and Naylor, 2012).

Relocation

In the flux of societal dynamics and environmental changes, people shifting from old towns to new ones is increasingly prevalent. However, amidst this transition, a curious trend emerged where some individuals, delayed their relocation despite owning residences in the new area. Given the above, Osofo, a fisherman maintained: "Now many people have moved from the old town to the new town over there. Although some are still living here, the majority have houses in the new town where the school is but they have not moved". This hesitancy hints at deeper complexities, perhaps rooted in attachments to the familiar or logistical hurdles. Concurrently, there is a proactive approach to acquiring new land as a safeguard against the looming environmental threats.

Amega, a resident in Anlo Beach, revealed: "The adaptation strategy I have employed now is, I have acquired some land elsewhere that I am praying if God permits and I get money, I will put up some structure there so that if the sea rises again and invades this place, I can move there for safety". This strategic manoeuvre reflects a forward-thinking mindset, acknowledging the volatility of climate patterns and the imperative of securing habitation on stable grounds. However, there are significant socio-economic and cultural implications to consider when planning relocation. It can disrupt established social networks, erode cultural ties, and potentially lead to the loss of traditional livelihoods (Gosling et al., 2017). It also comes with new health hazards, such as congestion, trauma, social unrest, a lack of safe drinking water and the transmission of contagious diseases (Bartlett, 2008).

Housing Adaptation Strategies

The choice of building materials and construction techniques reflects a balance between tradition and modernity, often influenced by climate, cost, and local resources. While modern materials such as blocks and iron sheets offer durability and convenience, there is a resurgence of interest in traditional materials like mud and thatch due to their effectiveness in regulating indoor temperatures and cultural significance. In the focus group, a man said, "We build with mud and thatch to prevent excess heat. The blocks and iron sheet absorb heat and so when the sun is too hot, you cannot sleep at night". The preference for using wood and thatch in coastal areas indicates a practical approach to minimize financial losses caused by potential damage from the sea.

Another man also said: "We build with wood and thatch because we know the sea can take it away and so we will not commit huge amounts of money into buildings that we know the sea will take away". These indicate an adaptive response to environmental challenges. They also serve as a testament to the resilience of age-old wisdom in the face of innovation. This finding agrees with Madhumathi et al., (2014), and Zhang et al., (2023), who found that mud and thatch houses maintained cooler indoor temperatures during hot weather than brick and concrete houses. They attributed the cooler temperature to the insulating properties of mud and thatch, which helped regulate indoor temperatures naturally. The use of wood and thatch is a practical strategy to minimize financial

losses from potential sea damage, as these materials are readily available, easy to replace, and less expensive than modern construction materials.

Flood Prevention and Management

As communities grapple with the perennial threat of floods, ingenuity manifests in various forms of adaptation and mitigation. One such practice involves the elevation of doorposts, a simple, yet effective measure to stave off the ingress of floodwaters into homes. This elevation serves as a literal barrier against the encroaching tide, safeguarding dwellings and belongings from inundation. James, a farmer in Akwidaa said: "It is only at your doorstep that you can do something to save it so that the flood waters do not enter your room. That is why you see most of our houses' doorposts raised like that. We elevate our door posts to a level we know when flooding comes, the water cannot enter our rooms". While large-scale infrastructure projects such as levees and dams play a crucial role, community-based adaptations like elevating doorposts offer complementary strategies that are often more accessible and cost-effective.

Such localized solutions underscore the resourcefulness inherent in communities facing environmental challenges head-on, relying on practical wisdom passed down through generations. Raising the entry points allows households to mitigate the damage caused by floods, preserve their living spaces and reduce the need for extensive repairs or relocation efforts. This finding supports the observation by Adger et al., (2005) that, in many cases, these grassroots initiatives are informed by indigenous knowledge and traditional practices passed down through generations, reflecting a deep understanding of local environmental conditions and the need for sustainable solutions. By minimizing flood damage to homes and belongings, communities can reduce the economic and social impacts of inundation, thereby enhancing their capacity to recover and adapt to future flood events.

Marine Safety Practices/Measures

In coastal areas where livelihoods are dictated by the unpredictable sea, marine safety becomes critically important. Anchors play a vital role in stabilizing boats amid stormy conditions, ensuring they remain resilient against turbulent waters. In response, Joseph, the fisherman in Akwidaa recounted: "We protect ourselves at sea using anchor. When we realize that things are getting out of hand, due to storms, we use it. The anchor is a metal tied with rope, so we leave it in the water; if the wind sends the boat away, it saves us". This age-old practice, rooted in maritime traditions, exemplifies the symbiotic relationship between humans and the maritime environment. Participants stated that securely anchoring vessels allows them to navigate precarious waters confidently, relying on proven methods to endure the storms that impact both their lives and livelihoods. This age-old technique draws attention to the significance of leveraging local knowledge and experience to navigate the unpredictable forces of nature, promoting resilience and sustainability in coastal communities.

Ecological Adaptation Strategies

Traditional rulers in coastal communities in Ghana are taking measures to adapt to climate change through bylaws. Large-scale sand mining has been banned in specific communities to reduce the erosion impacts. Koku, a fisherman in Anlo Beach, maintained: "Here, the chief has abolished sand mining. At first, trucks used to come here for sand but now the chief has stopped them. The community members have also been prohibited from using sand for making blocks, but they are allowed to use it for building their houses". The prohibition of sand mining by traditional rulers represents a strategic ecological adaptation aimed at mitigating environmental degradation and promoting sustainability. Sand mining, often linked to severe ecological consequences such as riverbank erosion, loss of biodiversity, and destruction of habitats, has been curtailed to protect the local environment.

The policy restricts commercial exploitation while allowing the community to use sand for personal construction, balancing ecological conservation with local needs. This localized approach ensures that while economic activities are regulated to prevent excessive environmental harm, the community's immediate construction requirements are met, fostering a sustainable coexistence. Implementing such measures can help to maintain river integrity and reduce sedimentation problems downstream, which are crucial for aquatic ecosystems (Kondolf, 1997). Additionally, this strategy empowers the local communities by involving them directly in conservation efforts, thereby enhancing communal stewardship of natural resources (Cinner et al., 2012).

4. CONCLUSION AND IMPLICATIONS

This study highlights how climate change profoundly impacts coastal communities in Ghana, leading to economic instability, food insecurity, and environmental degradation. Rising temperatures and unpredictable weather patterns diminish fish stocks and agricultural yields, exacerbating vulnerabilities. Extreme weather events and rising sea levels contribute to land loss and infrastructure damage. Health issues, including heat-induced ailments and vector-borne diseases, worsen the situation. Displacement and loss of ancestral lands disrupt social and cultural practices, threatening community cohesion. The extinction of aquatic species further jeopardizes marine biodiversity and local economies by disrupting delicate ecosystems and altering food webs. As species disappear, the balance within marine habitats is thrown off, leading to cascading effects throughout the ecosystem. This can lead to the loss of vital ecosystem services such as fisheries.

Ultimately, the extinction of aquatic species not only threatens biodiversity but also undermines the livelihoods and well-being of communities that depend on healthy marine ecosystems. Despite these challenges, communities demonstrate resilience through innovative adaptation strategies, blending indigenous knowledge with modern practices. Measures such as agricultural diversification, relocation, traditional building techniques, flood prevention, and marine safety practices reflect localized efforts to mitigate climate impacts and enhance sustainability. The current study implies that policymakers must prioritize integrating traditional knowledge with modern climate adaptation strategies to support these vulnerable communities.

Investments in infrastructure, such as seawalls and improved irrigation systems, are crucial, alongside policies that promote sustainable fishing practices and protect marine ecosystems. Public health initiatives must tackle the increased threats of environmental-related diseases and ensure access to clean water. Moreover, cultural preservation efforts must be intensified to maintain social cohesion amidst displacement. Furthermore, the inquiry emphasizes the desire for global action on climate change, as the experiences of Ghana's coastal communities reflect broader trends that, if unaddressed, will have devastating global consequences. Enhanced international cooperation and resource allocation are imperative to mitigate these impacts and support adaptation efforts, ensuring the survival and prosperity of coastal communities worldwide.

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Ethical Approval

This study is part of MPhil research: Ethical clearance with ID (UCCIRB/CANS/2022/14) was obtained from the University of Cape Coast's Institutional Review Board.

Informed Consent

Written and oral informed consent was obtained from all individual participants included in the study. Additionally, consent was obtained from participants before recording the proceedings of the interviews and focus group discussions.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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