Final Draft
of the original manuscript:

Evadzi, P.I.K.; Scheffran, J.; Zorita, E.; Huenicke, B.:

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In: Journal of Coastal Conservation (2017) Springer

DOI: 10.1007/s11852-017-0569-6

AWARENESS OF SEA-LEVEL RESPONSE UNDER CLIMATE CHANGE ON THE COAST OF GHANA

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ACKNOWLEDGMENT

This research received funding support from the Deutscher Akademischer Austauschdienst (DAAD) and the Institute of Coastal Research (Helmholtz-Zentrum Geesthacht). This research appreciates the support of Ghana Town and Country Planning Department, USGS and others for making data available for this research.

ABSTRACT

In response to climate change, coastal communities are expected to experience increasing coastal impacts of sea-level rise (SLR). Strategies formulated and implemented to curb these impacts can thus be more effective if scientific findings on the response to climate change and SLR impacts on coastal communities are taken into consideration and not based merely on the need for coastal protection due to physical coastal erosion. There is also the need to determine the level of awareness of sea- level rise and responses in coastal communities to improve adaptation planning. This study assesses the impact of future coastal erosion estimates by Evadzi et al. 2017 for the AR5 2.6, 4.5 and 8.5 RCPs on the Ghana coastal land cover. This assessment estimates approximately 2.66 km^2, 2.77 km^2, and 3.24 km^2 of coastal settlements, 2.10 km^2, 2.20 km^2 and 2.58 km^2 of lagoon, 1.39 km^2, 1.46 km^2 and 1.71 km^2 of Wetland to be at risk of inundation by the year 2050 based on coastal erosion estimates for the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC) 2.6, 4.5 and 8.5 Representative Concentration Pathways (RCPs)Evadzi et al. 2017 coastal erosion estimates. This study also assesses the level of awareness of respondents to SLR on the coast of Ghana and explores the availability and level of integration of scientific knowledge of SLR into coastal adaptation strategies in Ghana. Assessment of the awareness of SLR responses to the changing climate in Ghana is made through semi-structured interviews at national, municipal/district and coastal community scales. Although settlements may be inundated based on the coastal erosion estimates, coastal dwellers interviewed cherish their proximity to the sea and are determined to maintain their occupancy close to the sea as spatial location influences their source of livelihood (fishing). Respondents lack knowledge/understanding of SLR, as the majority of household interviewees attributed rise or fall in sea level to God. Respondents from Ngiresia alleged the ongoing coastal sea defence as a project in their community that has led to increased malaria cases.

KEYWORDS: Climate Change, Climate Change Adaptation, Coastal Impacts, Geographic Information Systems, Sea-level Rise

INTRODUCTION

Since the 1980s, anthropogenic climate change has raised growing concerns about sea-level rise (SLR) and its risk to many low-lying coastal areas (Nicholls et al. 2007; McGranahan et al. 2007; IPCC 2013). With the increasing awareness of SLR impacts, various mitigation measures are being taken to curtail the future threat of increasing temperatures by human intervention to reduce the sources and enhance the sinks of greenhouse gases. In addition, climate change adaptation measures that modify natural or human systems to moderate harm or exploit beneficial opportunities are encouraged (Klein et al. 2005; Hamin and Gurran 2009; Laukkonen et al. 2009).

Although adaptation to climate variability in some areas acts as a catalyst for social and technological innovation, harsh physical impacts, for example, increased rates of coastal erosion due to SLR, have prompted reforms in the economics and politics of climate change at global, regional and national scales (UNFCC 2006; Carter et al. 2015). It is observed however that investments in coastline protection through building hard structures in developing countries have remained ineffective (Klein et al. 2005).

Coastal erosion is one of the serious environmental problems facing West African countries situated along the Gulf of Guinea (Hinrichsen 1990). The coastal research report by Tilman et al. 1989 on the Bight of Benin (the bay of the coast of West Africa) extending eastward for about 400 miles (640 km), from Cape St. Paul (Ghana) to the Nun outlet of the Niger River (Nigeria), highlighted the need for coastal management along the region due to coastal erosion. The coast of Ghana continues to suffer from coastal erosion and flooding which in many cases has led to a loss of infrastructures thus posing an additional cost to its conventional development agenda (Evadzi et al. 2017; Jayson-Quashigah et al. 2013; Appeaning Addo 2011; Amlalo 2006; MoWH 2011).

In the 1990s several coastal zone policies and management strategies were developed in Ghana, such as the National Environmental Action Plan (1994), the Draft Integrated Coastal Zone Plan (1998), and the Coastal Zone Management Indicative Plan (1990). Although these reports, including the National Climate Change Vulnerability and Adaptation of Coastal Zone of Ghana (EPA 2000), identified SLR as having significant impacts on the coast of Ghana for which some projections were made, these sea-level projections for Ghana were based on global IPCC projections and not informed by scientific knowledge on sea-level change at the local Ghanaian scale.

Although the national Climate Change Vulnerability and Adaptation of Coastal Zone of Ghana report (EPA 2000) identified SLR in Ghana to impact shoreline recession, flooding and inundation of low-lying coastlands in Ghana, there is lack of information on the response to sea-level change and its integration into adaptation planning.

On the coast of Ghana, human activities of some coastal dwellers, mainly aiming for economic gains such as sand mining for construction purposes, mining of alluvial gold, and encroachment on lagoons, have made the coast more susceptible to erosion (Anim et al. 2013; Mensah 1997). In view of the physical evidence of coastal erosion and flooding, the government of Ghana adopted a reactive measure to reduce the erosion impacts through building sea defence structures on Ghana's coast.

The Keta Sea Defence Project (KSDP) is the first of such reactive projects which started in the year 2000. Geophysical surveys, geomorphic investigations and numerical modeling were the main assessments carried out to determine the causes of the coastal erosion in the Keta region before the construction of the KSDP. Similar investigations were carried out at Ada, a coastal town located near the Volta River estuary (Bollen et al. 2011) and other sea defence projects within Western, Central and Greater Accra administrative regions of Ghana. These assessments did not include scientific knowledge nor perceptions of local communities of sea-level responses to climate change on the coast of Ghana.

Coastal areas in the world are identified to have a wide variety of ecosystems, providing several services that influence human welfare, directly through human exploitation or indirectly through regulation of services in other environments (Alves et al. 2009; Martinez et al. 2007). According to Bolund and Hunhammar 1999, forests, cultivated land and wetlands generate a range of local ecosystem services such as air filtration, microclimate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational and cultural values that improve quality of life even if people are still dependent on global ecosystem services for their survival. These services may be lost or negatively affected by coastal erosion which is an obvious outcome of SLR (Dwarakish et al. 2009) although human activities may also have an important impact on coastal erosion (Ly 1980).

Estimates of natural and socio-economic values of these various land-cover types of coastal areas threatened by coastal erosion (Nicholls and Tol 2006; Alves et al. 2009) can help policymakers to anticipate coastal impacts and prioritize management efforts to minimize risks (Hinkel et al. 2009). Estimates and forecast of socio-economic values of land-cover types, however, are not very realistic as it may change with human decisions on climate protection, demographic and human development, thus vulnerability assessment approaches that identify the sensitivity of various coastal habitats may be useful for bridging the gap between impact analysis and adaptation strategies (Costa et al. 2009).

Martinez et al. 2007, claimed the Economic Service value (ES) for savannas (Savannas and Woody Savannas) globally is 499 US dollars per ha per year, whereas the ES for permanent wetlands is 14,785 US dollars per ha per year. For Ghana, the report estimated total natural Ecosystem Service Product (ESP) of coastal ecosystems in Ghana at 10,015.50 million US dollars whereas modified ecosystems (semi-altered and altered), are valued at 231.60 and 0.03 US dollars respectively.

According to Boateng et al. (2016), the sensitivity or susceptibility of coastal areas to sea erosion and the lack of capacity to cope and adapt to phenomenon determines how vulnerable the coast is. Boateng et al. 2016 utilized a Coastal Vulnerability Index (CVI) based approach to assess the vulnerability of the coastline of Ghana to erosion and ranked sections of coastline in terms of their potential for change and ranked the eastern and western portions of the Ghana coastline to be very highly vulnerable to SLR.

Olympio and Amos-Abanyie (2014) also identified locations of some recreational services and tourist attractions in Accra that could be impacted by SLR in the future, however, there is no assessment of local SLR impacts on land cover for the entire coast of Ghana.

Although concerns exist about integrating uncertainties of scientific sea-level research in adaptation planning (Brown 2016), first estimates of coastal erosion exist. A study by Appeaning Addo et al. 2008 revealed that in 250 years some low-lying elevations and wetlands will be inundated on the coast of Accra. Evadzi et al. 2017 revealed that the entire coast of Ghana has experienced different rates of coastal erosion. According to Evadzi et al. 2017, on average, sea-level in Ghana has risen by about 5.3 cm over the last 21 years and SLR accounted for ~31 % of the observed annual coastal erosion rate (about 2 m/yr) in Ghana. The study identified various sources of uncertainty associated with the shoreline data used, computed annualized uncertainty as the square root of the sum of squares for each of the shoreline data and utilized Weighted Linear Regression (WLR) method to generate the shoreline change rates. Statistical and spatial analysis based on the IPCC AR5 projected the rise in the model-ensemble-mean of the sea-level scenarios (2.6, 4.5 and 8.5 RCPs) for Ghana. These results show that by the year 2025, about 6.6 m, 4.7 m, and 5.8 m of coastland in Ghana with lowest slope range (0 - 0.4 %) is projected to be inundated, increasing projected changes to 19.8 m, 20.7 m and 24.3 m by 2050 and further to 36.6 m, 51.6 m and 83.9 m by 2100 for the 2.6, 4.5 and 8.5 RCPs respectively (Evadzi et al. 2017).

These estimates may not be valid for periods further into the future, when the contribution to SLR in Ghana may become either smaller due to reduced input from glaciers or larger due to accelerated melting of the polar ice sheets (Evadzi et al. 2017). Albeit these limitations, Evadzi et al. 2017 stated that the estimates are reasonable for next few decades.

Expanding previous work, there is the need to assess the impact of local SLR on different land cover types on the coast which may provide useful information for coastal adaptation strategies. Besides this need, there is often a relationship between the lack of understanding of the sediment redistribution process that shapes the coast and human-induced shoreline change (Anthony et al. 2016). Besides developing adaptation strategies to harness opportunities and reduce vulnerabilities to coastal erosion in Ghana, there is the need for continued assessment of coastal communities to understand the causes of coastal erosion, inform planning and improve community support to adopt the adaptation strategies. Previous studies show that societal support setbacks remain considerable if adaptation practices aimed at sustainable development do not cater for community livelihood systems (Ziervogel et al. 2010; Adger et al. 2009; Adger et al. 2003).

Although the Keta Sea defence has achieved some success with regard to reducing the perennial flooding of the deltaic region (Jayson-Quashigah et al. 2013), in the view of this study, the response to coastal erosion in Ghana is not integrative enough as coastal erosion has become severe in less affected neighboring communities. An example of this 'problem shifting' was reported by Bokpe (2016) on how the coastal erosion is steadily destroying 5 Keta communities. To minimize the likelihood of this 'problem shifting' scenario to other hitherto low-risk areas, climate change adaptation policies must include geographical and social dimensions components, since actions and policies formatted from such transdisciplinary study will involve multiple knowledge including traditional knowledge which may be useful for adaptation planning (Adger et al. 2013; Campos et al. 2016; Folke et al. 2005).

The levels of community awareness of climate change vary spatially across the world with most research outputs concentrated on Europe, Australia and the United States of America (Brulle et al. 2012; Lee et al. 2015; Lorenzoni and Pidgeon 2006). A global climate awareness study by Lee et al. 2015 revealed that less than 30% of Ghanaians and other West African countries are aware of climate change compared to most countries in Europe with more than 75% of awareness level. Aside from these differences in climate change awareness, Slovic 2001 also noted that there exist the possibilities of perception differences among professional groups as well as between professional groups and public groups regarding environmental issues. Despite the importance of awareness of sea-level response to adaptation strategies, there is no current study of such for the coast of Ghana.

In an attempt to provide some useful information that may be useful to coastal adaptation strategies in Ghana, this study assesses the impact of coastal erosion estimates on various land cover types and conducts semi-structured interviews at three scales (national, municipal and district level) to solicit responses on climate change awareness and adaptation strategies. This three-scaled semi-structured interview approach was used not only to increase the validity of the data but also to allow an exploration of the contradictions in responses garnered from respondents. An example of such a three-scaled semi-structured interview approach was utilized by Evadzi 2009 to assess the knowledge, attitude and practice regarding schistosomiasis in the Dangme East district of Ghana. In the following, we specify the methodology and present the results.

METHODS

The methods section comprises two parts: the first part describes the study area while the second presents the data and processing methods used for the data analysis.

Study Area

The coast of Ghana (Figure 1) and the entire West African coast has been formed by and continues to be influenced by several factors, including processes of the Atlantic Ocean, the geological composition of the coast, the geophysical characteristics of the river basins, the prevailing meteorological conditions and its slow tectonic processes (Allersma and Tilmans 1993). The western portion of the coast of Ghana from the Ankobra River to Ghana's Ivory Coast (Ghana's western neighboring country) and its eastern portion extending from Aflao (a border town to Togo) to Laloi lagoon west of Prampram, have sandy beaches with similar geomorphic characteristics. The central portion of the coast is however made up of rocky beaches (Ly 1980). Ghana's coast is generally low-lying, with a narrow continental shelf reaching outward to between 20 and 35 km except off Takoradi where it reaches up to 90km (EPA 2000). The coast is drained by many rivers including Tano, Ankobra, Butre, Pra, Kakum, Densu and Volta Rivers, and has over 90 coastal lagoons that shape the geomorphic composition of the beach (Armah and Amlalo 1998). The Volta Delta, for example, protrudes the coast, discharging on its western flank, which results in the formation of a very narrow sand barrier which separates the Keta Lagoon from the sea

(Allersma and Tilmans 1993).

About 70 % of the total population of Ghana lives in the southern half of the country (Ghana Statistical Service, 2013). The coastal zone represents about 7 % of Ghana's land mass yet is inhabited by 25 % of its people as well as occupied by ~75 % of the nation’s industries. The main occupation of inhabitants along the coast of Ghana is fishing, farming, transportation of goods and services, sand and stone mining for building and road construction, oil extraction and for tourism activities (EPA 2000).

The coastal zone of Ghana is rich in coastal habitats and biodiversity including, estuarine wetlands, lagoons, lagoonal depressions and their associated marshes, sandy shores, rocky beaches, rocky pools, savanna (grassland) to semi-deciduous and wet evergreen secondary tropical forests with rich biodiversity (EPA 2000). Coastal erosion is one of the serious environmental problems facing the West African coast including Ghana (Hinrichsen 1990). Not only does the response of SLR under climate change contribute to coastal erosion in Ghana (Evadzi et al. 2017) but the increased physical infrastructure development on the coast relies heavily on coastal sand and pebbles, which have accelerated coastal environmental degradation in Ghana (Mensah 1997; Jonah et al. 2016). Appeaning Addo (2015) projected some communities in Dansoman to be inundated by 2065 due to SLR.

Figure 1: Study area showing the entire coastline of Ghana and sample sites for the primary data collection

Data, methods and description of scope

This study consists of two components. First, this paper overlays the coastal erosion estimates generated by Evadzi et al. (2017) on land cover data on the coast of Ghana and quantifies the surface area of different land cover types at risk of future SLR by the years 2050 and 2100. Although changes in the various land cover types is expected for the coast of Ghana, no trend analysis of the various land cover types to estimate future changes is made due to lack of data. Thus, the coastal inundation estimates at risk of future SLR for the various land cover estimates may not be valid for the future, if the changes within each land cover types become smaller or larger. A similar approach used by Appeaning Addo et al. 2008 to assess coastal inundation in Accra, reported that some coastal areas including wetlands in Accra will be inundated in about 250 years into the future and this may affect the habitats of about 35,000 migratory birds. The only available national land cover data was the 2010 coastal land cover data obtained as shapefiles from the Ghana Town and Country Planning Department. The different land cover types (12 classes) are; grass/herb with/without scattered trees (0-5 trees/ha), grassland with/without scattered tree/shrub, lagoon, moderately closed tree (>15 trees/ha) canopy with herb and bush cover, moderately dense herb/bush with scattered trees (<15 trees/ha), mosaic of thickets and grass with/without scattered trees, planted cover, river, settlement, shrub thicket with or without trees, unclassified area due to cloud cover and wetland.

The second and main focus of this paper uses data from both primary (semi-structured interviews) and secondary sources (policy documents on coastal management in Ghana) to assess the level of SLR awareness in Ghana and find out whether scientific knowledge of the response of SLR under climate change on the coast of Ghana was available and integrated into coastal adaptation strategies in Ghana. This study solicits views from three scales/levels (national, municipal/district assemblies and coastal communities) for cognitive assessment of views related to coastal erosion and SLR responses under climate change on the coast of Ghana. At the national level (first scale), this study solicits views through semi-structured interviews with key informants at the Environmental Protection Agency (EPA), the Ministry of Environment Science and Technology (MEST), and the Hydrological Department of the Water Resources Commission whose mandate includes management of conditions along the entire coast of Ghana. For the municipal/district level (second scale), informants were interviewed from selected Municipal and District Assemblies (MDAs), namely, Keta Municipal Assembly (KMA), Sekondi Takoradi Municipal Assembly

(STMA), Ada East District Assembly and Ellembelle District Assembly. At the community level (third scale), respondents from eight communities (Ngyiresia, Esiama, New Takoradi, Anlogo and Blekusu from the western part of the coast of Ghana and Akplortorkor, Xorvi, Blekusu and Dzita from the eastern part of the coast of Ghana) were interviewed.

These communities were selected because they depend largely on the coastal resources for their sustenance and are within zones of a potential threat to SLR (Evadzi et al. 2017; Appeaning Addo 2015; Ly 1980). This study did not carry out a complete listing of community households for sampling because of cost and types of settlements but rather devised a pattern to select interviewees from these coastal communities to make room for randomness and unbiased response. The study thus selected 5 major spatial areas (~30 meters apart) in each of the 8 communities for household sampling. In each spatial area, the interviewer selects the first household and identify 4 other households within 10 m radius around this core household. The distance between and around the 5 main spatial areas in each community was chosen because of the spatial extent of these communities and the type of settlements which are predominantly nucleated settlements with compound houses. The measurement was aided by a handheld Global Positioning System (GPS) device. Each household offered a person willing to be interviewed. The outcomes of the analyses were views expressed in simple cross-tabulations and graphs with some views inserted as recorded speeches.

Informants and respondents from all categories address similar questions. This approach is adopted to identify contradictions in responses at these scales, especially from the first and second scales which are directly involved in coastal management in Ghana. The interviewer asked both open and close-ended questions for which respondents gave responses. Some of the sea-level awareness, coastal impact and adaptation questions for which responses were garnered from respondents from the communities are condensed in the box below. Informants at the national and municipal/district assembly also gave responses to questions on adaptation strategies (see box).

------------------------------------Box start---

Selected open-end questions for interviews

Sea-level awareness, coastal impact and adaptation questions

- Do you know about SLR (briefly explain if 'yes')?
- Is climate change mainly caused by human activity, on a scale of 1 to 7, where 7 means you are absolutely certain, and 1 means Not at all?
- Do you know whether for the past 5 to 10 years the volume of seawater close to this community has risen or fallen? How did you know?
- Is the coast nearby receding (briefly explain if 'yes')?
- Have you lost any item or property situated close to the coast due to SLR and coastal flooding (briefly explain if 'yes')?
- When and what really transpired including items lost?
- Did the event lead to your evacuation and resettlement (when and from where if 'yes')?
- Do you know any household close-by that also suffered from this disaster?
- Is the issue a reoccurring phenomenon (if yes, explain the nature of the event)?
- Do you know of any state/public (communal) infrastructure affected by the incident?
- Briefly, explain how you respond to the disaster associated with the rising sea-level and coastal flooding?
- Did National Disaster Management Organization (NADMO) or any organization assist you or the community due to the disaster?
- Is the government putting some mitigation measures in place to offset future impacts to sea-level in your community?
- Are you satisfied with the government's mitigation option?
- Are there some communities outside the mitigation region that are suffering from increasing coastal flooding because of the mitigation measure(s) adopted by this community?
- Is this community suffering from SLR and increasing coastal flooding because of mitigation measure(s) adopted by other communities?

Questions on adaptation strategies

- What do you think is the best mitigation option for the community?
- What is the District Assembly or government doing to adapt to and mitigate the future occurrence of such disaster?
- Are you satisfied with the government's adaptation option (briefly explain)?
- Is the adaptation option adopted (if any) based on scientific and expert knowledge on sea-level change and coastal impact assessment in the affected areas?
- Is there a national adaptation plan for SLR based on scientific and expert knowledge for coastal communities in Ghana? (Any document to support?)
- Are there some communities benefiting from the DA's or government's adaptation/ mitigation (please underline) plan?
- Are there some communities outside the mitigation region that are suffering from increasing coastal flooding as a result of the mitigation measure(s) adopted by this community?
- Is/are this/these community(ies) suffering from SLR and increasing coastal flooding as a result of mitigation measure(s) adopted by other communities?
- In your assessment (no reference to ranking) what are the barriers to the development of adaptation plan for sea-level change (local/national).

------------------------------------Box end---

While the open-ended questions allow the respondent to express his/her view on a particular question in detail (e.g. what causes climate change?), the close-ended questions demand 'yes' or 'no' responses (e.g. Do you know about climate change?). The interviews are conducted in four languages (English, Ewe, Ga and Twi) depending on spatial location and dialect of interviewees; the responses were recorded and summarized in English, analyzed and expressed in simple cross-tabulations, graphs and verbatim text by the interviewer. The responses given by respondents were not suggested by the interviewer.

To make room for randomness and unbiased responses from interviewees in the coastal communities, respondents are selected from 20 households that spread across the community and not from only one spatial unit. The research uses simple cross-tabulations for most of the analysis because the research attempts to summarize the relationship between two categorical variables.

The respondents interviewed at the community scale are largely dependent on the coastal resources for their livelihood. Fishing is their most important livelihood source, about 34 % of the respondents depend solely on fishing, 8.5 % combined fishing with farming as their sources of livelihood and 24 % of the respondents are fishmongers (Table 1). Although there are other non-fishing income-earning activities in the study area, they are mostly linked to the fishing sector. An example is carpenters specialized in building fishing boats. For these fishing dependent households, their proximity to the sea is to reduce their operational cost.

Table 1: Classification of households by main livelihood activities (%), N = 200

RESULTS

Findings from this study are presented in this section. The results cover four main topics namely, SLR and coastal inundation, climate change and SLR awareness, SLR adaptation strategies, and barriers to integrated coastal adaptation planning.

SLR and Coastal Inundation

Simple overlay of future sea-level induced coastal erosion estimates by Evadzi et al. 2017 on 2010 coastal land cover of Ghana reveals that the following approximate land areas will be at risk of inundation by the year 2050 for the 2.6, 4.5 and 8.5 RCPs respectively: 2.66 km^2, 2.77 km^2 and 3.24 km^2 of coastal settlements; 2.10 km^2, 2.20 km^2 and 2.58 km^2 of lagoons; 1.39 km^2, 1.46 km^2 and 1.71 km^2 of wetlands. These projected land cover losses would further increase by 2100 to approximately 4.83 km^2, 6.72 km^2 and 10.70 km^2 of coastal settlements; 3.87 km^2, 5.45 km^2 and 8.84 km^2 of lagoons; 2.74 km^2, 3.57 km^2 and 5.71 km^2 of wetlands (Table 2). Based on ES estimates by Martinez et al. 2007, coastal erosion estimates for Ghana by Evadzi et al. 2017 may result in inundation of wetlands of ES value of about 4,051,090 US dollars, 5,278,245 US dollars and 8,442,235 US dollars by the year 2100 based on the 2.6, 4.5 and 8.5 IPCC AR5 RCPs scenarios.

Similar analysis focused on specific urban communities located in the western, central and eastern parts that involved overlay of the future sea-level induced coastal erosion estimates on a 2015 Landsat image of the coast of Ghana reveals that coastal urban areas of Half Assini and Old Elubo communities with slope range (0 - 0.4 %) along the western coast of Ghana are projected to have urban land loss of ~5,000 m^2, ~7,000 m^2 and ~12,000 m^2 by 2050 for the 2.6, 4.5 and 8.5 RCPs respectively. These projected urban land losses would further increase by 2100 to 42,000 m^2, 70,000 m^2, 138,000 m^2 for the 2.6, 4.5 and 8.5 RCPs respectively (Figure 4.3). By 2100, ~24,000 m^2, ~34,000 m^2 and ~55,000 m^2 urban land loss may be expected for the Dansoman coastal area in Accra between the Densu River delta and Chorkor based on the 2.6, 4.5 and 8.5 RCP scenarios respectively. Many communities along the coast of the Keta Municipal Assembly are projected to be inundated, including a constructed sea defence infrastructure around Adzidze, by 2100 based on the 8.5 RCP SLR scenario. Some of the communities to be potentially affected include Cape Saint Paul, Ahaworyikope, Asiata, Aeleglokope, Klamatsi and Wogona.

Table 2: Different land cover types at risk of coastal erosion based on 2050 and 2100 coastal erosion estimates by Evadzi et al. 2017

Figure 2: Urban land area loss estimates for 2.6, 4.5, and 8.5 RCPs by 2100 at Half Assini in Ghana

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Climate Change and SLR Awareness

Figure 3 represents the summary of the responses on climate change awareness of household respondents on the coast of Ghana. Although about 81 % of all respondents said they were aware of climate change, about 38 % of those claimed that this a change in the weather caused by God (natural changes and not as punishment) whilst 12 % said it is a long-term change in the weather system (Figure 3). This study did not solicit information on interviewees religious backgrounds and reasons of attributing the change in weather to God.

Figure 3: Respondents' awareness and perception of climate change. (A) Refers to respondents who initially said 'Yes' they do have an idea about climate change. (B) Refers to respondents who initially said they have 'No' idea about climate change.

Only 10.5 % of the total respondents were certain that human activities are the main cause of climate change (Figure 4). This further buttressed earlier results on climate change awareness where 81% of the respondent attributed climate change to weather changes caused by God (Figure 3).

Figure 4: Degree of respondents' certainty about human activities as the main cause of climate change

Most of the respondents (151 out of 168) who claim to have knowledge about SLR, said they noticed a rise in the sea-level since about 5 to 10 years ago, attributing their assessment to the coastal recession (Table 3). However, 7 respondents from Ngyiresia (2 out of the 6 who claim sea-level has 'fallen', together with 5 out of 11 respondents who claim to have 'no idea' about the change in the sea-level), said some land was reclaimed from the sea during construction activities at the Takoradi Harbour, and as a result they are unsure whether sea-level has risen or fallen.

Table 3: Respondents' awareness of change in sea-level close to their community for the past 5 to 10 years

All interviewees from the national as well as from municipal and district assemblies are aware of SLR. Their sources of information were physical evidence, research reports, conference proceedings, mass media and national documents (National Climate Change Policy, and Medium-Term Development Plans).

According to 140 out of the 200 respondents interviewed on the coast of Ghana who claim to have lost items to coastal erosion, 115 also claim that the incident resulted in evacuation or resettlement (Table 4). The items listed to be affected are fishing nets, boats as well is buildings and household items.

Table 4: sea-level rise and coastal impact, (A) Have you lost any item or property situated close to the coast due to sea-level rise and coastal flooding? (B) Did the incident in 'A' lead to your evacuation and/or resettlement?

A respondent of Blekusu (Figure 5) who could not hold back her tears during the interview claimed she lost her building due to SLR: *"Since I was a child till now, I have seen submerged buildings and even one human death caused by the sea, but to think that my family house which was far from the sea today is also suffering makes me sad. But can I fight the sea? My children have left to Keta but I am old, I have nowhere to go"*. Figure 5 also shows the destruction of some buildings at Blekusu as a result of SLR and coastal flooding.

Figure 5: A resident of Blekusu responding to questions about the impact of SLR

93.5% of all the respondents interviewed said the coastal erosion process has resulted in a continuous reduction of their land over the years. However, 19 respondents out of 25 respondents from Akplortotor said the coastal retreat has stopped after the construction of the sea defence in their community. 24 out of 25 respondents from Dzita, however, expressed concern about the increasing rate of coastal erosion in their community after the sea defence project at Akplorwotorkor. A recent report by Seth J. Bokpe, published online on the 20th February 2016 by Graphic online, a Ghanaian local news agency, presented narratives how coastal erosion was steadily wiping out 5 communities within the Keta municipality including Dzita.

All Municipal Assemblies (MAs) and District Assemblies (DAs) respondents said they have witnessed or experienced some coastal erosion/flooding events in their communities, however, all respondents from national institutions interviewed, become aware of the incident through the mass media, mainly through radio and television. One of the respondents at the district level said: *"You can even see for yourself what is happening to this District Assembly building due to its location close to the sea. That road (pointing at the road) was reconstructed twice away from the sea because the sea consumed the previous ones. Just yesterday, Azizanya communities came here demanding for 'their sand (land)' saying their community is on extinction due to the sea defence project at Ada".*

One respondent at the national scale who was involved in the coastal project construction and monitoring in Ghana, commenting on the Azizanya coastal erosion problem said, *"I am aware they are suffering, but some communities are not supposed to be where they are".*

SLR and Adaptation Strategies

Construction of the coastal defence wall (Figure 6A) is the main adaptation strategy adopted by the Ghana government, however not all communities visited currently benefit from this facility. Coastal communities have resolved to temporary relocation when there is coastal flooding or inundation by the sea. In either situation, they salvage items that could be transported and relocate temporarily to higher grounds. The victims return to their structures if the flooding events do not result in permanent inundation (Figure 6B). These communities are linked by their profession (mainly fishing; Figure 6C), and in such events, the other community members assist the victims to salvage some items. Figure 6 thus shows the socio-economic importance of proximity to the sea to the interviewees.

The household interviewees expressed dissatisfaction at the National Disaster Management Organization (NADMO) in particular, for failing to provide needed relief assistance to the victims of the communities involved in this seemingly indefinite climatic phenomenon (Table 5).

Table 5: Relief assistance during coastal disaster events, (A) Did NADMO or any other organization assist you or the community due to the disaster? (B) Source of support if received some form of support ('yes')

Interviewed respondents from national institutions lacked details with regard to whether NADMO or any governmental organization offered any support to individuals and communities affected by the recent destruction related to SLR along the coast of Ghana, but said NADMO always provides relief to victims. Interviewees from MAs and DAs admitted that some assistance was received by victims from NADMO in recent cases. A key informant in the Ellembelle District Assembly, however, said*: "Although NADMO is expected to assist with items such as clothing, beddings, iron sheets, etc. they were unable to assist the Esiama when people lost their buildings and properties along the coast because they had no items to give"*.

Temporary relocation is the main strategy adopted by members of the communities during coastal flooding. Some used less expensive materials for the construction of their houses close to the sea to minimize loss during such events.

All respondents from Ngyiresia said the community initially opposed the construction of the sea defence project in their community because the design of the infrastructure will affect their livelihood and would result in losing the landing sites for their boats. Although a modified design (Figure 6A) was implemented, 17 respondents representing 68% of the respondents from Ngyiresia said they are not satisfied with the defence project because it does not allow drains to flow easily from mainland into the sea thus creating favorable moisture conditions that mosquitoes need to hatch their eggs, which they alleged to have resulted in increased malaria cases in the community.

Figure 6: Selected photos of the coast of Ghana showing sea defence structure at New Takoradi (A); Coastal settlers relocate close to the sea at Ngyiresia after a flooding event (B); Community members pulling in a fishing net at Blekusu (C).

Apart from the respondents from the Keta Municipal Assembly, other MAs and DAs expressed different levels of dissatisfaction with the reactive measure adopted by the government. One of the respondents whose unit is benefiting from the project said: "*I think there is lack of understanding of the cause of the problem because surrounding communities are suffering. Even some groins were reconstructed due to erosion. The engineers also said there has been accretion but I saw them filling the site with transported sand from other places and they also dredged the sea*".

A key respondent at the national level expressed satisfaction with the ongoing coastal defence projects in Ghana and made reference to some areas, including the Keta lagoon and the area behind the Adisadel College to be successful. However, in responding to questions on whether the ongoing coastal protection projects in Ghana are based on scientific and expert knowledge on SLR and coastal impact assessment in the affected areas, this key respondent said *"We did a lot of coastal engineering simulations including wave simulations but no thorough investigation on SLR. There are just some projections for SLR by EPA but I don't know what informed it"*.

An interviewee at the EPA whilst responding to a similar question said: *"I know about SLR through education, conferences, etc, however, our reports are based on IPCC projections. I doubt* *that the ongoing coastal protection along the coast of Ghana included a thorough scientific assessment of sea-level change along the coast of Ghana."* Interviewees at the district level all said they have no scientific knowledge of SLR along the coast of Ghana.

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Barriers to integrated coastal adaptation planning

Ghana has no integrative coastal adaptation plan, and respondents at the national and municipal/district levels acknowledge the need for such a policy with scientific knowledge on the response to SLR under climate change on the coast of Ghana. With no importance to ranking of barriers, respondents responded to the question, 'In your assessment what are the barriers to the development of sea-level change adaptation plan for Ghana?', and listed barriers to sea-level change adaptation plan in Ghana under the headings of governance, policy, psychosocial, resources and uncertainty. Lack of political will and clarity of roles and responsibilities across levels of government, Public disbelief in the science of climate change, Lack of scientific and expert knowledge on SLR, and uncertainty about climate impacts, were among the identified barriers to sea-level change adaptation plan for Ghana (Table 6).

Table 6: Barriers to integrated national adaptation plan for Ghana

DISCUSSION

Coastal areas in the world have a wide variety of ecosystem services that may be lost as a result of SLR (Martinez et al. 2007; Alves et al. 2009; Dwarakish et al. 2009) although human activities are also identified to contribute to coastal erosion (Ly 1980).

Analysis of sea-level, DEM and historical shoreline data by Evadzi et al 2017 reveals that SLR has ~ 31 % shoreline recession in Ghana for the lowest slope range (0 - 0.4 %) and suggested that based on the projected rise in the sea-level, by the year 2050 about 19.8 m, 20.7 m and 24.3 m and further to 36.6 m, 51.6 m and 83.9 m by 2100 more of coastal land in Ghana may be inundated based on the 2.6, 4.5 and 8.5 IPCC AR5 RCPs scenarios. The research reveals that by 2100 several square kilometres of coastal surface area may be lost for different types of land cover (coastal settlements, lagoons, wetlands).

Appeaning Addo and Adeyemi 2013 reported that accelerated SLR will destroy homes of inhabitants, inundate Densu wetland in Ghana and destroy the habitats of migratory birds and some endangered wildlife species such as marine turtle. Analysis focused on some specific communities undergoing different rates of shoreline change in Ghana that involves simple overlay of coastal erosion estimates for Ghana by Evadzi et al. 2017 (referring to chapter 3) on 2015 Landsat data reveals that by 2100, tens of thousands of m^2 urban land loss may be expected for the Dansoman coastal area between the Densu River delta and Chorkor.

Although this result on the exposure of the Dansoman coastal area to SLR confirms findings by Appeaning Addo et al. 2011, the research estimates the most likely recession by 2100 based on the AR5 8.5 RCP to be 86 m from the coast of Dansoman while in Appeaning Addo et al. 2011 the most likely recession based on IPCC Special Report on Emissions Scenarios - fossil intensive (SRES A1F1) was estimated at 202.06 m. The difference could be explained by the SLR scenarios used by both studies. As the research is based on the expected land cover loss analysis of climate simulations included in the CMIP5 driven by the IPCC RCPs and augmented by melting of land-ice estimations for the coast of Ghana, that of Appeaning Addo et al. 2011 was based on Commonwealth Scientific and Industrial Research Organization General Circulation Models (CSIRO_MK2) global SLR scenarios.

Based on the global ES estimate for permanent wetlands (14,785 US dollars per ha per year) by Martinez et al 2007, permanent wetlands in Ghana of ES value of about 4,051,090 US dollars, 5,278,245 US dollars and 8,442,235 US dollars may be lost by the year 2100 based on the 2.6, 4.5 and 8.5 IPCC AR5 RCPs scenarios.

Dansoman is not among the sampled communities in the research, however, the results from the research report 87.5% of respondents claiming to have evacuated or resettled due to past coastal flooding events whereas Appeaning et al. 2011 reported 70% of respondents from Dansoman to have evacuated due to coastal flooding events. These two exclusive studies all claim coastal dwellers are aware of the sea-level change and its impact on their community with higher awareness levels compared to the climate awareness level (less than 30%) reported by Lee et al. 2015 for Ghana. However, 81 % of the community respondents from the research attributed the cause of climate change to God. This result is partly confirmed by the identification of public disbelief in the science of climate change by the national and municipal/district assembly respondents as one of the barriers to the development of the adaptation plan.

Although there is recognition and inclusion of climate change adaptation practices in some development processes detailed in the National Climate Change Policy (2014) and the draft of the Policy Action Program for Implementation (2015-2020) as well as from other national reports, the research through semi-structured interviews reveals that there is no comprehensive coastal adaptation plan for Ghana that includes information on the response of SLR under changing climate. MDAs are aware of the ongoing reactive coastal adaptation program but had no knowledge whether the adaptation strategies adopted are based on scientific knowledge of SLR. This claim by MDAs of lack of information adaptation strategies is confirmed by Adu-Boateng 2015 and Mensah et al. 2016, who claim that there is not only limited stakeholder engagement in climate adaptation issues that could increase adaptation costs but also most existing climate change adaptation policies in Ghana are a mosaic of policies, actors, and strategic action priorities, which lack coordination.

CONCLUSION

There is lack of information on the extent to which different land cover types including wetlands, lagoons and settlements may be lost to coastal erosion in the future as well as information on the awareness of SLR and coastal impact in Ghana. This study attempts to provide this information that may be useful for adaptation strategies.

This study reveals that by the year 2050 about 2.66 km², 2.77 km² and 3.24 km² of coastal settlements will be inundated based on the 2.6, 4.5 and 8.5 IPCC AR5 RCPs scenarios. Wetlands, an important ecosystem in Ghana worth an ES value of about 4,051,090 US dollars, 5,278,245 US dollars and 8,442,235 US dollars may also be lost by the year 2100 based on the 2.6, 4.5 and 8.5 IPCC AR5 RCPs scenarios. These estimates may not be valid for the future, if the contribution to SLR in Ghana may become either smaller or larger.

According to the data garnered, most communities on the coast of Ghana are aware of SLR and the coastal erosion impact on their communities. The cause of SLR, however, has been largely attributed to God by interviewees on the coast of Ghana suggesting the need for educational outreach programs on sea-level rise at the coast of Ghana. This education programs may positively affect any coastal adaptation project.

Although respondents in some communities have expressed satisfaction with the ongoing coastal defence projects, other communities are dissatisfied based on the physical design of the project. Respondents from Ngyiresia, for example, alleged the defence wall in their community does not allow drains to flow easily from the mainland into the sea thus creating favorable moisture conditions that mosquitoes need to hatch their eggs, which allegedly have resulted in increased malaria cases in the community. Some respondents claim that their source of livelihood (fishing) is being threatened by the sea defence project because it made no provision for landing sites.

Municipal and District Assemblies are not sufficiently integrated into the sea defence projects and thus lack scientific knowledge on SLR in Ghana. There is the need for cooperative relationships between national, district, local authorities, coastal research scientists and engineers, and communities along the coast of Ghana through facilitated discussion learning programs.

There is a high readiness to adapt to climate change on the part of the Ghanaian government based on the physical evidence of ongoing coastal defence projects in Ghana. Despite the success chalked by the projects in some communities including Keta, the project has exacerbated the coastal erosion in neighboring and other communities which hitherto experienced low levels of coastal erosion prior to the construction of the sea defence projects. In the opinion of this study, the identified reactive measure is not comprehensive and integrative enough and lacks sound scientific knowledge on climate change impact on the coast of Ghana.

Integrated and comprehensive coastal management policies informed by thorough research findings of natural and anthropogenic causes of coastal erosion along the entire coast of Ghana as well as the identification of suitable adaptation options for different spatial units across the entire coast of Ghana is needed to interactively and sustainably curb the devastating coastal erosion in Ghana.

Although the 2010 land cover data provide useful information on which land cover types on the coast of Ghana is expected to be impacted by accelerated SLR, there is the need for current data on land cover types on the coast of Ghana and estimates of their economic values as well as research on the influence of land use changes on historical and future sea-level and land cover estimates for the coast of Ghana.

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Table 5: Relief assistance during coastal disaster events, (A) Did NADMO or any other organization assist you or the community due to the disaster? (B) Source of support if received some form of support ('yes')

Table 6: Barriers to integrated national adaptation plan for Ghana

Figure 1

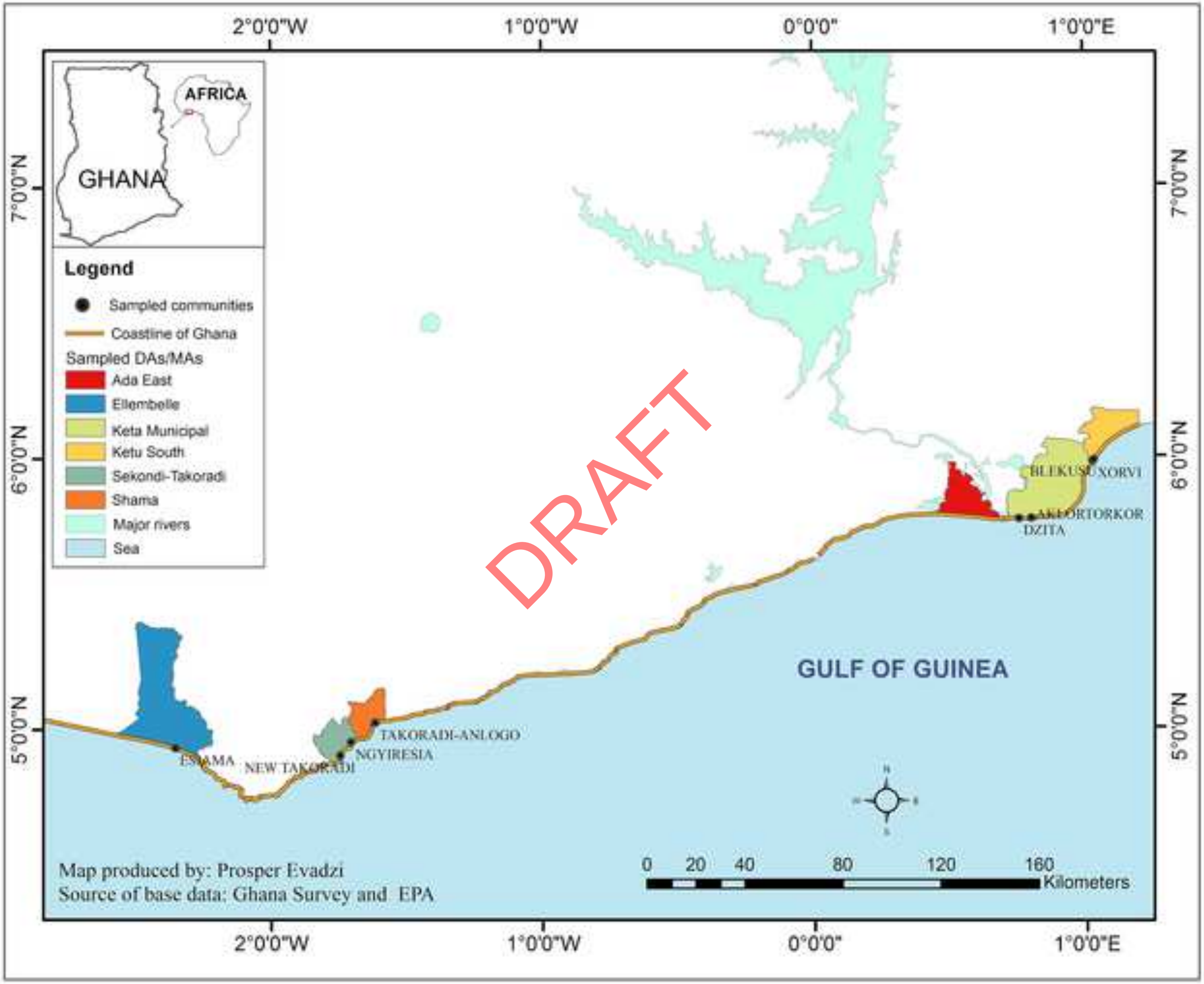
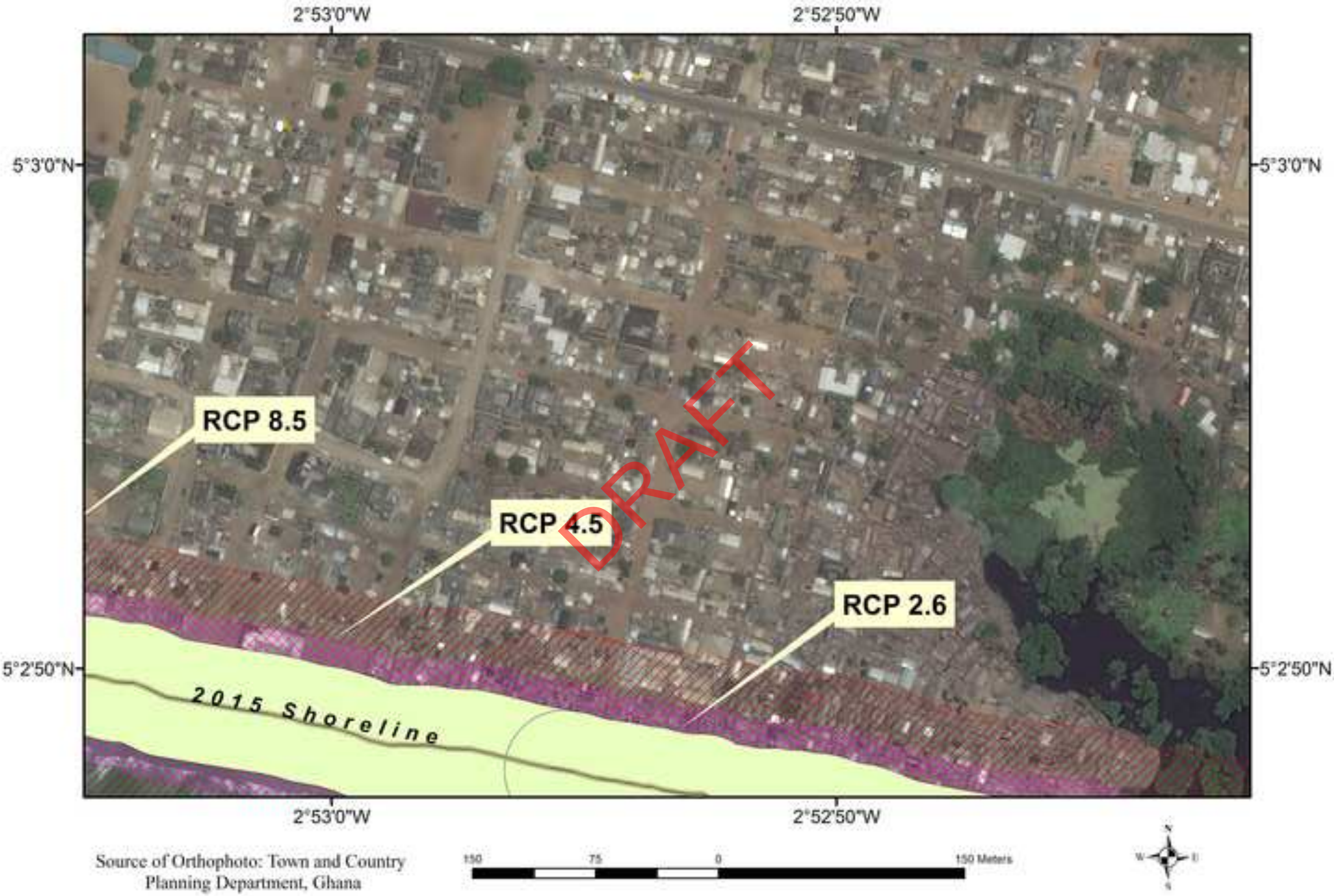
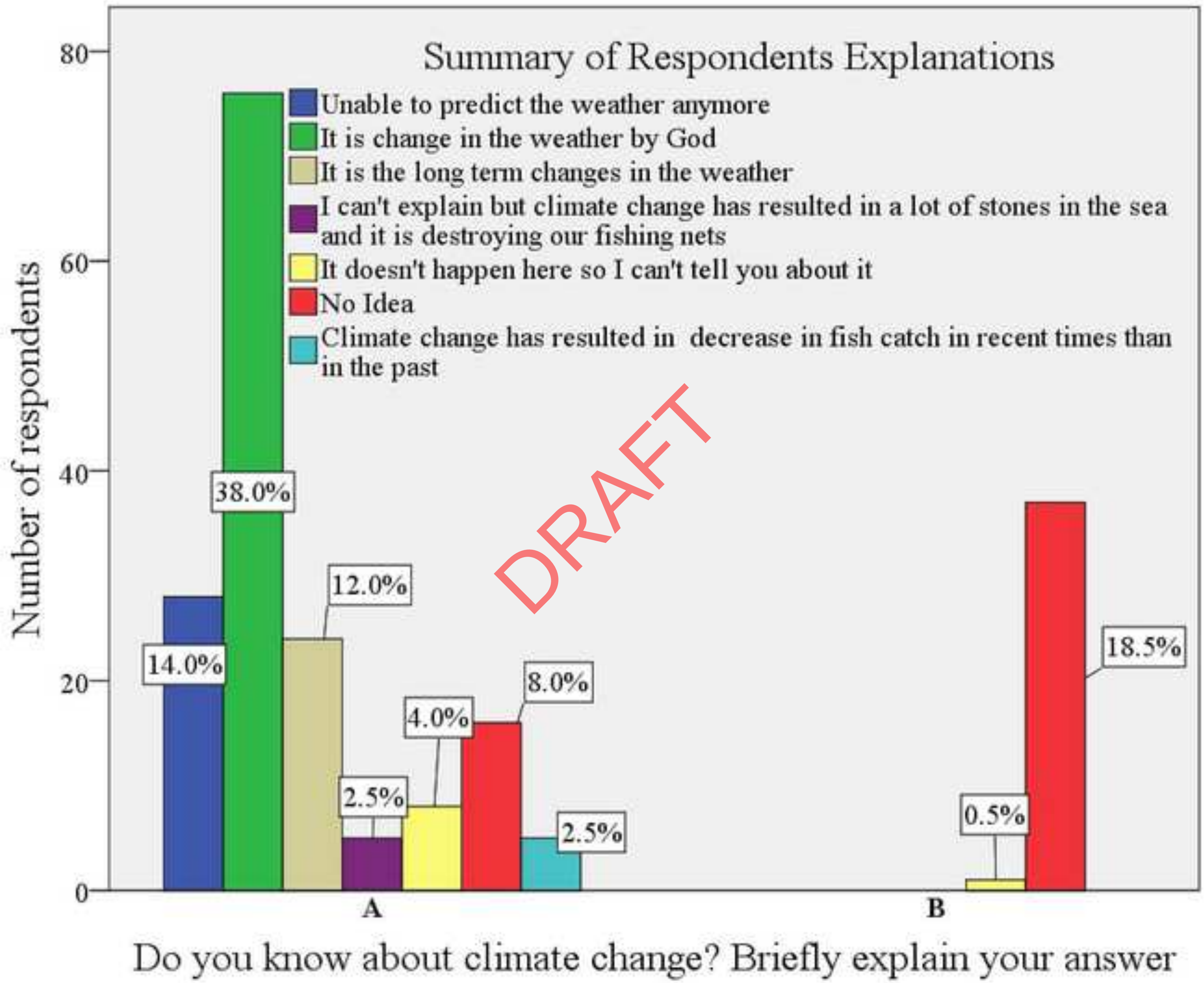

2°0'0"W
1°0'0"W
0°0'0"
1°0'0"E
7°0'0"N
6°0'0"N
5°0'0"N
GHANA
AFRICA
Legend
Sampled communities
Coastline of Ghana
Sampled DAs/MAs
Ada East
Ellembelle
Keta Municipal
Ketu South
Sekondi-Takoradi
Shama
Major rivers
Sea
DRAFT
BLEKUSU
XORVI
AKPORTORKOR
DZITA
GULF OF GUINEA
TAKORADI-ANLOGO
NGYIRESIA
NEW TAKORADI
ESIAMA
0 20 40 80 120 160
Kilometers
Map produced by: Prosper Evadzi
Source of base data: Ghana Survey and EPA

Figure 2



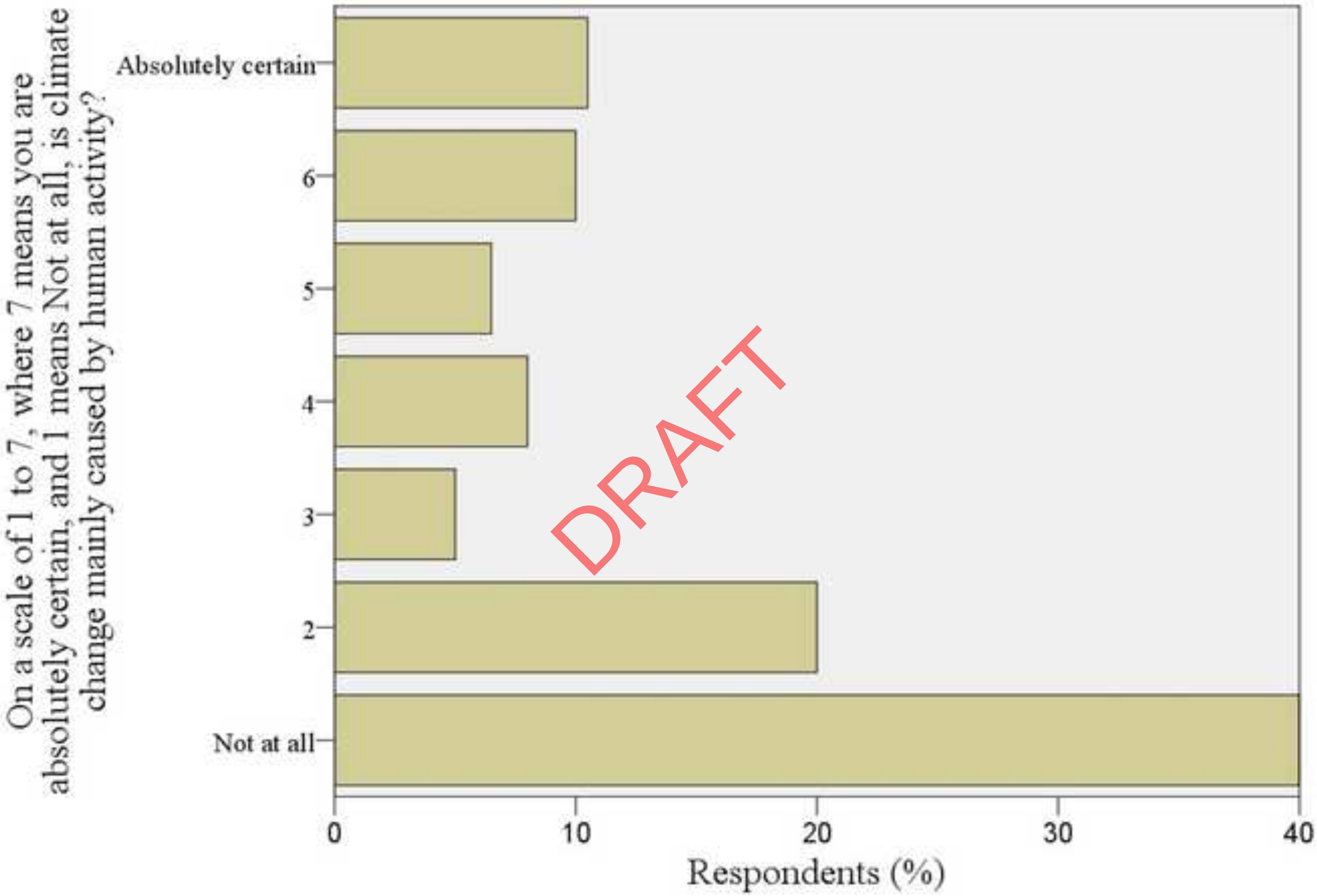
2°53'0"W
2°52'50"W
5°3'0"N
5°2'50"N
RCP 8.5
RCP 4.5
RCP 2.6
DRAFT
2015 Shoreline
Source of Orthophoto: Town and Country Planning Department, Ghana
150
75
0
150 Meters

Figure 3



Summary of Respondents Explanations
Unable to predict the weather anymore
It is change in the weather by God
It is the long term changes in the weather
I can't explain but climate change has resulted in a lot of stones in the sea and it is destroying our fishing nets
It doesn't happen here so I can't tell you about it
No Idea
Climate change has resulted in decrease in fish catch in recent times than in the past
Number of respondents
80
60
40
20
0
14.0%
38.0%
12.0%
2.5%
4.0%
8.0%
2.5%
0.5%
18.5%
DRAFT
A
B
Do you know about climate change? Briefly explain your answer

Figure 4



On a scale of 1 to 7, where 7 means you are absolutely certain, and 1 means Not at all, is climate change mainly caused by human activity?
Absolutely certain
6
5
4
3
2
Not at all
0
10
20
30
40
Respondents (%)
DRAFT

Figure 5

Figure 6 C

Figure 6 A

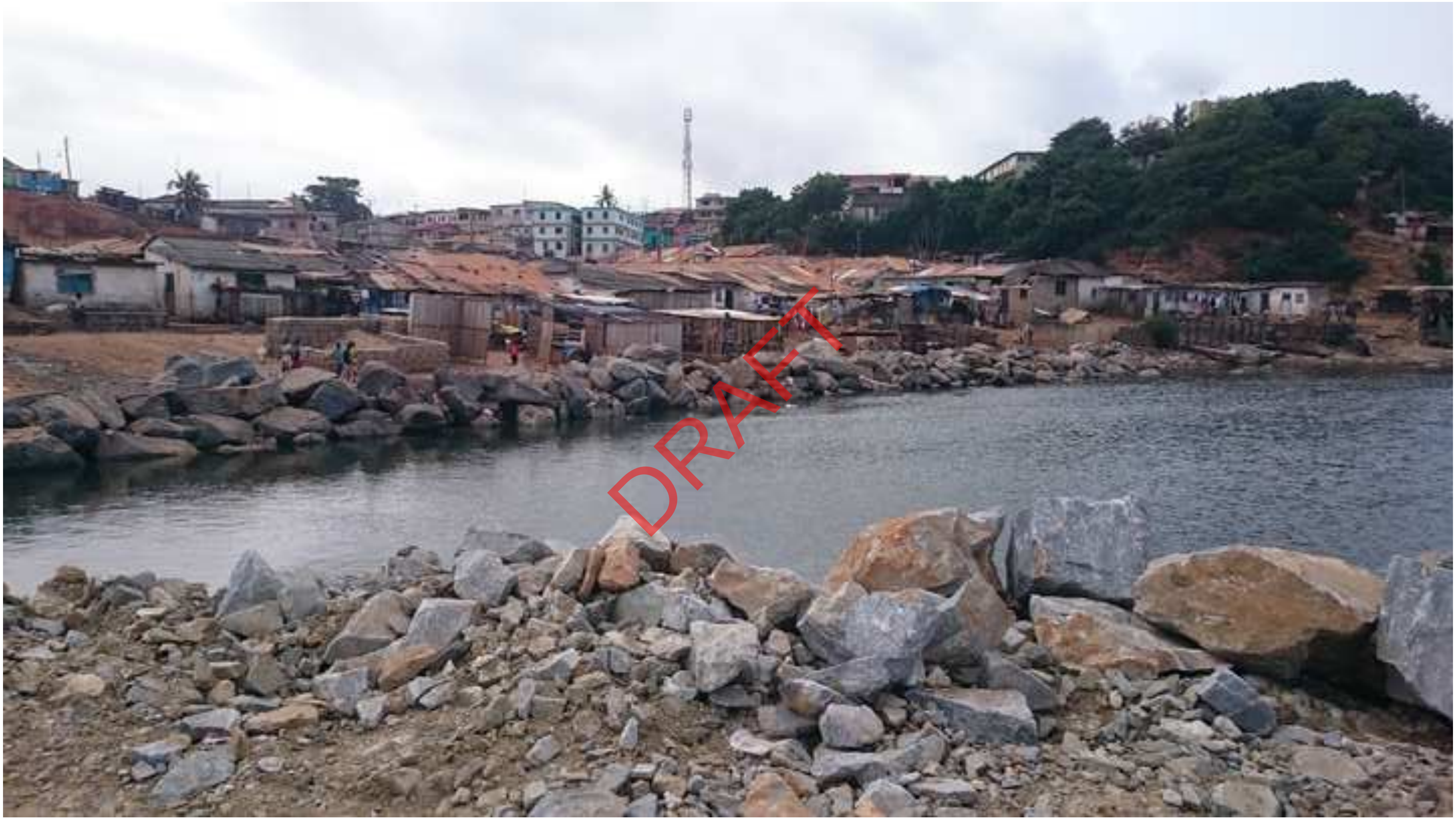


Figure 6 B

Table 1: Classification of households by main livelihood activities (%), N = 200

		%
Agricultural-Fishing sector	Fisherman	34.0
	Fisherman and Farmer	8.5
	Fishmonger	24.0
Fishing sector -total		66.5
Non-Fishing	Farmer	6.5
	Farmer and Trader	.5
	Carpenter	7.5
	Mason	1.0
	Trader	6.5
	Food Vendor	1.5
	Tailor/Seamstress	3.5
	Driver	.5
	Public Servant	1.5
	Teacher	3.5
	Student	.5
Non-Fishing -total		33
	Unemployed	.5
	Total	100.0

Table 6: Barriers to integrated national adaptation plan for Ghana

Governance	- Lack of political will and clarity on roles and responsibilities across levels of government. - A mismatch between the time horizons for adaptation and political and management practices.
Cultural	- Public disbelief in the science of climate change. - Cultural resistance to change.
Resources	- Lack of scientific and expert knowledge on sea level rise. - Capital costs of engineering solutions - Lack of staffing, skills and expertise. - Lack of access to funding.
Uncertainty	- Uncertainty about climate impacts. - Lack of data. - Lack of confidence in climate change projections. - Uncertainty about appropriate planning tools and methodologies. - Lack of research focusing on adaptation. - Lack of standards for interpreting data reliability.

Table 5: Relief assistance during coastal disaster events, (A) Did NADMO or any other organization assist you or the community due to the disaster? (B) Source of support if received some form of support ('yes')

		B				Total
		Support from NADMO	Support from NGOs	Support from community	Others forms of support	
A	Yes	8	25	39	16	88
	No	-	-	-	-	112
Total						200

Table 4: Sea level rise and coastal impact, (A) Have you lost any item or property situated close to the coast due to sea-level rise and coastal flooding? (B) Did the incident in 'A' lead to your evacuation and/or resettlement?

		B		Total
		Yes	No	
A	Yes	115	25	140
	No	60	0	60
Total		175	25	200

Table 2: Different land cover types at risk of coastal erosion, based on 2050 and 2100 coastal erosion estimates by Evadzi et al. 2017

Landcover	RCP 2.6 (km²)		RCP 4.5(km²)		RCP 8.5(km²)	
	2050	2100	2050	2100	2050	2100
Grass/herb with/without scattered trees (0-5 trees/ha)	2.21	4.06	2.31	5.71	2.71	9.26
Grassland with/without scattered tree/shrub	1.24	2.28	1.30	3.20	1.52	5.18
Lagoon	2.10	3.87	2.20	5.45	2.58	8.84
Moderately closed tree (>15 trees/ha) canopy with herb and bush cover	0.40	0.73	0.42	1.03	0.49	1.65
Moderately dense herb/bush with scattered trees (<15 trees/ha)	3.94	7.22	4.12	10.12	4.82	16.29
Mosaic of thickets & grass with/without scattered trees	2.43	4.45	2.54	6.24	2.97	9.99
Planted cover	2.31	4.26	2.42	5.99	2.84	9.66
River	0.44	0.81	0.46	1.14	0.54	1.86
Settlement	2.66	4.83	2.77	6.72	3.24	10.70
Shrub thicket with/without trees	0.43	0.78	0.45	1.07	0.53	1.67
unclassified area due to cloud cover	0.09	0.18	0.10	0.26	0.12	0.46
Wetland	1.39	2.74	1.46	3.57	1.71	5.71

Table 3: Respondents' awareness of change in sea-level close to their community for the past 5 to 10 years

		Sea level 5 to 10 years ago			Total
		Risen	Fallen	No idea	
Do you know about sea level rise?	Yes	151	6	11	168
	No	22	4	6	32
Total		173	10	17	200