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CLIMATE CHANGE VULNERABILITY ASSESSMENT IN MANGROVE REGIONS OF SIERRA LEONE

Abridged Report

MAY 2017

This work was conducted under the USAID-funded West Africa Biodiversity and Climate Change (WA BiCC) project.

This report is the abridged version of the report Climate Change Vulnerability Assessment in Mangrove Regions of Sierra Leone (http://www.ciesin.columbia.edu/wa-bicc/). The vulnerability assessment was led by the Center for International Earth Science Information Network (CIESIN) of the Earth Institute of Columbia University under contract with Tetra Tech, and CIESIN also led the analysis and report development. In addition to the CIESIN lead researcher, Sylwia Trzaska, the field research was conducted by a team comprised of representatives from the WA BiCC technical unit in Freetown, Fourah Bay College, Njala University, the National Protected Areas Authority (NPAA), Environmental Protection Agency (EPA), the Ministry of Agriculture, Forestry and Food Security, the Ministry of Lands, Country Planning and Environment, the Ministry of Fisheries and Marine Resources, Conservation Society of Sierra Leone and other stakeholders.

The authors of the report are Sylwia Trzaska, Alex de Sherbinin, Paola Kim-Blanco, Valentina Mara, Emilie Schnarr, Malanding Jaiteh, and Pinki Mondal at CIESIN. The team wishes to acknowledge the contributions of Zebedee Njisuh, Aiah Lebbie, Samuel Weekes, George Ganda and Michael Balinga. A full list of field research staff can be found in Annex 5 of the full report. Without their hard work and dedication under challenging conditions, this vulnerability assessment would not have been possible.

Cover page: Various Activities from the Sierra Leone Coastal Landscape Complex

June 2016.

Credit: S. Trzaska

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Tetra Tech ARD Contacts:
Stephen Kelleher
Chief of Party
West Africa Biodiversity and Climate Change (WA BiCC) project
Accra, Ghana
Tel.: +233 (0) 302 788 600
Email: stephen.kelleher@wabicc.org

Vanessa Litz
Project Manager
Burlington, Vermont
Tel.: +1 802 495 0303
Email: Vaneska.litz@tetratech.com

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ACRONYMS

CIESIN	Center for International Earth Science Information Network (CIESIN), the Earth Institute at Columbia University
CMA	Community Management Association
CSSL	Conservation Society of Sierra Leone
DFID	UK Department for International Development
DHS	Demographic and Health Survey
EPA	Environmental Protection Agency
EWS	Early Warning System
FBC	Fourah Bay College
GLCME	Guinea Current Large Marine Ecosystem
HFIAS	USAID's Household Food Insecurity Access Scale
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
MAFFS	Ministry of Agriculture, Fisheries, and Food Security
MFMR	Ministry of Fisheries and Marine Resources
MOHC	The Met Office Hadley Centre
MRU	Manu River Union
NAPA	National Adaptation Programme of Action
NPAA	National Protected Areas Agency
NU	Njala University
PRA	participatory rural appraisal
RCM	Regional Climate Model
RCP	Representation Concentration Pathway
SRES	IPCC Special Report on Emissions Scenarios
SRTM	Shuttle Radar Topography Mission
USAID	US Agency for International Development
VA	vulnerability assessment
WA BiCC	West Africa Biodiversity and Climate Change project

EXECUTIVE SUMMARY

RATIONALE

The purpose of this coastal climate change vulnerability assessment (VA) is to understand factors that contribute to the vulnerability and resilience of communities and mangrove ecosystems in coastal Sierra Leone. The goal is to inform the design of project interventions, including climate adaptation activities under the West Africa Biodiversity and Climate Change (WA BiCC) project. The work was led by the Center for International Earth Science Information Network (CIESIN) at Columbia University, and included a team of field researchers drawn from WA BiCC staff, Fourah Bay College, Njala University, the National Protected Areas Authority (NPAA), Environmental Protection Agency (EPA), the Ministry of Agriculture, Forestry and Food Security, the Ministry of Lands, Country Planning and Environment, the Ministry of Fisheries and Marine Resources, Conservation Society of Sierra Leone and other stakeholders. This study is the most comprehensive assessment to date of the vulnerability of fishing communities in Sierra Leone – and perhaps for all of coastal West Africa.

APPROACH

A preliminary scoping mission in February 2016 concluded that the communities that will be most adversely impacted by the effects of climate change such as sea level rise and increased storm intensity are coastal fishing villages that are located in or near mangroves. Furthermore, studies suggest that the mangroves themselves, important to coastal resilience, will be adversely affected by climate change. Thus, the VA focuses on coastal fishing communities like the one captured on the front page. Given that the study aims to inform adaptation strategies at the community level we adopted a bottom-up approach and gained some degree of generalizability and scalability of the recommendations by studying mangrove forests and populations in the four primary mangrove regions in Sierra Leone (from North to South): The Scarcies River Estuary, the Sierra Leone River Estuary (SLRE), Yawri Bay, and the Sherbro River Estuary.

The VA seeks to determine the relative vulnerability of fishing communities and ecosystems – sometimes referred to in the literature as the coupled socio-ecological system – through household surveys, participatory rural appraisals and mangrove forest inventories. The VA was carried out in 12 clusters comprising one mangrove transect and two villages distributed across the four regions. A total of 261 household interviews were conducted addressing a variety of issues related to economic assets, wellbeing, livelihoods, food security, fish harvesting and processing, use of mangroves, and awareness of climate change issues. Participatory Rural Appraisals (PRAs) were also conducted in each settlement, with separate male and female participants for a total of 96 group meetings. Finally, 12 mangrove transects were inventoried, assessing mangrove health in the form of species mix, biomass density, and water depth. Three teams of 12 experts were trained then deployed to the field. The training included a review of methods as well as hands-on testing and refinement of the instruments in the Sierra Leone River Estuary (SLRE).

MAIN FINDINGS

SOCIO-ECONOMIC CHARACTERISTICS OF THE POPULATIONS

The demographic characteristics of the populations surveyed are comparable to those of rural populations of Sierra Leone as a whole, as inferred from national census and Demographic and Health Survey (DHS) results. The socioeconomic analyses show **very high poverty levels** and low education levels. Around 60% of the respondents (adults) reported no education and those levels reached 70% for women. Eighty-five percent of the respondents fell in the **severely food insecure** category of the USAID Household Food Insecurity Access Scale[1], and this rate reached 100% in some locations. Access to **clean water and adequate sanitation** is generally low. Although sanitation conditions are comparable to national results for rural areas, they might affect the coastal populations more strongly as space is limited, and the potential for contaminating water supplies and surrounding water bodies is high. Similarly, while reported levels of access to improved water sources are comparable to national levels, experience shows that these are often outside of the villages and water is actually brought in containers, which means that the water can easily become contaminated.

As expected, **livelihood strategies** are dominated by fishing and related activities but the overall diversification is low, with a median value of 1.9 activities per household and 30% reporting only one activity. Diversification is larger in smaller settlements, indicating that households need to engage in more activities to insure their subsistence. Fish smoking is mostly carried out by women and, based on interviews, may actually cost more than is received in compensation through commercialization. The absence of alternative fish preserving methods means that these households have few choices but to engage in smoking. Around 30% of the households engage in farming but the rates strongly vary according to location, ranging from over 85% to none in several locations.

Access to **savings and credit** is low. Only 25% of the households had engaged in any type of savings scheme, and less than 10% of households had accessed credit in the past year. The highest frequencies of credit are linked to microcredits from NGOs and local credit rotation schemes. Access to saving schemes significantly depends on the size of the settlements with 46% of respondents having accessed saving schemes in larger locations and only 18% in smaller.

Overall, the population has low **access to information**. About 30% of the surveyed households indicated having constrained access to **schools and markets**, and more than 40% have limited or no **access to health centers**. In some small villages access to all three vital resources is severely constrained. Over 90% of the respondents indicated not reading a newspaper but 60% indicated listening to the radio, although this percentage drops dramatically in small villages. Yet, nearly two thirds of the respondents own or have access to a cell phone.

Access to **aid and social networks** appears to be low as well, with 40% of respondents stating they have not received any aid of any kind in the past year and 40% not participating in any groups and associations other than religious.

1.The survey was conducted in July, which corresponds to the 'hunger season' – a period from June to late fall, before the new harvest, when the staple food is rare and expensive and sea conditions make the catch low thus reduce fishermen income. The results may have been affected by the timing of the survey.

CLIMATE AND ENVIRONMENT

Sierra Leone enjoys a tropical climate with a **prolonged and abundant rainy season** from May to November. Due to the orientation of the coast and main mountain ranges the coastal regions are among the wettest regions in Africa receiving close to 3,000mm of rainfall per year. Rainfall varies on interannual and decadal time scales but the variations are low compared to the total amounts received, with a coefficient of variation of the order of 11%, and no clear, significant trend in rainfall is observed. Temperatures, on the other hand, have risen at the rate of **0.14°C per decade**. Climate change projections indicate no or small tendency of rainfall increase and a consistent increase in temperatures. Thus, if managed properly water resources should not be a threat to Sierra Leone while temperature change may affect ecosystems and agricultural systems in the long term.

High winds and floods are the main climate/weather-related disaster with high impacts reported by the communities. However, while the majority (63%) of the respondents said they have heard about **climate change** and believe it is happening, more than one third indicated they did not consider this to be a major concern for their community. The low ranking of climate and environmental issues in the spectrum of current preoccupations was further confirmed in focus group discussions, where participants emphasized other development issues (poverty, food security, and access to markets, among others) and is characteristic of many communities in developing countries.

Total **mangrove** cover in Sierra Leone is estimated to have decreased by approximately 25% since 1990, but very unequally among regions: while the decrease reaches 46% in the Scarcies River Estuary, due to widespread conversion of the land to rice farms, mangrove cover has marginally increased in Ywari Bay and Sherbro River Estuary and significantly increased in SLRE due to reforestation efforts. *Avicennia germinans* is the dominant species in all the regions but Sherbro, where *Rhizophora Racemosa* dominates. Despite deforestation, the remaining mangroves in the Scarcies region are in good health, with high species diversity, mature forest and high regeneration level, indicating high regeneration potential should human pressures be lowered or better managed. The Sherbro area is on the opposite end of the spectrum, with lowest species diversification, highly dominated by *Rhizophora Racemosa*, with the oldest trees and lowest regeneration rates, showing high commercial potential but low current regeneration potential. SLRE has the youngest forests, a sign of past and current exploitation of the forest, while the Yawri Bay has fewer adult trees but the highest number of seedlings, both showing signs of good potential for regeneration and sustainability.

Mangroves are perceived mainly as source of fuel wood, with 70% of the households reporting a reliance on mangrove wood for cooking and smoking fish, and this proportion reached 100% in several smaller localities. Approximately 48% of respondents have noticed a decrease in mangrove cover in the past decade, but nearly 30% could not tell the difference. There is a shared perception that the decrease is linked to human activities rather than changes in climate, and nearly two thirds of respondents stated a willingness to participate in conservation/restoration activities.

According to the focus groups, most **natural resources** – farmland, fishing grounds, mangroves, other forests, and sand – are open access. A small minority of focus group participants mention traditional or government restrictions, with the highest being traditional restrictions for farm land. This view of natural resources as essentially open access may influence behaviors around resource capture, and under such circumstances there can

be little incentive for conservation and sustainable management. Eighty-seven percent of respondents engaged in fishing activities indicated the resource has decreased and linked it to overfishing and bad fishing practices (too many fishermen and trawlers, and catching juveniles) rather than to changes in the environment.

AGGREGATED WEALTH AND VULNERABILITY MEASURES

The highest proportions of households in the highest category of the **wealth index** are found in the urban and peri-urban settlements of Tombo, Tssana, Dibye Water, Bonthe and York Islands. Villages with high proportions of households in the lowest wealth index category exist in all four regions. Those are usually the smallest and most remote villages.

Scores on a **community vulnerability index** combining various socio-economic and climate impact factors show limited degree of spatial organization. Highest **exposure** levels are recorded in the Scarcies River Estuary, while Yawri Bay and SLRE have lowest exposure levels (owing to higher ground) but highest sensitivity levels, independently of locality size. Villages in the Scarcies and SLRE are composed of households with all five levels of **adaptive capacity**, independently of settlement size and accessibility. Yawri Bay and Sherbro settlements show a very contrasting adaptive capacity picture, with larger and more accessible settlements dominated by households with higher adaptive capacity while smaller, more remote villages are dominated by households with lowest adaptive capacity.

An **ecosystem vulnerability index** comprises indicators of mangrove quality and health together with anthropogenic pressures and community readiness to engage in conservation activities. As with the community vulnerability index, it shows limited spatial clustering. The SLRE and Yawri Bay regions have marginally lower vulnerability, but transects within each region show highly variable levels of vulnerability. An **overall vulnerability index** combining the community and ecosystem indices shows higher vulnerability in the Scarcies and Sherbro regions, linked to high exposure (Scarcies) and low adaptive capacity (Sherbro), while SLRE and Yawri Bay have somewhat lower overall vulnerability, despite higher sensitivity of the communities.

ADAPTATION SOLUTIONS

Climate-related stressors rank relatively low among community concerns, which instead are dominated by concerns over lack of resources and education, constrained access to markets, food insecurity, health problems and inadequate shelter. **Adaptation solutions** spontaneously listed in focus groups fall into four categories: reforestation and climate awareness, infrastructure, livelihood and financial strategies, water and sanitation, and health, broadly corresponding to exposure, adaptive capacity and sensitivity in the vulnerability framework. Building resilience in the region will require attention to not just environmental remediation, but also to awareness building/access to information and meeting basic needs.

Focus group participants ranked from low to high their preference, the degree of difficulty, the ability of the community to organize, and need for external assistance associated with each solution. The **most desirable** solutions were also deemed by the respondents to be most difficult and most likely to need external support. Among such solutions the highest ranked were: reforestation, house improvements, drainage systems (to mitigate flooding), local water supplies, river embankments, and expansion of farming and fishing. They address

mainly exposure and, to some extent, sensitivity of the populations. Highly preferred, easy to implement solutions with little dependency on external assistance include: savings schemes, climate awareness, improving farming, improving roads and building schools. These mostly address adaptive capacity. Preferences change when villagers considered modified climatic conditions, such as a potential increase in the amplitude and/or frequency of harmful climatic events. Reforestation, drainage system and increase in fishing activities all showed a strong decrease in preference for at least 50% of participants, indicating that these solutions are not seen as very effective to address potentially increased occurrence or magnitude of disasters. **Strong increase in preference** under climate change scenarios was recorded for: sturdier homes, saving groups, improved water supplies, and health facilities. This shows that solutions leading to more secure and healthier living conditions would be the priority for the majority of the respondents.

RECOMMENDATIONS

Based on the findings of this study we suggest the following set of recommendations:

- **Improve Sierra Leone's capacity to monitor environmental conditions and projected impacts of climate change.** This includes building the capacity of the Meteorological Agency of Sierra Leone to provide quality information about past, current and future climate conditions based on local data; monitoring of physical and chemical properties of water and its levels in the coastal areas; and developing research to assess climate impacts on ecosystems and economic sectors tailored to Sierra Leone's context.
- **Improve natural environment management practices,** focusing on sustainable, community-based mangrove management that recognizes the variety of ecosystem services mangrove provides and accounts for different mangrove vulnerabilities in different regions; and on improvement of coastal water quality as well as of the coastal dynamics. Build a national mangrove management system based on the pilot systems developed in different communities, following a bottom-up approach.
- **Lower exposure to climate/weather disasters,** in particular to heavy winds and floods, through early warning systems, and through supporting community in better understanding potential changes in disaster risk and, where relevant, support community organizations to establish protective infrastructures (drainage, higher embankments, wind barriers) and/or increase their capacity to combat the disasters, such as fires due to heavy winds, and mitigate their effects.
- **Lower the sensibility** of the populations through support to livelihood diversification, improved food security, health, sanitation and housing conditions. Design specific portfolio of actions focusing on female headed-households, given current very low education levels and very limited livelihood opportunities available to women.
- **Increase the adaptive capacity** of the populations through climate impacts, sea level rise and related risks awareness building and improved access to information (including early warning systems), education and financial instruments targeting specifically populations in the mangrove areas.

Several interventions are akin to standard development interventions but the selection was based on communities' preferences, given their current status, capacities and current and projected climate impacts. Given very high levels of exposure and overall vulnerability of the fishing communities living within the mangrove areas in Sierra Leone such standard development interventions are a prerequisite to building resilience of these communities in

1. INTRODUCTION

This coastal climate change vulnerability assessment (VA) was conducted to inform the design of West Africa Biodiversity and Climate Change (WA BiCC) project's coastal adaptation interventions in the mangrove forest areas of Sierra Leone. Given that data in this region are sparse and often outdated, the VA also provides a socio-economic and environmental baseline for other environmental conservation and development planning.

Figure 1.1: General view of the village of Njajeiam
This view is typical of fishermen villages surveyed in this VA: dense build-up only few feet above the water level.
Visible on the foreground are makeshift protections from the impacts of waves and storm surge. July 2016. Credit: S. Trzaska.

In the future, these coastal regions will be affected by sea level rise, increase in temperature, climate extremes such as high winds and heavy storms, and changes in the amounts and distribution of rainfall. The communities that will be most adversely impacted by the effects of sea level rise and increased storm intensity are the low-lying, coastal fishing villages that are in or near mangroves, like the one pictured in figure 1.1. In this context, mangroves play an important role in resilience to climate change by providing protection against erosion and strong winds, and by serving as fish nurseries and providing fire wood for fish smoking, which support the main livelihood of fishing communities. However, mangroves will also be adversely affected by the effects of climate change through sea level rise and changes in water characteristics and sedimentation patterns. Those stressors will add to current, human-induced stressors such as pollution, unsustainable harvesting, and deforestation for agricultural land conversion.

Protecting and conserving mangroves will alleviate some of the effects of climate change in the future, but these efforts can only be initiated and sustained with the support of local populations. Hence, in order to co-design interventions with the local population, the WA BiCC project needed to understand their basic needs and livelihood strategies and their perceptions of climate change and the of status of mangroves and fisheries. By the same token, an understanding of the differential vulnerability of local communities is necessary in order to best target interventions.

In July 2016, CIESIN/Columbia University led a VA with a team comprised of staff and researchers from the WA BiCC Freetown project office, Fourah Bay College, Njala University, and a number of government and NGO partners. The purpose was to collect data pertaining to the socio-economic status of fishing communities and their perceptions on climate, mangroves, and fisheries. The team surveyed neighboring mangrove ecosystems to understand ecosystem health and human pressures.

This report presents the summary of the approach and the main results of the VA and is organized as follows: Section 2 presents the overall context of the VA and the main research questions; Section 3 describes the approach and methods. Section 4 presents the main findings and, finally, section 5 provides some recommendations after a brief discussion of the findings. More detailed descriptions of the methods, VA implementation and the results are available in the full VA report (USAID, 2017).[2]

2. THE CONTEXT

THE COASTAL AREAS IN SIERRA LEONE

The Sierra Leone coastline stretches for about 506 km and the continental shelf extends for about 27,500 sq. km. Natural conditions lead to high marine productivity, especially along the northern portion of the coast, down to Sherbro island, leading to well-developed artisanal fishing (Heymans and Vakily, 2004; GCLME, 2013). Fisheries represent around 10% of the GDP of Sierra Leone and directly employ over 40,000 fishermen with a total of 500,000 of people employed in the fisheries-related sector (fish processing, marketing, trading and transporting, boat building, wood cutting, weaving baskets, selling fishing gear and petty trading). Fish are also the most affordable and widely available protein source, and constitute 80% of animal protein consumed in the country (EJF, 2009). Fisheries contribute significantly to poverty reduction and food security in Sierra Leone.

Figure 2.1: Boat loaded with smoked fish leaving Yeliboya in the Scarcies region.

2. Full VA Report (http://www.ciesin.columbia.edu/wa-bicc/)

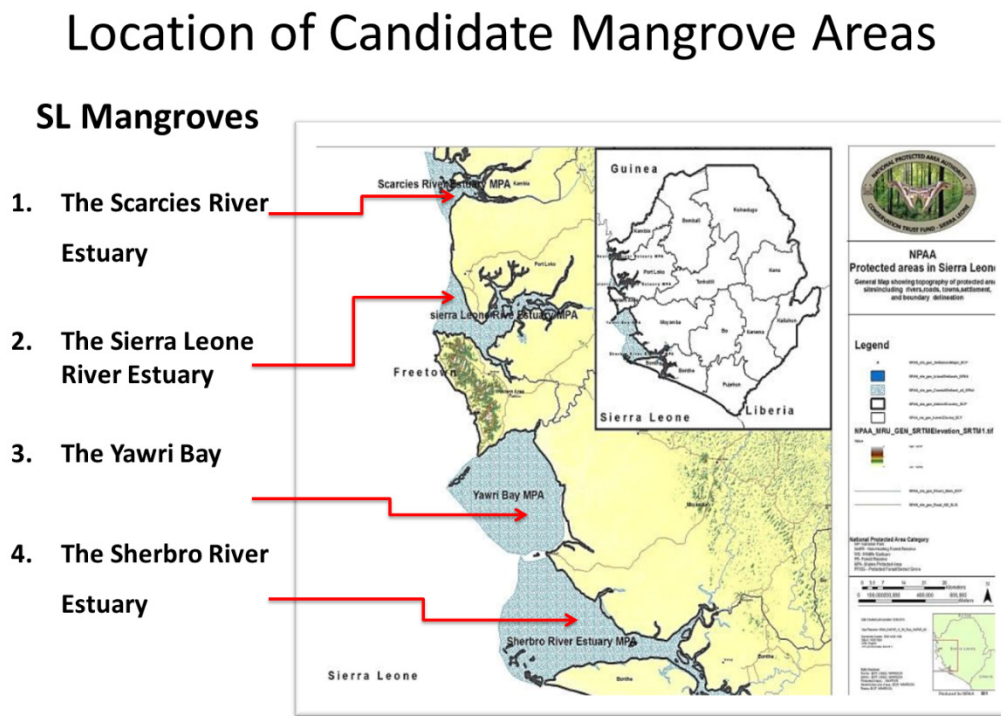

Figure 2.2. Location of major mangrove areas in Sierra Leone

Most of the artisanal fishing activities occur around the estuaries of four rivers, the Scarcies, Sierra Leone and Sherbro, as well as around Yawri Bay (IUCN, 2007), areas that also covered with mangrove forests (fig. 2.2), an important habitat for fish, shrimp and other marine fauna.

Mangroves are also an essential source of wood. The population of Sierra Leone is in general heavily dependent on fuelwood for domestic energy, and in mangrove areas mangrove fuelwood is additionally used for fish smoking. It is also exploited as poles for construction and household furniture and provides the secondary services of coastal protection and fish-breeding sites.

A study in the 1980s estimated that 47% of Sierra Leone's coastline is covered with mangroves, representing a total area of 171,600 hectares (Chong, 1987). A 2013 study based on Landsat imagery processed by the US Geological Survey estimated the mangrove area at 152,575 hectares (Tappan forthcoming). A more recent estimate (Trzaska et al., 2017) suggests that the mangrove area is 182,792 ha (see Section 4, subsection on Mangrove). Fluctuations in mangrove cover can partly be explained by different mapping algorithms, and partly by the way short-term degradation (thinning or cutting) shows up in the satellite record as deforestation.

In Sierra Leone, despite sporadic efforts to control cutting by government authorities, mangroves are not legally protected. The only regulations are through traditional restrictions or international treaties affecting all countries along the coast. Fishing and wood cutting, which constitute the most important economic activities in the area, are controlled by traditional by-laws imposed by chiefdom authorities and Community Management Associations (CMAs) in the fishing communities. The efficiency of this approach to

management needs to be assessed (IUCN, 2007).

FINDINGS FROM THE SCOPING VISIT

A preliminary visit to Sierra Leone's coastal area (Scarcies, Yawri Bay and Sherbro Island) from February 1-12, 2016 by a WA BiCC team[3] supports the findings above and provided some additional observations on the Sierra Leone coastal context (cf. de Sherbinin and Trzaska, 2016):

- Mangroves are under varying degrees of pressure in Sierra Leone, ranging from high pressure and rapid depletion in the Scarcies Basin to the North, to slightly lower pressure and still more abundant mangrove resources in the Bonthe-Sherbro River basin to the South.
- In high fishing/fish processing and trade areas, local stands of mangroves are often depleted and wood is imported from further away.
- Mangrove cutting is unregulated and the resource is perceived as inexhaustible, even in places where it was depleted. It is being brought from areas further away with implications on the prices. For fish smoking, few alternatives exist, and efforts to introduce more efficient smoke houses have had limited success.
- Generally, fishing communities rely more on mangrove resources and benefit more from ecosystem services than coastal communities with other livelihood types (e.g. farming, fig. 2.3), and thus they may see larger benefits from mangrove restoration and conservation/management measures.

Figure 2.3: Landscape typical of the Great Scarcies river where the mangroves on the banks have been replaced by rice farming. Note the erosion of the unprotected banks. The dwellings are usually on higher grounds and populations have access to other type of wood thus they do not see the direct benefits of mangrove restoration, rather see it as competition with rice farming.

- Communities are aware of the importance of mangroves for fisheries, and there is growing appreciation of their benefits for coastal protection (shielding from winds and limiting coastal erosion).
- In many areas, however, short-term subsistence needs take precedence over long-term stewardship of mangroves. Furthermore, apart from relatively small areas where there are traditional management systems in place, they are largely perceived as an open access resource, with consequent lack of incentives for conservation.
- Fishing communities complained several times that they rarely benefit from development projects, presumably due to accessibility issues.

3.The team was comprised of representatives from CIESIN, WA BiCC, Wetlands International, NPAA and MRU.

After the scoping visit, the WA BiCC project decided to focus the VA on fishing communities in mangrove areas. While the mangrove area may seem not suitable for human settlements, the scoping visit and subsequent examination of satellite data and imagery shows a multitude of small and medium-sized settlements within the mangrove areas of Sierra Leone, with a population of tens of thousands of people.

RESEARCH QUESTIONS

WA VA seeks to gauge the degree to which lives and livelihoods – as well as the natural, economic, institutional systems on which they rely – are susceptible to climate change impacts and have the capacity to adapt to a changing climate. The specificity of a VA lies in the fact that climate is the driver of change (USAID, 2014a). The objective of this VA was to inform WA BiCC and other stakeholders about the specific challenges faced by the communities and ecosystems in the mangrove area of Sierra Leone under changed rainfall, temperature and sea level conditions.

More precisely this VA attempts to answer the following questions:

- What are the main climate-related impacts experienced by the fishing communities living within the mangrove areas?
- How important are these impacts to the communities and how is this importance likely to change under modifies climatic conditions?
- What is the current capacity of these populations to adapt to future changes in climate?
- What are community priorities with respect to adapting to climate change?
- What is the status of the mangroves and their vulnerabilities along different segments of Sierra Leone's coastline to the effects of climate change and human activities?

3. APPROACH AND METHODS

THE APPROACH

VULNERABILITY FRAMEWORK

This assessment puts the communities and ecosystems at the heart of the study following the so-called bottom-up approach[4]. The overall vulnerability framework in this VA is that of the Intergovernmental Panel on Climate Change (IPCC), whereby vulnerability to climate change is the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change (Füssel and Klein, 2006). It recognizes that vulnerability is a function of (IPCC, 2007):

- Exposure: the magnitude or risk of physical changes in climate conditions
- Sensitivity: the likelihood of adverse effects to an organism, system or community given climate changes
- Adaptive Capacity: the intrinsic ability for an organism or system to reduce its sensitivity by successful response to changing climate

It is often represented by the formula:

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

where increased Exposure and Sensitivity increase Vulnerability, while increased Adaptive Capacity decreases Vulnerability. Therefore, reducing vulnerability would involve reducing exposure through specific measures like building a dyke in case of sea level rise, or increasing adaptive capacity through activities that are closely aligned with development priorities.

A COMBINATION OF ECOSYSTEM AND POPULATION VA

In this particular VA we assessed simultaneously the vulnerability of the socio-economic system (fishing communities) and of the ecosystems (mangroves). Figure 3.1 captures the main aspects of this approach.

The socio-economic VA follows the methodology proposed by Hahn et al. (2009) and is based on data collected through household level questionnaires, complemented by Participatory Rural Appraisals (PRAs) based on the approach by Tschakert (2007). The ecosystem VA uses the approach to mangrove vulnerability proposed by Ellison (2012). The detail of the indicators used in the different components of the vulnerability assessment of each sub-system are presented in the full report.

CLIMATE AND CLIMATE CHANGE INFORMATION

In general, a climate change vulnerability assessment (CCVA) differs from a more traditional VA in that it incorporates estimates of potential change in climate conditions and their impacts on productive or eco-systems on which the livelihoods are based. In the current

4. The bottom-up approach recognizes that adaptation occurs at local scales, and puts communities at the center, assessing their current vulnerabilities. It is better suited for planning purposes. The top-down approach focuses primarily on the bio-physical systems and attempts to quantify the impacts of climate change on those systems at larger scales and for longer horizons. A longer exposition of the bottom-up and top-down approaches can be found in the full report.

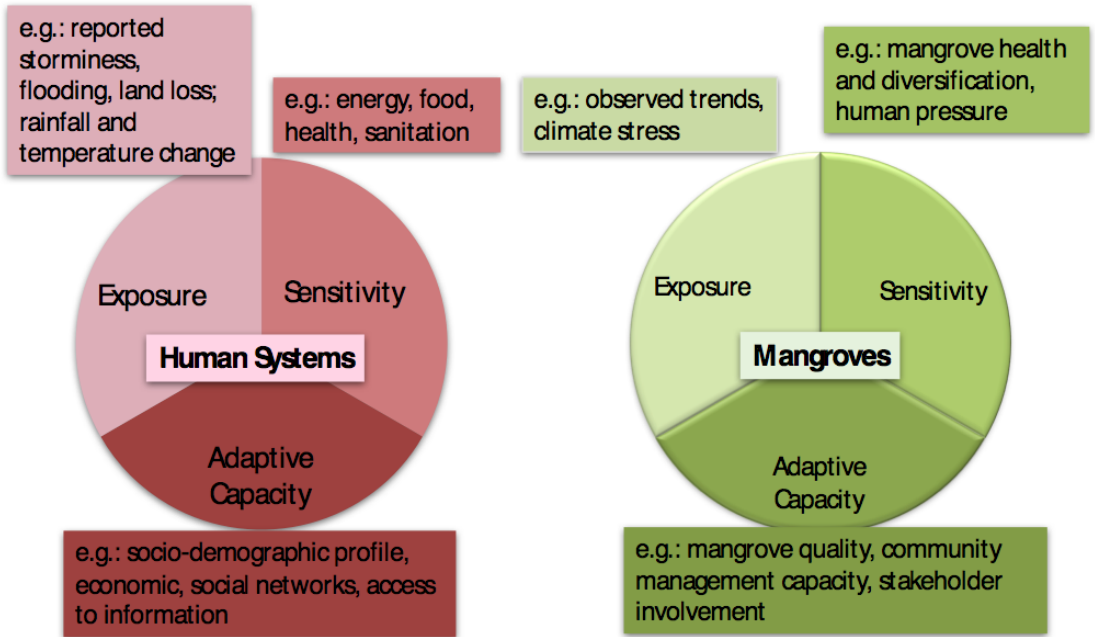

Figure 3.1: Schematic representation of the vulnerability indicators in each vulnerability sub-components: the vulnerability of human systems (left), the vulnerability of the mangrove ecosystems (right). The figure lists examples of indicators included in each sub-component and more information on the indicators in each component can be found in the full report.

VA this would mean estimating how the large scale projected changes in rainfall and temperature for West Africa, with large uncertainties, would translate in a very narrow (by climate projections standards) coastal strip a few miles wide by about 200 miles long, that includes very sharp topographic and ecological gradients, specific coastal currents, and hydrology. Such translation is not trivial and requires complex additional tools and very high resolution, reliable data to derive information at such small spatial scales[5]. In the absence of adequate tools and historical data for Sierra Leone's coast, the projected changes in climate and sea conditions will not be reliable. In addition, they will still provide a rather wide range of potential changes due to the uncertainties in the projections and downscaling procedures. Rather than developing projections with high uncertainty levels, we chose a more qualitative approach to understanding the potential impacts of future climate by introducing to respondents different scenarios of changes in the frequency and magnitude of current climate hazards that impact fishing communities.

To assess current impacts of climate we relied on individual reports on climate-related disasters on households and their assets such as the number of floods, number of times a house was destroyed due to weather, number of times members of the household were hurt (or died) in a climatic event. We recognize that some of this information is subjective but the analysis is mostly based on ranking of households and settlements, not on actual values, and the sample size permits us to capture differences in climate impacts between locations.

Similarly, we did not attempt to assess the current, or projected quality of the entire marine environment, including water characteristics or fish species. This study is limited to the assessment of the mangrove forest as an important and under-studied resource for the

5. A description of the procedures underlying downscaling of climate change projections can be found in USAID (2014b). horizons. A longer exposition of the bottom-up and top-down approaches can be found in the full report.

communities and a potential factor in climate change impact reduction. While critical to the assessment of climate change on the environment, monitoring of water characteristics, fish species, sedimentation rates and compositions were beyond the scope of this study. Long term monitoring of such variables needs to be part of the country long-term climate change assessment strategy.

THE METHODS

AREA SELECTION

Because of the intricate relationship between mangroves and fishing populations and the important role mangroves play in alleviating some of the effects of climate change, the VA focused on mangrove areas and the communities living nearby. After consultation with WA BiCC staff, the study was conducted in the four main mangrove regions (fig. 2.2) since they present different mangrove forest conditions as well as different economic activities and socio-cultural characteristics – and therefore different pressures. In this way, common and area-specific needs and interventions will be documented, allowing better targeting of the interventions and policies at different levels. The main characteristics of these four areas, from North to South, can be summarized as follows.

NORTHERN SHORE OF THE GREATER SCARCIES RIVER MOUTH - KAMBIA DISTRICT

This area represents 7.6% of Sierra Leone mangroves, in large patches of compact mangroves. Mangroves extend inland 8-10 km and up to 15 km along the rivers. Inland trees can be tall and of commercial quality. The area is highly populated with large economic activity from fishing where large amounts of smoked fish are exported to Freetown and Guinea.

FREETOWN AREA: MOUTH OF SIERRA LEONE RIVER - PORT LOKO AND WESTERN AREA RURAL DISTRICTS, A RAMSAR SITE

Estimated mangrove cover in this area is 19.9% of the total mangrove cover of Sierra Leone, but is less compact, and tends to be concentrated along different tributaries, extending between 0.5 and 3km inland. Mangroves are more shrubby and often freshwater swamps extend behind. 295,000 hectares of this estuary is protected under the Ramsar Convention on Wetlands of International Importance. The estuary is under numerous environmental threats from urbanization and industrial activities.

YAWRI BAY - MOYAMBA DISTRICT

Mangroves in this area represent 14.3% of the total mangrove cover, in the form of a coastal belt 1-5 km deep with a few compact patches. Dense mangroves extend further inland, up to 20 km, along the three main rivers, Ribi, Bumpe and Kagboroo creek. Fishing is an important activity with Tombo and Shenge ports supplying most of the fish consumed in Freetown. Its intensity has been increased by the development of small artisanal fishing projects in many communities, funded by various agencies, especially UNDP and AFRICARE. Other economic activities include salt production, which requires large quantities of fuel wood and agriculture including rice.

SHERBRO ISLAND AREA - BONTHE DISTRICT

Mangroves in the Sherbro Island area are part of the Sherbro River mangrove system which concentrates the largest part of the total mangrove in Sierra Leone - 58.2%. Extensive areas of large trees (*Rhizophora racemosa*), up to 40 m, can be found in the Sherbro River complex. The scoping visit found that the mangroves appear to be in better condition than the other regions and are not overexploited. With lower population and levels of extraction and well preserved mangrove system this area has the biggest potential for conservation and introduction of sustainable management practices, although perceptions that mangroves are an inexhaustible resource may undermine conservation efforts.

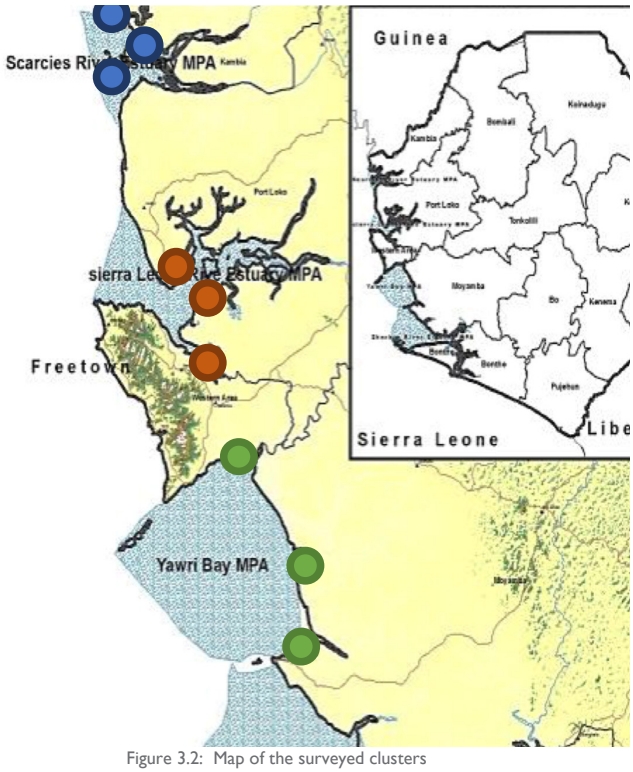

Figure 3.2: Map of the surveyed clusters

SAMPLING STRATEGY

The primary goal of the VA was to understand the community vulnerabilities and interactions between human activities and mangroves. Therefore, the sampling strategy was limited to investigation of coastal villages that are in close proximity to mangroves or that rely heavily on mangrove wood. Household surveys and PRAs were conducted in the villages, together with a forest inventory of neighboring mangroves. The villages were selected through a stratification method where three mangrove transects were first selected in each region among mangroves estimated to be in best, worst and medium states, based on the satellite-derived maps. Two coastal villages within 2-3 km of the transects were then selected. Thus, in each region the team conducted surveys, PRAs and mangrove assessments in three clusters composed of one transect and two villages (fig. 3.2) for a total of twelve transects and 24 locations. Across all four regions the team conducted 261 household interviews and 96 PRAs, and sampled 100 forest plots along 12 transects.

THE INSTRUMENTS

HOUSEHOLD SURVEY

The survey collected baseline information on the status and wellbeing of households, information about livelihoods (especially fishing and mangrove harvesting), and information on perceptions of changes in both mangrove forests and in climatic patterns. The results were compared to national census and Demographic and Health Survey (DHS) results to check for consistency. The household survey included ~170 questions structured in the following sections:

1. Generic information, and consent
2. Demographic information
3. Literacy
4. Economic activities
5. Mangroves
6. Assets/ basic services, and pressing needs
7. Food insecurity
8. Climate change impacts and risk perception
9. Knowledge, attitude, behavior
10. External assistance, and community involvement
11. Customary and formal regulatory frameworks
12. Housing construction material, and size of banda (fish smoking house)

More details on the survey and its implementation can be found in the full report.

PARTICIPATORY RURAL APPRAISAL

The purpose of the PRA, conducted mostly through focus group discussions, was to get a broader picture of coastal climate impacts, community resilience, coping/adaptation mechanisms, and the role of mangrove ecosystems in promoting resilience. It also explored gender issues in terms of differences in perception of major problems/stresses or available solutions to climate-related problems, as well as gender differences in access to resources. The PRA complemented the household survey and field research being conducted along the mangrove transects. The PRAs were conducted in the same villages as the household surveys and included a broader group of respondents. The PRA included the following modules:

1. Participatory risk ranking and scoring – to highlight problems that are most relevant for building resilience and adaptive capacity, and to understand how important climate stress is compared to other risks the communities face.
2. Climate-related stressors and mental mapping – to elicit the positive and negative consequences of climate change and variability, for both people and the environment, and discuss solutions, including feasibility, community readiness, barriers and needs for external assistance.

3. Coping/Adapting to climate change – to review the proposed coping and adaptation strategies under a possible future in which a given climatic extreme was greater in magnitude or were to occur twice as often or last much longer. Participants explored which coping and adaptation strategies would still be viable in this context.

4. Participatory resource and risk mapping – to indicate any access agreements or restrictions as well as different risks to the main resources of the community. Examples might include zones susceptible to periodic flooding, areas that have suffered erosion, or lands / soil types that are susceptible to drought.

All PRA exercises were conducted with groups of 10-12 participants, and lasted 2-3 hours.

ECOSYSTEM VULNERABILITY ASSESSMENT

This assessment drew strongly on the methodologies described in Ellison (2012), Clausen et al. (2010), and Ajonina (2011). Numerous effects of climate change can potentially affect mangroves (Ellison, 2012) such as rising sea level, extreme storms, increased rainfall, reduced rainfall, reduced humidity, inscreased air/sea temperature, higher concentrations of carbon dioxide, and UV-B radiation. Some of the indicators presented by Ellison (2012) can only be obtained through long-term observation and monitoring, and others require sophisticated measurement techniques that were not possible through this assessment. Thus, in our methodology we followed the general approach proposed by Ellison and designed our indicators based on data collected during the forest inventories and during the household surveys. Detailed lists of indicators to estimate the vulnerability of mangroves is presented in the full report. In the forest inventories, conducted along 12 transects of approximately 500m, the team collected the following parameters:

a. Number and type of mammals, birds, and crustaceans visible from the location; presence of fish (type if possible)

b. Main vegetation/patch type

c. Dominant mangrove species

d. Type of human activity (cutting, clearing, cultivating, etc.)

e. Evidence of regeneration

f. Height of high tide mark on mangrove roots using meter stick (vertical distance from sand/mud to water mark on roots)

g. Patch type

h. Number of adult mangrove species

i. Height (distance between collar and top of tree) and diameter (at collar) of mangrove measured every 10th tree

j. Presence of diebacks and/or human activities (e.g. harvesting of roots, wood, etc.)

k. Number of individual seedlings and identification if seedlings in general are short, medium, and/or tall

l. Seedling species

DATA COLLECTION AND ANALYSIS

DATA COLLECTION

Socio-economic and ecosystem data were collected by three teams composed of four household survey enumerators (three enumerators and one supervisor), four PRA facilitators and two mangrove surveyors. A total of 12 household enumerators, 12 PRA facilitators and 6 mangrove surveyors were recruited from Fourah Bay College, Njala University and partnering institutions (National Protected Areas Agency, Environmental Protection Agency, MAFFS, and Ministry of Land). Prior to deployment the enumerators were trained on their respective instruments during one week training session that included a one day field-test in a location near Freetown as well as training on the ethics of data collection.

DATA ANALYSIS

Data were then digitized where needed and quality controlled by CIESIN. Household survey data were analyzed at national and regional levels and, where relevant, compared to national indicators from censuses (2004 and 2015) and the 2013 DHS survey to compare the selected populations to general population of Sierra Leone. Differences by gender were also analyzed as well as by larger and smaller settlements. The data were further analyzed at the household and village level to obtain indicators relevant to the assessment of vulnerability of populations to climate change, such as a wealth index and aggregates of vulnerability sub-components: exposure, sensitivity and adaptive capacity.

The results of the PRA were aggregated to national levels to present the overall picture of stressors and adaptation solutions, and to regional levels to highlight potential differences between regions. Where relevant, analyses were also carried with respect to gender.

Forest inventory data were aggregated to transect level to present the main characteristics of the mangroves and human activities. Finally, indicators from both assessments were combined to assess the vulnerabilities of the socio-economic systems and ecosystems at the village and regional levels.

Data collected through the household survey and in the mangrove, transects were subsequently used to construct the combined vulnerability indicator at the village level as well as at the household level, for the socio-economic data. More detail on the specific indicators can be found in the full report.

Figure 3.3: Participatory Rural Appraisal with a group of women in Katta Warf, Yawri Bay, July 2016. Credit: S. Trzaska.

4. MAIN FINDINGS

This section presents the main findings organized as follows: the first sub-section presents the main characteristics of the populations, followed by a section presenting the main characteristics of the climate and mangroves. The third subsection presents the results of the vulnerability and adaptation solutions.

POPULATION CHARACTERISTICS

DEMOGRAPHICS

The demographic analysis of the population surveyed indicates that its characteristics **closely match those of the general population** of Sierra Leone as inferred from the 2004 and 2015 census and the 2013 DHS Survey. The median age of the sample is 18, comparable to the 18.5 found in the 2015 census and the sex ratio (number of males for 100 females) ranges from 86 to 95, comparable to 94 and 96 in the 2004 and 2015 census, respectively. The lowest ratio is recorded in the Sierra Leone River Estuary (SLRE) and could be related to higher levels of migration of males to Freetown in search for work. The gender distribution of household heads is again comparable to that of the rural population (27% female, 73% male) with, however, slightly lower proportion of female-headed households in most of the regions except Sherbro. There is a lower prevalence of female-headed households in smaller settlements (16%) while in larger settlements the percentage of female-headed households (32%) is larger than the national or rural percentage.

EDUCATION

The education level, albeit low – more than 60% of the respondents report no education – is again comparable to the country rural average and the **disparities between men and women are very strong** (fig. 4.1). The percentage of men with no education in large and small settlements is 51% and 49%, respectively, and is lower than country's average for the rural population (54%). A high percentage of women have no education in large (69%) and small settlements (72%), which compares to a nationwide rural average of 68.5%, indicating

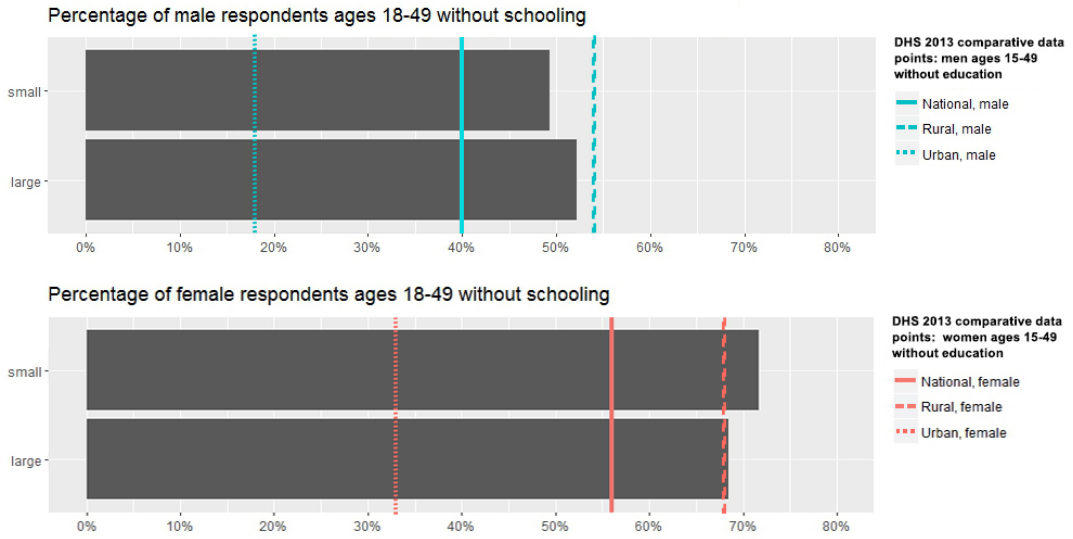

Figure 4.1: Percentage of respondents without schooling by size of locality, with DHS' national, urban, and rural levels for comparison.

constrained access to education for women even in larger settlements where schools are present. The issue of schooling levels of children, very relevant for the resilience of future generations, was however not directly addressed in the survey and may warrant special attention as about 30% of the respondents report no access or constrained access to schools.

SANITATION

Access to improved water sources seems better than in other rural areas and even the national average, reaching urban levels in Yawri Bay. However, this result needs to be qualified. In numerous settlements **no improved sources exist within the village** and water is brought from improved sources by container (fig. 4.2), often by boat, and sold to households, highly burdening their budgets. Water transported in containers may also become contaminated.

The percentage of households having access only to unimproved sanitation facilities is slightly higher than the national average, reaching 66% in small settlements and 45% in larger settlements. These results need to be qualified too as **unimproved facilities are highly constrained by lack of space**. Open defecation on the beach and in close proximity to the settlement can lead to **contamination of the water** surrounding the villages, where villagers walk, fisher folk launch their boats, and shellfish are collected. There is high risk of contamination of seafood with pathogens and high prevalence of diseases like cholera and typhoid.

Figure 4.2: Containers of clean water brought from mainland on the beach of Yeliboya, March 2016. Credit: S. Trzaska.

FOOD SECURITY

Households score overall **very low on food security** (i.e. severely food insecure on the USAID Household Food Insecurity Scale which documents households' food security and access over the month preceding the interview). On average 85% reported a situation that placed them in the severely food insecure category and values ranged between 50% and 100% depending on the location. The survey was conducted during the 'hunger season' and reflects the extent to which households are food insecure during that period. Fifty percent of the households' report not having enough food to meet their family's needs for two to four months a year.

LIVELIHOOD STRATEGIES

As expected from the choice of the populations surveyed, livelihood strategies are **dominated by fisheries-related activities** (fig. 4.4). More than 50% of households are involved in capture fisheries (as opposed to aquaculture) with an average contribution of 70% to household economy; fish processing is reported by 35% with a contribution of approximately 30% to their economy; followed by farming and small businesses. Logging of the mangroves, albeit reported by only about 10% of households, contributes on average to 30% of those household's economic activity.

Livelihoods have relatively **little diversification**, with an average of 1.9 activities across all households surveyed and about 30% of households reporting only one activity (fig. 4.3). Larger diversification exists in smaller localities, which is consistent observations in other developing countries where rural households tend to diversify subsistence activities as a risk management strategy.

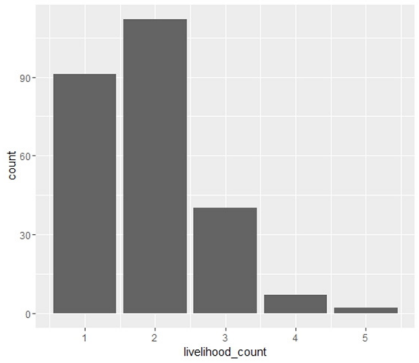

Figure 4.3 Distribution of the average count of livelihood strategies mentioned by households

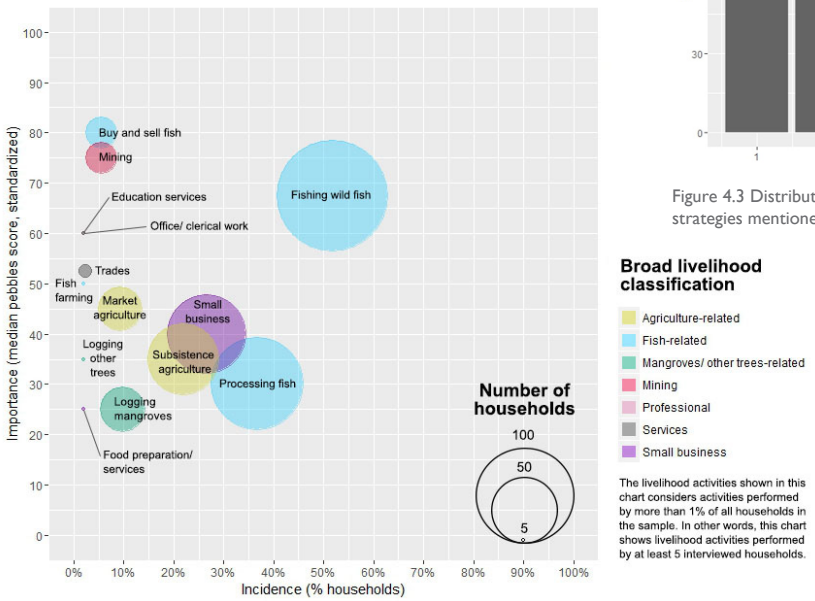

Figure 4.4. Incidence and relative importance of livelihood strategies reported by the households

FISHING LIVELIHOODS

Figure 4.5: Fishing activity in the coastal areas of Sierra Leone. Fishing remains artisanal and is mostly carried out in engine powered boats by multi-person crews like the one above. Boats vary in size and equipment and their fishing range. Scarcies River Estuary, July 2016. Credit: S. Trzaska

FISHING

The survey included questions related to fishing activities. Most households sent a member fishing 2-3 times, and in some cases, every day, of the previous week. There are slight differences between the regions that may be related to the type of fish caught and its availability and differences between large and small settlements that may be indicative of different labor organization, with people working for wages in the larger settlements. Similarly, lower diversification of catch is observed in larger settlements, which may be indicative of differences in fishing gear and market opportunities.

FISH SMOKING AND TRADING

Fish smoking is traditionally carried out by women (fig. 4.6). Interviews with women (and some men) engaged in smoking fish and estimates of expenditures (fish, mangrove wood, help) versus sale prices indicate that smoking fish is not lucrative, but may be carried out under social pressure, since this is the only way to preserve fish. In the case of female-headed households it may not be sufficient to support a family. Many women indicated that they had no alternative but to smoke fish. Nevertheless, the information on economic returns may be inaccurate since, despite assurances of confidentiality, some respondents may have downplayed the financial returns for personal reasons.

Figure 4.6: Woman fish-smoker in Bonthe, July 20, 2016. Credit S. Trzaska

FARMING LIVELIHOODS

Approximately **30%** of the respondents indicated **agriculture** as one of their livelihood strategies but the distribution is very uneven. In some settlements, more than 85% of households engage in farming at least as a secondary livelihood, whereas in other locations where no farming was reported (fig. 4.7).

FINANCIAL CAPITAL

SAVINGS/CREDIT

Only **25%** of the respondents indicated the household accessed any type of **savings** scheme in the past year, and less than **10% accessed credit**. Among those who accessed savings, approximately 21% also accessed credit. Only 6% reported not accessing any savings scheme. The **size of the settlement seems to play** a role: 46% of households in large settlements indicated accessing savings scheme and only 18% in small localities. This difference is statistically significant. A slightly higher percentage of female-headed households access savings and credit schemes.

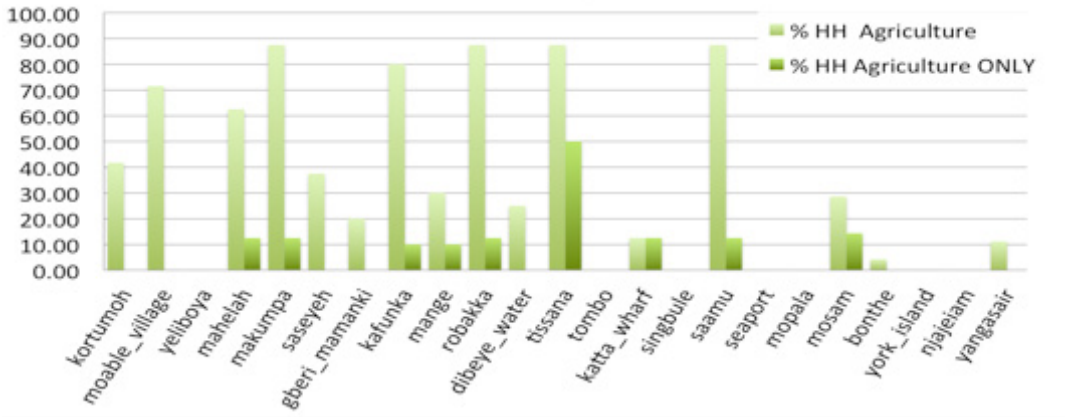

Figure 4.7: Percentage of households engaging in agriculture and percentage of households where agriculture is the only economic activity, by village.

OWNERSHIP

Eighty-nine percent of households owned their own house, and almost 30% own also own a house in another settlement. There is no difference in accessing savings/credit between those who own and do not own a house. Note that assets, including a house, were not considered as savings by the respondents.

Among those households engaging in **agriculture**, only **a few own the land** they farm or access savings/credit schemes.

The ownership of a house reflects very different realities, as illustrated in fig.4.8. Some houses are highly exposed to floods and winds and are regularly destroyed while others, especially in villages located on higher grounds, are sturdier. Building materials and other assets are further captured in the wealth index.

Figure 4.8: Although house ownership is widespread, the living conditions in the fishing villages are difficult. Settlements are dense and villages prone to flooding. Upper left picture shows houses on stilts in the village of Saseyeh (Scarcies), as adaptation to regular flooding. This village has already relocated several times in the past. The village of Moable (upper right picture) is located only a few feet above sea level and is flooded periodically, especially at the peak of the rainy season. The characteristics of the dwellings vary from village to village and houses range from mud huts with thatched roofs to cinderblocks with zinc roofs: village of Mosam (Sherbro) at low tide (lower left panel) is characteristic of fishing communities of Southern Yawri Bay and Sherbro area with houses made of mud and thatched roofs; village of Mange (lower right) in SLRE is located on higher grounds and has sturdier houses than villages located directly on water. June-July 2016. Credit: S. Trzaska.

SOCIAL CAPITAL AND ACCESSIBILITY

Figure 4.9: Most of the village are only accessible by boat, resulting in limited accessibility in bad weather or night time. Disembarking from a boat – most of the villages do not have a dock. Credit: S. Trzaska, June 2016

ACCESSIBILITY

About 30% of the sampled population indicated having no access to schools and local markets and more than 40% had no access to a health center. Several villages like Moable, Sasseyah and Makumpa face strong constraints in access to all three venues.

PARTICIPATION IN GROUPS

Only 25% of respondents do not participate in any group or association but this rate reaches 40% if religious groups are excluded. Participation rates in groups and associations are lowest in small settlements such as Njajeiam, Seaport and Mahela. Support networks are also limited. About 40% of respondents stated they did not receive any kind of support from individuals or organizations. This is consistent with the relative absence of projects and programs in the fishing communities, as opposed to the farming communities, a few miles inland on the mainland, where signs of past and present projects and programs were observed by the team. The situation differs from village to village but it appears that fishing communities have fewer sanitation, nutrition, maternal health and education projects.

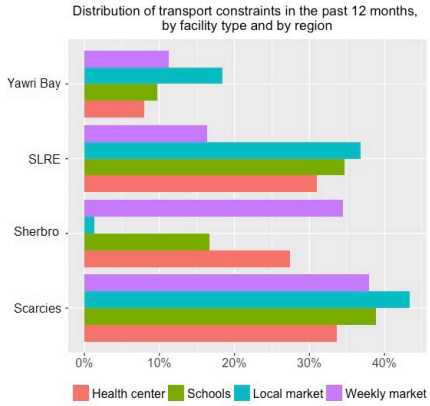

Figure 4.10: Percentage of households reporting access constraints in the past 12 months, by facility type and by region.

MEDIA

The overall ability to access information is limited and the main source is radio. Ninety-six percent of the respondents indicated they did not read a newspaper in the past month. About 60% of the respondents indicated listening to radio once a week but this rate drops in small localities, where 60% or more of respondents indicated they did not listen to radio in the past month.

That said, there is a high use of cell phones: 72% of the respondents own or use a cell phone regularly.

WEALTH INDEX

Various indicators related to the household socio-economic profile, economic and social networks, access to information, energy, food, health, climate impacts and household assets were aggregated into a wealth index and vulnerability components: exposure, sensitivity and lack of adaptive capacity (we invert adaptive capacity so that – as with exposure and sensitivity - high scores are bad). A quick correlation analysis showed that none of the three indicator were significantly correlated with the others, indicating that each indicator captures a different element of vulnerability.

The map in figure 4.11 presents the distribution of households in different wealth categories in each village. There is no clear spatial clustering of the wealthy or poor populations by region. Rather, the wealth index is heavily influenced by the size and remoteness of the village. The highest proportions of households in the wealthiest category (blue) and lowest proportions in the lowest categories (red) are found in the urban and peri-urban settlements of Tombo, Tssana, Dibye Water, Bonthe and York Islands. Villages with high proportions of households in the lowest wealth index category exist in all four regions. Those are the small, most remote villages of Seaport, Singbule, Yangasair, Njajaiem, Robakka, Kortumoh and Moable. The villages visited in the Scarcies region seem to present the best mix of all categories.

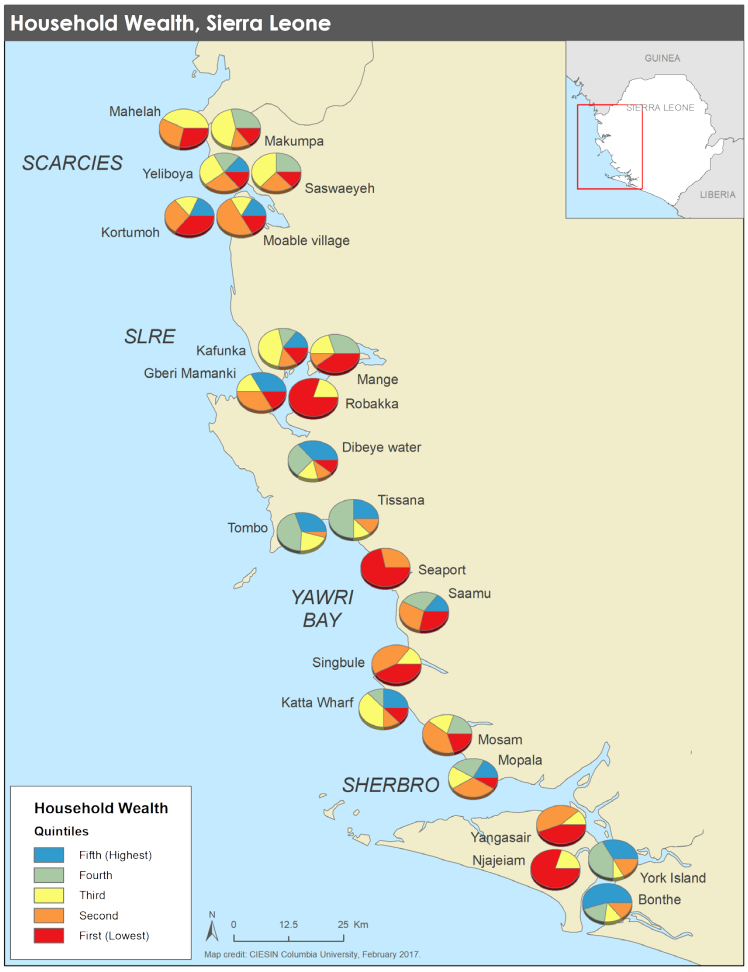

Figure 4.11: Map of the distribution of households by wealth category in each village (note: scores are not absolute but relative to the villages in the study).

CLIMATE, ITS VARIABILITY AND CHANGE

Average conditions

Sierra Leone benefits from a mild tropical climate dominated by one rainy season, the West African Monsoon, from May to November (fig. 4.12). The interactions between this large scale rain-bearing system and local topography leads to annual rainfall amounts, especially in coastal zones, that are among the highest in Africa. Long term estimates of May-November rainfall in the coastal areas based on global gridded data show an average rainfall amount of about 2,700mm/year.

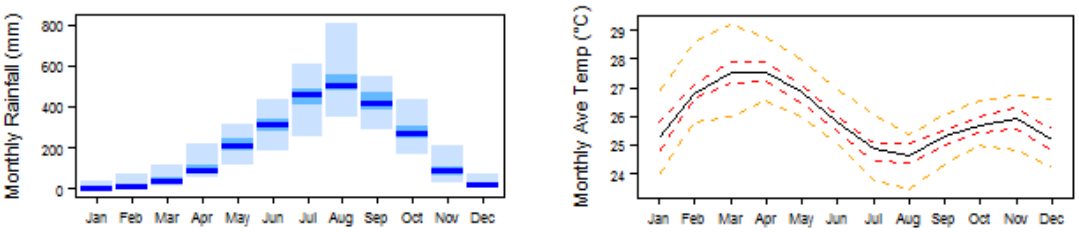

Figure 4.12: Average monthly rainfall (upper panel, mm/month) and temperature in Sierra Leone. (lower panel, in C). Plots based on CRU data (Jones and Harris 2013). Rainfall, upper panel, in mm/month; 1950 – 2012 median (dark blue), interquartile range (medium blue) and max and min for each month (light blue). Temperature, lower panel, in C; dotted lines represent interquartile and maximum and minimum ranges. Source: British Geological Survey, 2015.

Observed climate variability

Rainfall exhibits variations on interannual and decadal scales with a coefficient of variation of about 11%, which is relatively low, and no strong evidence of trends (fig. 4.13). On the other hand, temperature shows an evident and statistically significant trend of approximately 0.14°C per decade (fig. 4.13). The Sierra Leone National Adaptation Programme of Action (NAPA) (Government of Sierra Leone, 2007) describes changes to the timing of the seasons and the number of extreme events.

Projected climate change

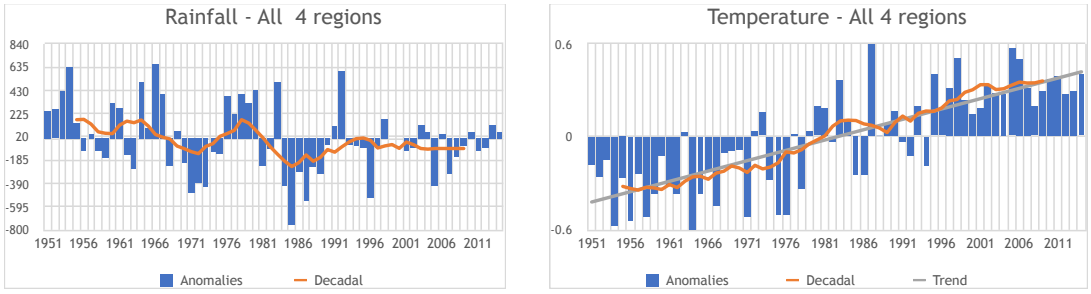

Figure 4.13: Anomalies of rainfall and temperature for the May-November season in the coastal areas of Sierra Leone, over the period 1951-2014. Data Source: CRU, (Harris et al. 2014)

The team has not found customized projections for the coastal areas of Sierra Leone, and instead relied on projections for the country or the larger region. Long term projections indicate an overall increase in temperatures ranging between 1.5°C and 4°C and potential

increase in rainfall (Hartley et al., 2015, McSweeney et al. 2010, Sylla et al., 2016). Thus, if water resources are managed properly, Sierra Leone should not experience water resource scarcity, but the impact of temperature increases on coastal ecosystems needs further investigation.

Within Sierra Leone, there are local differences in climate owing to sharp topographic and ecological gradients. Global datasets and projections often lack fine scale input, thus the information may lack the granularity and accuracy required for local decision-making. However, Sierra Leone currently lacks access to relevant, in situ information about climate, and many other environmental factors. It is only by refining and contextualizing this large-scale picture that a meaningful picture can be developed about potential changes in climate and their impacts.

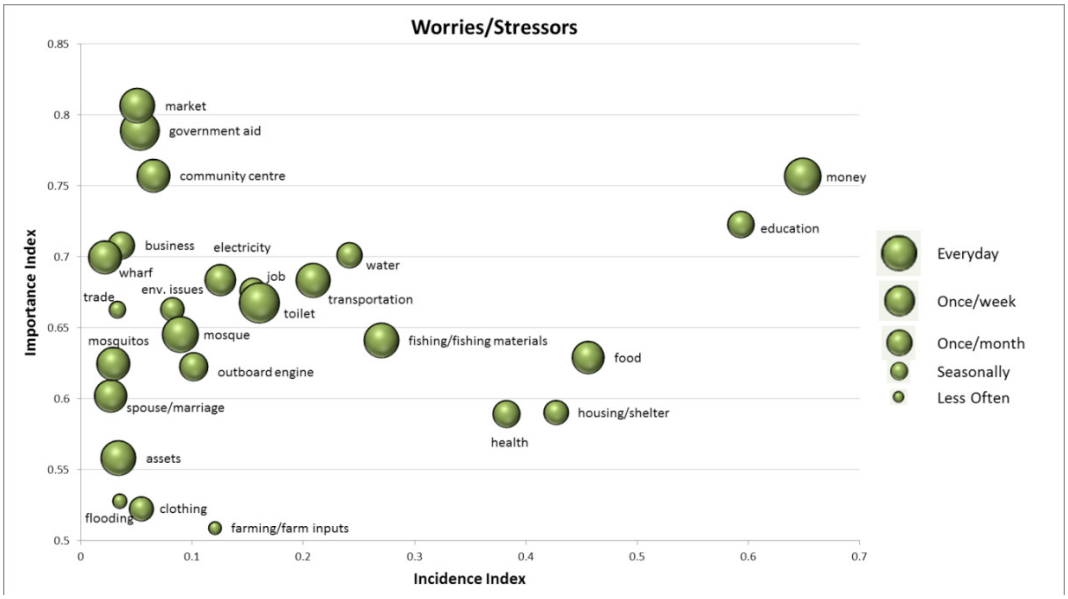

Figure 4.14: Most common worries/stressors identified by participants in focus group discussions, with the frequency of incidence on the X axis, and the relative importance on the Y axis.

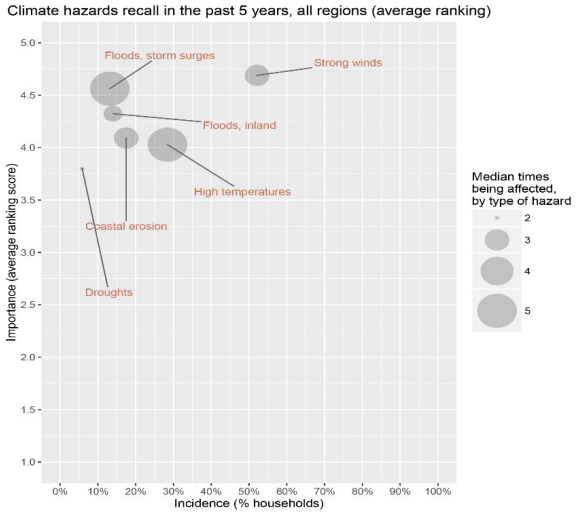

Figure 4.15: Relative rank of climate hazards by the percent of households affected and the median number of times over the past five years that respondents were affected (bubble size)

CLIMATE IMPACTS AND PERCEPTIONS OF CLIMATE CHANGE

Importance of climate-related hazards

Communities living in the coastal areas are strongly affected by climate and weather variability, although those impacts rank low on their list of major concerns. The most important and frequent stressors relate to lack of money, jobs and education (fig. 4.14).

The most frequently mentioned climate/weather impacts are related to heavy winds and flooding (fig. 4.15). Heavy winds cause fires to spread from traditional smoke houses that can destroy houses (fig. 4.16). These winds also damage roofs, and can cause passenger boats to capsize, leading to loss of property and even life. Fires are particularly feared by inhabitants of densely built-up villages and towns. Flooding occurs frequently but is of less concern because it is mainly seasonal and is predictable, which gives populations time to prepare. It is often linked to salt water intrusion and soil and well salinization, thus loss of farm-land and water sources. Hot temperatures are also often cited, but with lower level impacts. of densely built-up villages and towns. Flooding occurs frequently but is of less concern because it is mainly seasonal and is predictable, which gives populations time to prepare. It is often linked to salt water intrusion and soil and well salinization, thus loss of farm-land and water sources. Hot temperatures are also often cited, but with lower level impacts.

Communities and Climate Change

While almost two-thirds of respondents said they have heard about climate change and believe it happens, one-quarter remain uncertain, and 37% indicate they do not consider this to be a major problem for their community. Such low priority given to climate-related issues is consistent with the results of focus groups and underscores the relatively higher importance of other development issues to the communities. It suggests that resilience building in these communities will partly be a function of meeting basic needs while tending to mangrove health.

Figure 4.16: Landscape after fire in Yeliboya, Scarcies region. Several houses had completely burned down.
Credit: S. Trzaska, February 2016

MANGROVES

Mangrove cover and composition

Based on satellite estimates Sierra Leone has lost approximately 25% of its mangroves since 1990. The loss varies according to the regions and is highest in the Scarcies with more than 40% of mangrove forests lost to rice farming, while a marginal increase is observed in Ywari Bay and Sherbro regions. Larger increases in mangrove cover in SLRE can be attributed to reforestation efforts (Fig. 4.17).

Five species of mangrove were recorded across the three regions. The most common is *Avicennia germinans*, followed by *Rizophora racemosa*, *Rizophora harissonii, Laguncularia racemosa* and *Rhizophora mangle*. *Avicennia* dominates in most of the regions except Sherbro, where *Rizophora racemosa* dominates. The Scarcies and SLRE regions have the highest species diversity (all five species are present) while in Yawri Bay and Sherbro only three species were found. In general, the mangroves that have not been converted to farming in the Scarcies region are doing relatively well, with high species diversity, mature forests and high regeneration levels. They are under pressure from cutting and farming, but if human pressures are limited they have high potential to remain resilient.

Sherbro area is on the opposite side of the spectrum, with lowest species diversification, highly dominated by *Rhizophora racemosa,* with the oldest trees and lowest regeneration rates. It is unclear why the regeneration is so low, nor is it clear why there is a predominance of one species. This requires further research. Human cutting for firewood and construction is high in Sherbro, which could be due to the presence of large trees and desirable species. Yet deforestation rates and conversion to rice paddies are lowest in that region. This area has probably the highest commercial potential provided proper management strategies. SLRE has the youngest forests, and signs of past and current forest exploitation. But the regeneration rates and species diversity indicate a healthy forest if human pressures are reduced. The Yawri Bay has fewer adult trees but the highest number of seedlings and is expected to recover easily if protected and sustainably managed.

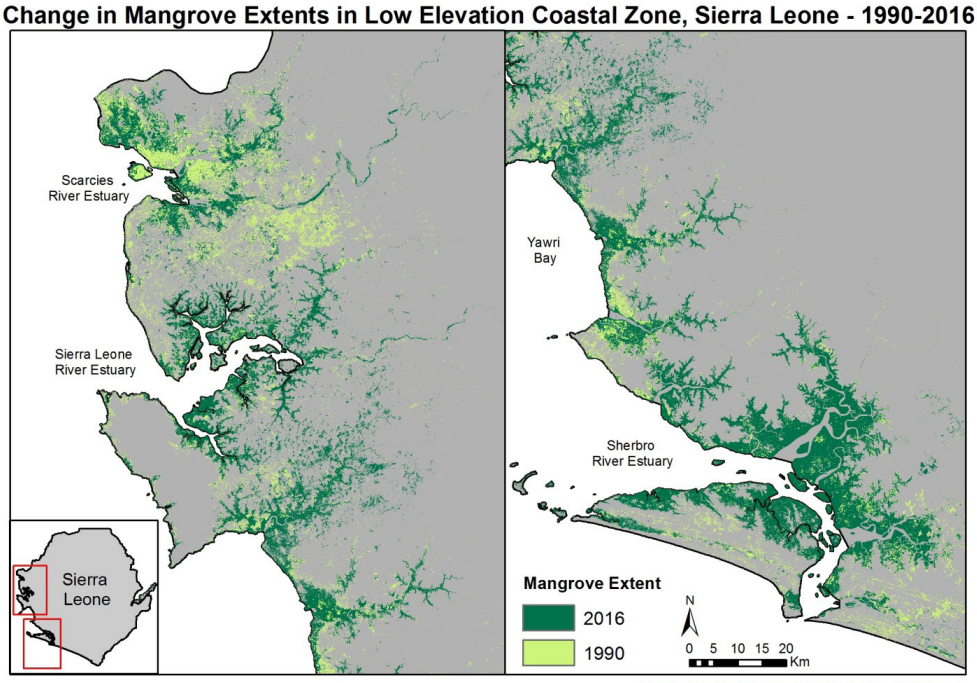

Figure 4.17: Changes in mangrove extents in coastal Sierra Leone between 1990 and 2016. Light green color represents mangrove loss between 1990 and 2016.

Figure 4.18. Adult mangrove trees in the Sherbro area. Photo credit: S. Trzaska, February 2016

Figure 4.19. Young seedlings in the mangrove forest. Photo credit: A. Lebbie, July 2016.

Figure 4.20: Reforested mangrove area in the SLRE region. All the mangrove trees are of same age, and relatively young. Photo Credit: S. Trzaska, June 2016

Mangrove use and perceptions by the populations

Communities depend heavily on mangrove forests. Most respondents (71%) cited fuel wood as a main benefit from mangrove forests, followed by construction and fish breeding sites. Respondents recognized that mangrove wood was used in the household in the previous week, mostly for cooking and fish smoking, and less frequently for construction. About 20% of the households indicated using mangroves as the sole source of fuel for smoking fish and those rates are above 70% in locations like Yangasair and York Island, and reach 100% in Njajeiam. Less than 30% of respondents in each region mentioned traditional or customary rules regulating access to mangroves, and the majority said there were no rules or, if there are such rules, that they are unaware of them.

Approximately 48% of the respondents noticed a decrease in mangrove cover, but nearly 30% could not tell the difference. The decrease has been mostly associated with use of wood for livelihoods and fuel, then construction, while pests and natural causes were listed by less than 10% of the respondents. Loss to farmland was listed only marginally, mostly in the Scarcies where mangroves have been converted to rice paddies. There is a shared perception that the loss of mangroves is linked with human activities. Nearly two-thirds of the respondents stated their willingness to participate in voluntary mangrove preservation/restoration projects and, among those who prefer not to volunteer, 65% said they would participate in exchange for compensation. These rates vary by region with higher levels of potential participation in mangrove reforestation efforts in the Scarcies. It is possible that communities' stated willingness to volunteer to replant mangroves was biased by awareness that the WA BiCC project had a particular interest in the health of mangrove ecosystems.

Figure 4.21. Freshly cut mangrove 'sticks' off-loaded on the beach In Yeliboya. Such sticks are used for cooking and fish smoking. Photo credit: S. Trzaska, June 2016

OTHER ENVIRONMENTAL ISSUES

Resource and governance

An important finding is that most natural resources – farm land, water, fish, sand, forests, and oceans – are considered by the majority of respondents as open access. A very small minority of focus group participants mentioned traditional or government restrictions, with the highest being traditional restrictions for farm land. This view of natural resources as essentially open access may influence behaviors around resource capture. In the absence of restrictions – whether governmental, or preferably agreed upon by the community as a whole through co-management of natural resources – benefits can be captured (or privatized) at minimal cost, and there may be a perception that it is best to capture resources quickly, before others do so. Under such circumstances, there can be little incentive for conservation, and mechanisms such as collaborative management may be required to balance rights of access with responsibility for sustainable management.

Perceptions of changing fisheries resources

Eighty seven percent of respondents engaged in fishing activities indicated that the resource has decreased and linked it to overfishing and bad fishing practices (too many fishermen and trawlers, and catching juveniles) rather than to changes in the environment. The issue of monofilament nets, which are illegal and result in catching of juvenile fish, was frequently brought up in informal discussions. While there is a strong agreement that this is an extremely harmful practice, it remains the most affordable fishing gear and, in the absence of support for traditional nets, their use will likely remain widespread.

OVERALL VULNERABILITY AND ADAPTATION SOLUTIONS

Vulnerability of the socio-economic system

We developed indicators of socio-economic vulnerability – exposure, sensitivity and adaptive capacity – from the survey and PRA data. The highest levels of exposure are in the Scarcies while the lowest levels are found in Yawri Bay and parts of SLRE, where the villages are often located on higher ground (fig. 4.22). Several low-lying villages in the Sherbro area are sheltered from direct impacts of weather and exhibit lower exposure scores.

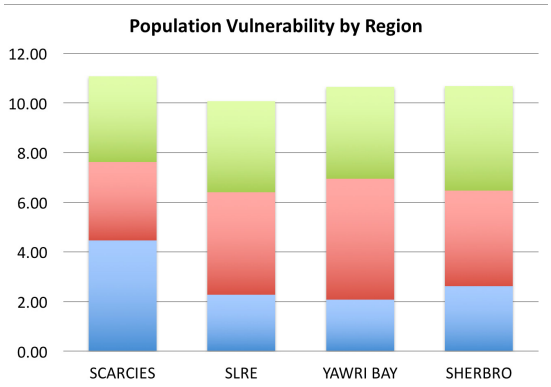

Figure 4.22: Distribution of Exposure, Sensitivity and lack of Adaptive capacity of the socio-economic systems aggregated by region. For a more detailed distribution of different sub-components of the vulnerability, the reader is invited to consult the full report.

The sensitivity of the populations is highest in Yawri Bay and Sherbro area and is independent of locality size.

Villages in the Scarcies and SLRE have varied levels of adaptive capacity, independently of settlement size and accessibility. In Yawri Bay and Sherbro settlements show contrasting adaptive capacity pictures, with larger and more accessible settlements dominated by households with higher adaptive capacity while smaller, more remote villages are dominated by households with lowest adaptive capacity.

Vulnerability of the mangroves

We also developed indicators of mangrove vulnerability based on forest inventories and household interviews. The indicators show highest exposure levels in the Scarcies region and lowest in Yawri Bay (fig.4.23). Yet, the adaptive capacity of the mangroves in the Scarcies, which includes community attitudes towards mangrove conservation, is highest in the Scarcies and lowest in the Sherbro region. Sensitivity, which incorporates current pressures on mangrove forests, is the highest in Yawri Bay and SLRE. Overall vulnerability is highest in the Scarcies due to highest exposure levels and in Sherbro due to lowest adaptive capacity.

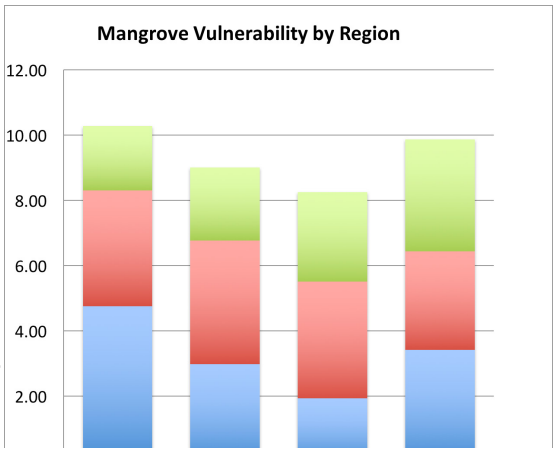

Figure 4.23: Distribution of Exposure, Sensitivity and lack of Adaptive capacity of the mangrove systems aggregated by region

Combined vulnerability

There is no clear spatial pattern to the combined vulnerability; different localities within the same region exhibit different levels of vulnerability. However, localities in the Scarcies and Sherbro areas tend to score higher on overall vulnerability while SLRE and Yawri Bay, with the exception of Seaport, tend to score lower (fig. 4.24). Higher vulnerability levels in the Scarcies are mostly due to higher exposure levels of the human and mangrove systems while in Sherbro area the vulnerability is linked with low adaptive capacity of both systems. The lower vulnerability of SLRE and Yawri Bay seems to be primarily linked to low exposure levels, while sensitivity and lack of adaptive capacity levels (especially of human systems) are among the highest in several of the villages in Yawri Bay.

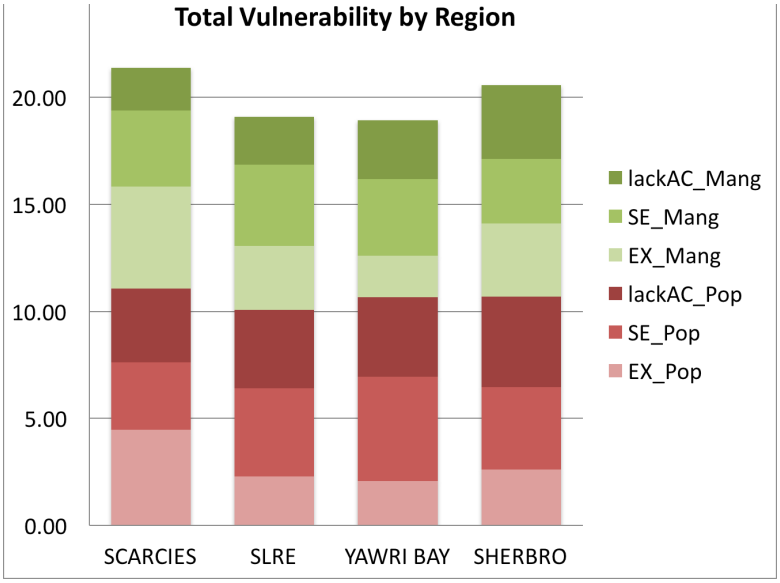

Figure 4.24. Distribution of Exposure, Sensitivity and lack of Adaptive capacity of the socio-economic (red) and mangrove (green) systems summarized by region.

Adaptation Solutions

Communities perceive adaptation to climate change as a multidimensional problem and cite various strategies. Spontaneously cited strategies range from climate change awareness building to construction of improved homes, which includes making them sturdier and/or using local materials, as well as construction of drainage systems, livelihood diversification and contributions to the osusu traditional money pooling system. Approximately two-thirds of focus groups listed reforestation as an adaptation strategy. However, responses may have been biased by the knowledge that mangrove conservation is a WA BiCC project focus area.

Solutions were then qualified according to the degree of preference, difficulty, ability of the community to organize and dependence on external assistance (fig. 4.25). In general protection of homes and reforestation score high on preference and community self-organization, but they are deemed to require external financial or technical assistance. Those interventions that are highly preferred and easy to implement, with the community ready to act and relatively low external dependency include: savings, climate awareness, improving farming, improving roads and building schools. These mostly address the low levels of adaptive capacity. The solutions that are highly preferred by respondents, but categorized as highly difficult to implement with relatively high chance of communities to

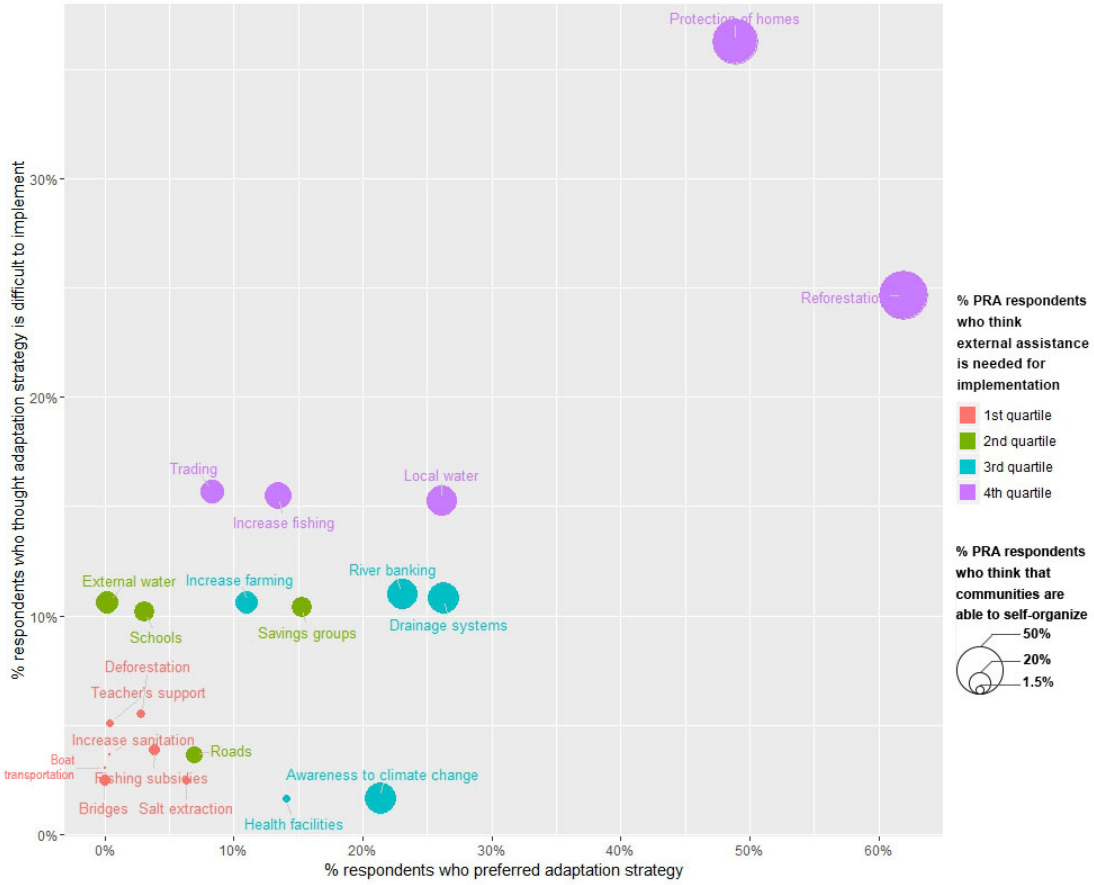

Figure 4.25: Representation of the adaptation solution according to preference (X Axis), difficulty of implementation (Y axis), community readiness (size of the bubble) and need for external assistance (by color, red is lowest need and purple is highest), in all regions but the Scarcies

self-organize, and with relatively high scores for external dependence include: reforestation, house

improvements, drainage systems, improved local water supplies, river bank reinforcement, and expansion of farming and fishing. They mainly address exposure and, to some extent, sensitivity of the populations.

We also sought to determine if the rankings would change in light of potentially changed climatic conditions, such as an increase in the amplitude and/or frequency of harmful climatic events (fig. 4.26). Reforestation, drainage systems and increase in fishing activities all showed a strong decrease in preference for at least 50% of participants (more than 80% for fishing activities) indicating that these solutions are not seen as very effective in addressing potentially increased occurrence or magnitude of disasters. Strong increase in preference was recorded for: sturdier homes, saving groups, improved local water supplies and health facilities. This shows that solutions leading to more secure and healthier living conditions would be the priority for the majority of the respondents.

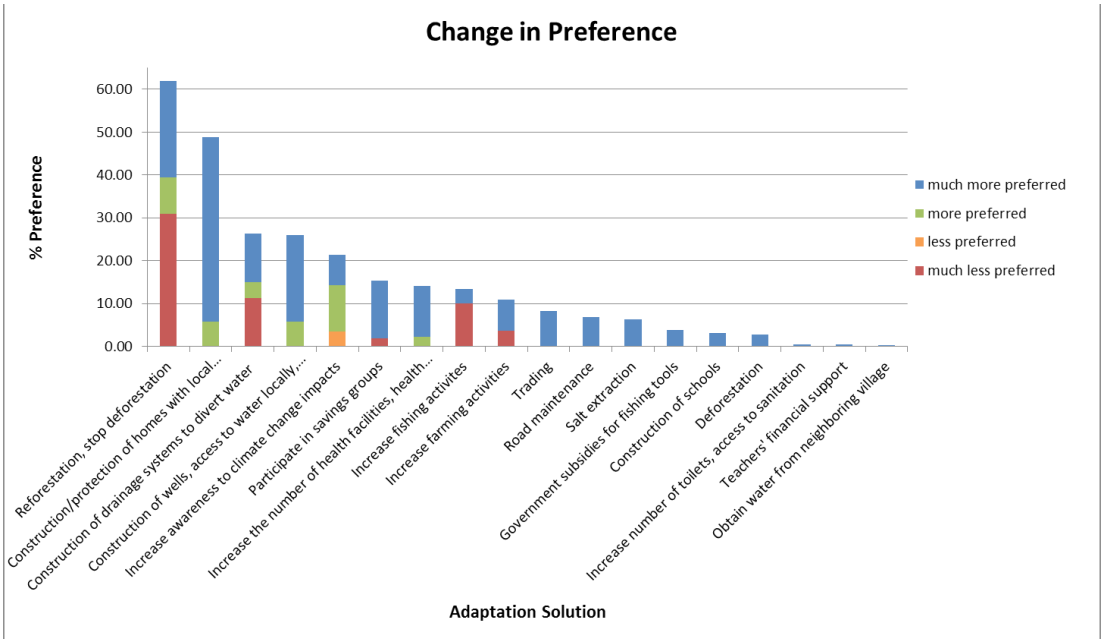

Figure 4.26: Change in the preference for a given solution as percentage of the initial preference score when considering potential future climate impacts. Blue bar indicates the percentage of participants favoring given solution that will prefer it much more, green – more, orange – less and red

5. DISCUSSION AND RECOMMENDATIONS

This study is the most comprehensive assessment to date of the vulnerability of fishing communities in Sierra Leone – and perhaps for all of coastal West Africa. It is based on extensive data collection in 24 villages and 12 transects across the four main mangrove regions. The VA was conducted in close collaboration with national and regional as well as local stakeholders and experts from MAFFS, Ministry of Land, NPAA, EPA, Fourah Bay, Njala University, MRU and Wetlands International. Results were vetted with local experts, and shared during a December 2016 options analysis workshop.

SUMMARY OF FINDINGS

The overall exposure levels are high although differ among locations. The most frequently cited disasters are floods but also winds (and wind-induced fires), which destroy houses and other assets and impact household ability to invest in livelihoods diversification and education. Highest exposure levels are recorded in the Scarcies while in SLRE and Yawri Bay most of households reported that they were not strongly affected. Climate-related disasters do not rank highly among current household worries where short term needs, such as money, food, jobs, education and shelter take precedence. This is consistent with Reid and Vogel (2006) who pointed out that climate stressors are rarely the only concern or stress that constrain 'quality of life' in rural, resource-poor communities in Africa.

The sensitivity of the populations to climate change is high as they are nearly exclusively dependent on highly climate-sensitive resources that are unmanaged and open access, and that will be highly impacted by the effects of climate change in the future. Surveyed populations are characterized by low levels of education, low levels of access to information and financial instruments, low levels of external assistance, pointing to an overall low level of adaptive capacity. Constrained access to vital infrastructure and poor sanitation and water access additionally burden households. Planning for the future and especially anticipating climate change is difficult under such conditions, and more immediate needs take precedence over adaptation to climate change. Yet people see such adaptation as a multidimensional problem and often cite improvement to their current living conditions as the main adaptation strategy.

Differences between communities exist but are not striking. The main differences between the small and large settlements are in terms of wealth index and access to financial instruments. Some degree of spatial clustering is observed in exposure, where the villages in the Scarcies show systematically higher levels of exposure then the villages in SLRE and Yawri Bay, and in general between low lying villages and villages slightly higher up. Interestingly, despite higher exposure levels, the Scarcies are the region scoring lowest on sensitivity which was found highest in Southern parts of the coastal stretch surveyed in this study. Lack of adaptive capacity reflected to a certain degree the wealth index with lowest levels in smaller and more remote localities of the Yawri Bay and Sherbro region. It exhibited a rather equal distribution among the households in the Scarcies. Different components of vulnerability often compensate smoothing the contrast between regions and locations but overall the highest levels of vulnerability are observed in the small, more remote villages, across all regions.

Mangrove status differs between regions but here too, compensation between different components also plays a role in the vulnerability of the mangroves. Mangrove forests have been most severely cut down in the Scarcies region, including around fishing villages and present the highest species diversification and regeneration rate among all the areas visited. While species diversification is an indicator of forest disturbance in the short term, in the longer term it will help the forest to adapt to new environmental conditions. Communities living in the mouth of the Scarcies river are also the most willing to participate in reforestation and management efforts. This points to the fact that with a strong community engagement and some external

technical support for reforestation and implementation of management practices there are good prospects for mangrove forest regeneration in this region.

In the SLRE overall the mangrove extent has increased thanks to multiple reforestation projects but in many of reforested areas mangroves remain young and have not reached self-sustained regeneration stage. With multiple pressures present, from urbanization, to agriculture, to sand mining and industrial pollution, working with the communities and building their capacity to better understand the benefits of mangroves and sustainably manage and protect them is essential in this region. The picture is very different in the Sherbro area, where mangroves are oldest but less diversified (indicating lesser forest disturbance but lesser adaptive capacity) and with smaller regeneration rates. Understanding the reasons for this lack of regeneration and working with communities to establish sustainable management practices will be necessary to maintain the resource in the future in this region. In Yawri Bay mangroves are also mature, with larger regeneration rates but have marginally decreased over past decades on their landward side, indicative of encroachment from farming. Community awareness building around mangrove services and community-based management systems should ensure sustainability of the resource.

IMPLICATIONS

Fishing communities are likely to be among the most highly affected by climate change in Sierra Leone through combined impact on their habitat and livelihoods. They reside in areas already strongly affected by climatic events, such as floods and heavy winds - which may become more frequent and/or stronger - and rely nearly exclusively on unmanaged resources – wild fish catch and mangrove wood for fish processing and other household fuel needs, all of which will be affected by changes in temperature, rainfall and wind patterns. Living in remote, difficult to access areas these populations remain largely 'below the radar' of government and international aid or NGOs and could be considered as marginal. Yet, experience from the field, combined with inspection of satellite images of the mangrove areas, shows a significant population living within the mangrove zones in a multitude of small, but densely built and populated settlements. In addition, fisheries, while contributing only moderately to the overall GDP of Sierra Leone, are important for country's food security and nutrition as fish is the main source of animal proteins for an overwhelming part of the population. Most of the catch and its processing is still done within the artisanal sector and generates significant employment.

While the fish and mangrove resource seem still sufficient to support these populations, changes in water depth, water temperature and rainfall patterns could potentially affect it in the future, especially in terms of species distribution and availability. There is little information and little institutional planning for the resource evolution in the future. Populations are mostly unaware of the potential resource evolution linked to future changes in climate and sea-level, and are unable to prepare for it, given their focus on meeting short-term subsistence needs. Limited knowledge and access to information and education, high burden from basic needs combined with limited financial capacity and limited access to financial instruments are not conducive to autonomously generated long-term planning and adaptation.

Current institutional support within community-based management systems, when implemented, is mostly geared towards short-term resource exploitation, promoting for example conversion to rice paddies, rather than having a holistic approach that includes all the ecosystem services and long term perspective. On the other hand, in certain areas, mostly where significant mangrove restoration efforts have taken place, the authorities have adopted harsh approaches to mangrove protection (fines, burning of the boats and imprisonment), without accompanying measures, thus often antagonizing populations.

Sustainability of the resources and future benefits from mangrove conservation such as coastal protection or carbon sequestration will be contingent on appropriate institutional mechanisms and buy-in from the communities. The latter will require addressing their basic needs and empowering them to manage their own resources. While some of the interventions fall into traditional development realm, they are a pre-requisite to successful resource conservation and reflect the current lack of support and interventions in those difficult-to-access areas[6]. The effort of reaching out to those remote communities will result in resource conservation and resilience that will benefit Sierra Leone as a whole, not solely the targeted populations.

RECOMMENDATIONS

The following is a proposed set of interventions. Some of these recommended activities go beyond the mandate of the WABiCC project, reflecting the most salient needs of the populations and ecosystems that would build the resilience of communities and productivity of the coastal zones in Sierra Leone. We organize our recommendations in the following categories:

IMPROVE NATURAL ENVIRONMENT MANAGEMENT PRACTICES

Current institutional support within community-based management systems, when implemented, is mostly geared towards short-term resource exploitation, promoting for example conversion to rice paddies, rather than having a holistic approach that includes all the ecosystem services and long term perspective. On the other hand, in certain areas, mostly where significant mangrove restoration efforts have taken place, the authorities have adopted harsh approaches to mangrove protection (fines, burning of the boats and imprisonment), without accom

For mangroves:

- Sensitize the populations to the issues of mangrove ecosystem services and dynamics in order to develop a better understanding of the requirements for sustainable mangrove forest use, beyond fulfilling short-term needs.
- Design and implement community-based mangrove management systems that take into account direct and direct ecosystem services, building on existing community-based management systems.
- Design a national guidance for community-based mangrove management system and national rules for mangrove areas access and use, encouraging communities to take responsibility for mangrove management in return for rights of access and use.

For water and sanitation:

- Design and deploy sanitation systems suitable for low-lying and flood-prone villages to insure a healthier environment and decrease water contamination. This should also improve the sanitary quality of fish and shell-fish.

6. Field team has observed many signs of various projects and initiative a few miles inland, within more accessible farming communities but little, if any, such presence in the fishing communities within the mangrove areas, in agreement with the findings from the survey.

LOWER EXPOSURE AND IMPACTS OF CLIMATE AND WEATHER DISASTERS

- Design and implement effective fire prevention and combat systems in all the villages, working with communities and building off existing initiatives such as a Red-Cross supported project in Bonthe.
- Support the Meteorological Agency of Sierra Leone in designing an extreme wind and storm early warning system (EWS) for different sections of the coast. This activity will require additional research into synoptic situations leading to heavy wind/storm events and their predictability and research on the most effective ways of disseminating alerts, e.g., through SMS. Eventually, a flood EWS could also be designed.

Figure 5.1: Village of Moable (Scarcies) at high tide, July 2016. It is easy to imagine the impact of storm surge and high winds on the village and the importance of monitoring and early warning systems to anticipate short term and long term adverse effects of extreme weather and climate change Credit: S. Trzaska.

- Facilitate implementation of locally designed infrastructure such as drainage systems, higher embankments, and wind barriers (tree planting) to lower exposure to weather and climate disasters and their impacts, taking into account and sensitizing populations about future changes in disaster frequency and/or amplitude.

LOWER THE SENSITIVITY OF THE POPULATIONS TO CLIMATE RELATED DISASTERS

- Support livelihood diversification
- Improve food-security and nutritional status through implementation of raised-bed gardens that could provide supplementary vegetables and condiments, especially during the hunger season, as well as an activity for women and in particular female-headed households.
- Improve health and sanitation; support design and implementation of sanitation facilities addressing the particular conditions in low-lying, flood-prone villages.

Figure 5.2: Raised-bed garden in a village a few miles inland in Yawri Bay area. Raised bed gardens have the advantage of being flood- and soil salinization-proof and could be installed in areas where farmland is limited and tended to by women. Photo credit: S. Trzaska, July 2016

- Explore housing construction techniques that are suitable for the particular conditions in the coastal areas. For example thatch roofs are most suitable for the sea spray conditions, provide best thermal insulation and rely on local materials and skills, but are flammable and not durable. Zinc has low insulation capacity, is also not very resistant to sea spray and is relatively costly, but resists fires better (especially for bandas).

INCREASE THE ADAPTIVE CAPACITY OF POPULATIONS

- Build awareness around climate variability and change to allow populations to better understand and anticipate changes to their livelihoods and prepare autonomous adaptations. In particular create greater awareness around sea level raise and temperature increase.
- Improve access to information on climate and climate change and its understanding for different stakeholders, from local government to individuals.
- Improve access to education, including vocational education and education for girls and women.
- Improve access to and understanding of financial instruments.

IMPROVE SIERRA LEONE'S CAPACITY TO MONITOR ENVIRONMENTAL CONDITIONS AND PROJECT IMPACTS OF CLIMATE CHANGE

In order to develop national and local climate change adaptation strategies a better understanding of current and future climate impacts is needed. Since adaptation occurs at the local level, such understanding needs also to be developed at the local level and needs to be anchored in local information and data. At this stage little quantitative information about the climate system is available to decision-makers in Sierra Leone at scales compatible with adaptation. Given the steep climatic and environmental gradients existing in Sierra Leone the reliance on global gridded datasets cannot provide information that is detailed enough to capture local differences. As discussed earlier, such datasets also interpolate between existing observational records, which, in areas with little in situ information may result in information that is not accurate and reflects rather distant observations. While such datasets are useful at global scale they cannot be used to design local adaptation strategies. In addition, because of the interpolation, they usually poorly capture the extreme events that are most damaging. It is thus critical for Sierra Leone to develop the capacity to monitor, archive, analyze and extract information in a number of areas such as: rainfall, temperature and wind; sea-level and storm-surge; physical and chemical characteristics of coastal waters; and sedimentation. In addition there is a need to develop the capacity to model coastal dynamics and ecosystems to evaluate impacts of changing climate conditions in the future on the coastal zones. Such models have been developed for other regions but need to be adapted for the local conditions of Sierra Leone.

More concretely we suggest:

- Increasing the capacity of the Meteorological Department of Sierra Leone to provide stake-holders with relevant information on past, current and future climate. This includes digitizing current data holdings and ensuring the automation of future record acquisition, sufficient storage, appropriate software and personnel training. The information that could be provided ranges from the statistics of historical climate, to seasonal climate forecasts, early warning systems, to localized projections of climate, contextualized using historical climate records and tailored to different sectors.
- Development of coastal water monitoring system capturing its level and physical and chemical properties, with relevant data storage capacities as well as strengthening the capacities of relevant institutions to analyze the data.
- Support the capacity of the research institutions to develop ecosystem and sectoral

impact models tailored and validated to Sierra Leone enabling the use of information on past and future climate to derive impact of climate change on natural and human systems.

LESSONS LEARNED

- **Shaping the research focus based on initial reconnaissance** – In places like Sierra Leone little recent scientific and grey literature is available. The two week long mission to Freetown and to several potential research locations conducted in February 2016 was critical to the design of the study as it helped to formulate some early conclusions that oriented the scope of work and survey content, as well allowed to identify collaborators in Freetown.

- **Working with local research teams** – While not necessarily a major innovation, this research confirmed that field research in Africa is best undertaken by teams with extensive local knowledge who are also invested in successful results. While recent scientific publications may be sparse, there usually is good local knowledge as well as understanding of local conditions within local research and governmental institutions.

- **Adequate training and preparation of field teams** – The training period is vital and included both theoretical training in field research methods, and hands-on training in the SLRE. This combination ensured that the teams understood well the objectives and importance of the study and that data collection was conducted in a consistent way by different teams in different locations. Issues were worked out in advance of the deployment

- **Linking with local communities** – a visit to the communities selected for the surveys prior to the deployment of the full teams allowed to explain the study and obtain the buy-in of the communities, as well as to assess the logistics of the field work[7] in such remote areas. A result restitution and further focus groups discussions conducted by WABiCC as a follow-up allowed to prioritize intervention options the project can further support. However, given that these communities receive little support in general, special care needs to be taken in managing their expectations.

- **Exploiting the information** – the analyses performed for this vulnerability assessment allowed to document the main socio-economic and biophysical aspects of the vulnerability to climate change of the target populations and mangroves but much more information can be further extracted from the data collected. It will be vital to design a mechanism or a platform to share the data and support further research in this generally data sparse region.

7. In particular the capacity of these small, remote communities to host teams of a dozen of socio-econmic and forestery enumerators.

AREAS FOR FURTHER RESEARCH

While the VA collected a large amount of quantitative data, several aspects of the systems still require further documentation and data collection. A detailed discussion of these aspects is provided in the full report and here we provide a summary list of aspects not included in this study. Among these:

- **Physical and chemical properties of the water and dynamics of sedimentation** – requires longer term monitoring, beyond the scope of this study.
- **Sea level rise** - sea level rise will not be globally uniform and at local level will depend on numerous local factors for which data are not currently available for the coastal areas of Sierra Leone. Rather than use only global projected trends we have preferred to focus on understanding vulnerabilities experienced by the populations.
- **Food security and nutrition status**. This study found alarmingly low food security status among surveyed populations. A bias in answers cannot be ruled out as well as the influence of the 'hunger season'. It is advisable that food security surveys be conducted at different times of the year to assess more robustly the food security and nutrition status of the populations.

Figure 5.3: Left: Woman sitting in the smoke house in Bonthe. At the time of the picture the grill was folded and not used for smoking fish, only as cooking facility, but it is easy to imagine the smoke women are exposed to while tending the banda, which cannot be left unsupervised. Right: children, especially girls, spend a significant amount of time with their mothers inside the bandas Photo Credit: S. Trzaska, July 2016

- **Health issues related to fish-smoking**. Smoke-related health problems may be under-reported in local health facilities as women seem to self- medicate and resume their activities, even after hospitalization[8]. Smoke may also affect children as young children tend to stay with their mothers and caregivers around the bandas and older children often help with the smoking process. Impacts of smoke on health warrants more investigation[9].

8. Surveys of health-related issues require much higher levels of confidentiality and scrutiny of survey instruments under Columbia University ethics rules, not compatible with the WA BiCC project time frames. The team was however able to conduct informal inter views with women engaging in fish-smoking[7]

9. No data are available on cancer rates among those involved in fish smoking, but given Sierra Leone's average life expectancy of only 52 years at birth (for women) (PRB, 2016), it may be that cancer is not a major cause of death.

- **Health issues related to poor sanitation** also need more attention. Lack of toilet and reliance on the tide to clean the beach lead to high levels of water contamination that leads to outbreaks of water-borne diseases such as cholera and typhoid, since the populations frequently enter contaminated water. Incidence of water borne diseases and their economic burden on populations should be assessed.
- **The economics of fish smoking** – in many instances this is the only activity available to women and the economics require further study.
- **Shell-fish harvesting** - a widespread activity that also uses significant amounts of mangrove wood to process oysters. The reader is invited to consult the documentation of a project specifically designed to study this activity[10]. WA BiCC may benefit from the approach used to community-level work implemented in that project.
- **Education levels among children** – given the reported constraints in access, as well as high overall rank of education on the list of stressors, current levels of schooling among the children warrant further investigation and support[11]. Education is an important means of increasing autonomous adaptive capacity of individuals, households and communities and may require specific support in these isolated and vulnerable communities.
- **Migration** - It will be interesting to analyze the outmigration and the net migration in the coastal mangrove communities to assess whether this is one of the adaptation strategies already taking place.
- Finally, it is noteworthy that **several economic forces and different actors** are present in the area. In addition to unauthorized foreign fishing boats, several foreign companies have access to fishing grounds legally, and that these activities potentially compete with local populations[12].

Figure 5.4: Chinese tuna fishing fleet in the Scarcies River Estuary (right) and a boat belonging to South Korean Company on York Island (left). Photo Credit: S. Trzaska, July 2016

10. See http://www.stir.ac.uk/aquaculture-mangrove-oyster/

11. The team noticed numerous schools and projects around education in farming villages, a few miles inland but no signs of such activity in the fishing villages.

12. E.g. a South Korean investor on York Island and an even larger player in Yawri Bay and Sherbro area, the Neptune Company from Iceland, with a large volume smoking facility and plans for export.

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U. S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, D.C. 20523
Tel. 202-712--0000
Fax. 202-216-3524
www.usaid.gov/biodiversity