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TECHNICAL REPORT

CLIMATE CHANGE AND HEALTH RISKS IN SENEGAL

September 2015

This document was produced for review by the United States Agency for International Development. It was prepared by Chemonics for the ATLAS Task Order.

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Cover Photo:

A woman practices good mosquito net care and repair, a key component of campaigns in Senegal with NetWorks and the National Malaria Control Programme (NMCP). © 2011 NetWorks Senegal/CCP, Courtesy of Photoshare

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September 2015

Prepared for:

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Climate Change Adaptation, Thought Leadership and Assessments (ATLAS)

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ACRONYMS

AEJ	Africa Easterly Jet
AMCOW	African Ministers Council on Water
AR5	Intergovernmental Panel on Climate Change 5th Assessment Report
CDCS	Country Development Cooperation Strategy
CMIP5	Climate Model Intercomparison Project 5th Iteration
CSAG	Climate Systems Analysis Group
CSO2	Second Country Status Overviews
CRU	Climatic Research Unit of the University of East Anglia
DLM	Ministry of Health's Directorate of Disease Control
DRM	Disaster Risk Management
FEWS NET	Famine Early Warning Systems Network
FAO	Food and Agriculture Organization of the United Nations
GCM	Global Chronic Malnutrition
GIS	Geographic Information System
GFCS	Global Framework for Climate Services
GOS	Government of Senegal
HNAP	Health National Adaptation Plan
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
IYCF	Infant and Young Child Feeding
IVM	Integrated Vector Management
MOH	Ministry of Health
MPHPA	Ministry of Prevention, Public Hygiene and Sanitation
NAPA	National Adaptation Program of Action
NTD	Neglected Tropical Diseases
ORS	Oral rehydration salts
PDNS	National Health Development Program
PIS	Program Investment Sector

RCP	Relative Concentration Pathway
SCI	Schistosomiasis Control Initiative
SDE	Sénégalaise des Eaux
SOMD	Self-Organizing Map based Downscaling
SONES	Société Nationale des Eaux du Senegal
SST	Sea surface temperatures
TEJ	Tropical Easterly Jet
UNOCHA	UN Office for Coordination of Humanitarian Affairs
WHO	World Health Organization

EXECUTIVE SUMMARY

The aim of this study is twofold: 1) to identify the extent to which the health sector in Senegal is vulnerable to climate risks, and 2) to suggest ways to integrate a climate change perspective and thereby improve resiliency of interventions into USAID/Senegal's health portfolio. It is meant to be a tool for USAID/Senegal's Global Health Program to assist in implementation and decision making in the face of unprecedented changes in climate that affect USAID/Senegal's health portfolio work. Specifically, the study examined the potential change in health outcomes due to climate change, analyzed existing capacity to respond to these changes, and identified strategies to better prepare and strengthen response systems.

Key findings from this work are presented here.

A. CLIMATE CHANGE AND VARIABILITY IN SENEGAL

Senegal is already vulnerable to climate variability. Meteorological records available over the last 40 years (1965-2008) suggest a strengthening of the hydrological and climate cycles, with more intense rain falling in shorter periods of time, and an amplified dry season, both of which have affected agricultural production and food security. Floods now occur more frequently during the rainy season (June to September) as a result of intense rain, coastal erosion, and soil degradation. The following specific changes in climate have been observed in Senegal:

- Increased temperatures of 0.9°C per year since 1975, a value higher than the projected global averages.
- Rapid decline in rainfall between 1950 and the mid-1980s, with partial recovery through 2009.
- Even though rainfall totals recovered from the 30-year period between 1950 and 1980, this recovery was only partial, and remains below the long-term averages by 15 percent. This change corresponds to a 150 to 50 millimeters reduction across much of the country and is particularly important in the densely populated western regions of Thies, Diourbel, and Kaolack as well as the southeast, in Tambacounda.

These trends already pose significant impacts on agricultural productivity (malnutrition), water availability and quality (waterborne disease outbreaks), and health system functions (infrastructure and service delivery), which are themselves already under stress from high population growth rates and other development pressures.

The best available predictions of long-term changes in climate are derived from the large-scale Global Circulation Models (GCM) that informed the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report. According to the report, the following high confidence changes are projected for Senegal:

Temperatures will continue to rise, with higher increases in the interior than in coastal areas and also higher increases in the dry season. According to the IPCC's high range scenario for the mid-21st century (2040-2059), Senegal as a whole will experience a significant rise of about 1.0-1.4°C by mid- century, when compared with the 1986-2005 period. By themselves, increases in temperature can have a significant impact on human health. For example:

- Increased incidence of waterborne diseases such as cholera and diarrheal disease especially during the dry season, which will be more pronounced. This is because higher temperatures will alter water availability and quality.
- Negative impact on agricultural productivity, with increased malnutrition in chronically food insecure regions. Even without climate change, there are already serious concerns about agricultural productivity in Senegal.

Incidences of extreme weather events could increase, with implications for nutrition and disease burdens. The range of projected changes for rainfall in Senegal is large, with GCM-based projections ranging from increased rainfall to decreased rainfall. What is clear, however, is that climate variability and the incidences of extreme events will increase in the future. The resulting impacts on human health are potentially quite large. For example:

- Three decades of drought — which has been called "the biggest climatic anomaly observed to date"— have led to increased migration to cities. This migration has resulted in a rapid and uncontrolled urban growth of the country's cities, where service provision for lifeline utility systems (e.g. water, waste management and electricity) has lagged behind and contributed to increased incidence of waterborne disease outbreaks. The health impacts of drought, a slow onset, long-duration and spatially diffuse emergency, are indirect and under-reported. But in Senegal, they likely include nutrition-related effects (general malnutrition, mortality, and micronutrient malnutrition) as well as waterborne illnesses.
- Evidence from other African regions point to spikes in the reported incidences of waterborne diseases due to extreme and heavy rainfall. It is likely that extreme/heavy rainfall will increase slightly during the rainy season, which could increase the risk of flooding, a hazard that already causes significant damage in the country. For example, the floods of 2009 in Saint Louis, Kaolack, Thies and Dakar caused the temporary displacement of more than 200,000 people and resulted in more than US$103 million in damages and losses. Flooding in 2012 in St. Louis, Bambey, and Dakar displaced more than 5,000 families. In addition to losing their homes, displaced persons frequently lose their livelihoods as well.

High uncertainties in rainfall projections suggest two plausible pathways of changes in climate for the country, both with significant implications for the health sector. When looking to future health risk, one is faced with a wide spread of future climate projections. This is largely due to the complexities of the West African climate, which is characterized by multiple drivers. It is important to note that, based on current science, the scenarios described are equally plausible. Health adaptation should aim to address risks incurred equally. However, regardless of scenario, it is clear that Senegal's future will be warmer under both wet and dry scenarios—suggesting the need to emphasize adaptation mechanisms that address and target temperature impacts through training, surveillance and resources:

- Mosquito borne diseases such as malaria and lymphatic filariasis, particularly in the south.
- Diseases resulting from reduced quality or viability of water resources such as cholera, especially in the south and northeast.
- Projected increased risks of schistosomiasis outbreaks in the northeast.
- Meningococcal meningitis detection and treatment in the center of the country.

The two scenarios include:

1. Moderately warmer and wetter. Cooler maximum temperatures are often found during Senegal's core rainy season and are attributed to the increased cloud cover and moisture during this period. In this "Moderately Warmer and Wetter" scenario, a future increase in rainfall would result in the change in temperature only being moderately higher than those currently observed. This is particularly true for southern areas, which are projected to be wetter than the rest of the country. The wetter conditions in the south could arise from either a more intense monsoon or a prolonged monsoon. The dry season will still experience the greatest increases in temperature. Under the wet future scenario, the risk of malaria and lymphatic filariasis may increase in the north.

2. Stronger warming and drying. In contrast to the previous scenario, with drier conditions (i.e. less cloud cover and rainfall), the country would not experience, to as great an extent, the cooler temperatures often found during the rainy season. The seasonal variation in temperature would also be much greater than currently observed across the country. The inland regions (especially the northeast) would experience greater temperature increases than the coastal regions. Given the low rainfall totals experienced in today's climate across the north, this area could be more vulnerable to a decrease in rainfall compared to the southern parts. Nutritional declines could also take place there given the projected decrease in rainfall. Under a dry scenario, the risk of malnutrition is elevated across the country. The risk of malaria and lymphatic filariasis may decrease in the north.

Given the uncertain climate projections, particularly in this region of Africa, both scenarios are equally plausible. This points to the need to improve surveillance and response protocols in a targeted geographic way to address both potential scenarios as discussed in Section V. Climate-linked Approaches to Health Systems Strengthening.

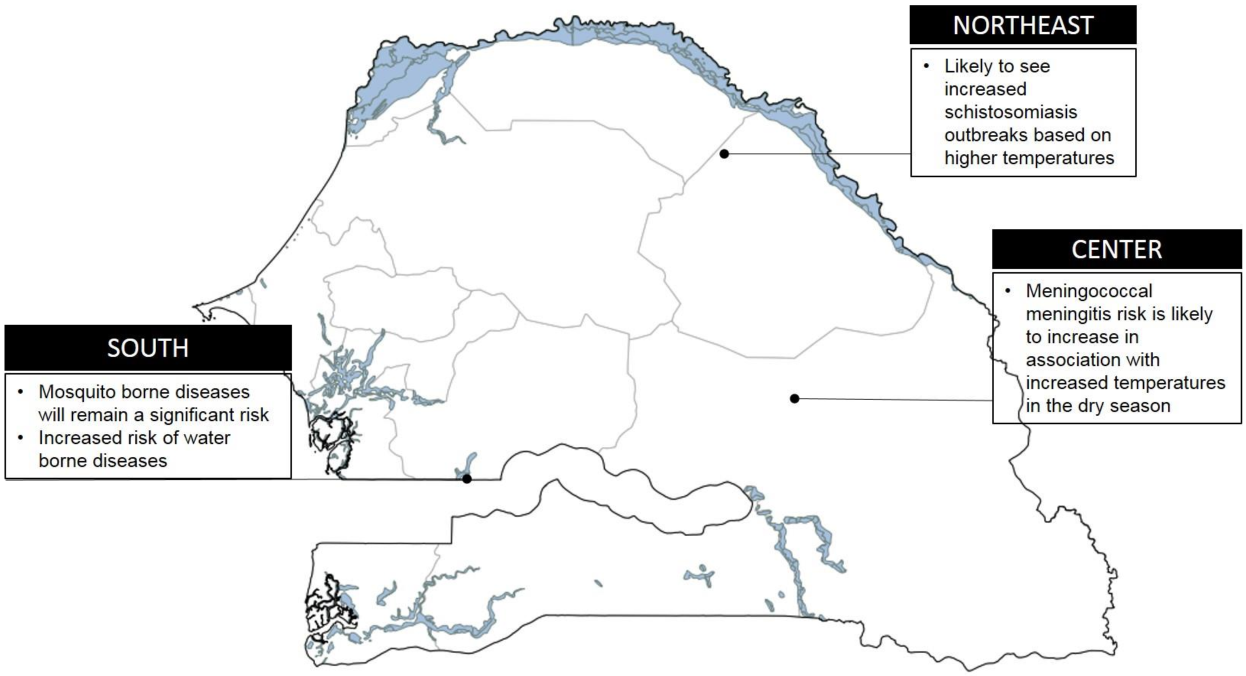
B. GEOGRAPHIC HEALTH PRIORITIES

It is important to note that with regard to the changing climate, four regions of Senegal emerge as priorities, with location-specific disease burdens that should be closely monitored, and for which specific surveillance systems need to be designed. These are summarized in the matrix below and described in detail in the following sections:

Table 1: Summary of key climate-related health risks projected for Senegal

HEALTH RISK	PROJECTED CHANGES	EXPLANATION	GEOGRAPHIC HEALTH PRIORITY
MALARIA	+++	uncertain in the north	South
LYMPHATIC FILARIASIS	+/-	uncertain in the north	North
DIARRHEAL DISEASE AND CHOLERA	+++++		South
SCHISTOSOMIASIS	+++		Northeast
MENINGOCOCCAL MENINGITIS	++	dry season	Center
UNDERNUTRITION	++		South

Figure 1: Summary of key climate related health risks projected for Senegal



South:

- Mosquito borne diseases will remain a significant risk, particularly in the south of the country. The south could face an increased rainfall scenario with potential changes in the distribution of waterborne diseases and those with clear linkages to more intense rainfall events such as cholera.

- Malnutrition is already a problem in this region, where the majority of the country's food insecure people reside, particularly around Ziguinchor and Kolda regions of Casamance, and in Kédougou and Kaffrine regions.
- Increased risk of waterborne diseases. There is a consistent message of warming across all models. This higher temperature may lead to reduced water supplies and reduced water quality, particularly during dry periods.
- The risk of cholera, diarrheal diseases and schistosomiasis may remain high across the country, in association with the increase in extreme/heavy rainfall. However, the risk may be more acute in the south.
- Increased risk from waterborne diseases such as cholera and diarrheal disease – particularly around Dakar and vicinity – home to 25 percent of the country's population, which is prone to flooding as well vulnerable to coastal erosion and sea level rise.

Northeast:

- Likely to see increased schistosomiasis outbreaks based on higher temperatures.

Center:

- Temperatures are expected to increase more in the interior than at the coast across both scenarios, with temperature increases higher in the dry season than the wet summer season.
- Meningococcal meningitis risk is likely to increase in association with increased temperatures in the dry season. This is particularly important in the inland areas more than the coast.

North:

- Under the wet future scenario, the risk of malaria and lymphatic filariasis may increase in the north. However, under a dry scenario the risk of malaria and lymphatic filariasis may decrease in the north.

C. RECOMMENDATIONS

Evaluation of the Government of Senegal Ministry of Health's readiness defines strategic planning activities that can help the country evolve along an adaptation continuum, which begins at 'good development' to increasing levels of action in light of projected climate risks. The available evidence base, existing planning mechanisms and capacity for adaptive management are all components which must be considered when determining the GOS/MOH readiness to adapt to a changing climate. Adaptation interventions to be implemented to help the country's health system become more prepared to deal with current and projected future risks are prioritized below. The prioritization is based on several factors including: the robustness of the evidence available for linking climate change to health risks, the urgency of the risk with respect to current climate variability and the potential to mitigate these risks by implementing early action. It is important to note however, that these early recommendations are based on a thorough desktop analysis and could be further strengthened by a grounded institutional assessment in country.

C.1 TOP-TIER PRIORITIES

Geographic health priority 1: Waterborne illnesses in the south

Develop flood early warning system in the south that links weather observations to epidemiological surveillance to prevent and/or contain waterborne diseases. With each rainy season in Senegal come reports of large-scale flooding and equally large-scale damage, particularly in the southwestern part of the country, affecting between 100,000 and 300,000 people. These events are linked to increased burdens from waterborne illnesses such as cholera and diarrheal disease. While quantitative data for Senegal on the number of people affected by cholera are not available, evidence from other countries such as Nigeria (2012) and Mozambique (2013) suggest that floods and heavy rains in rural areas, where safe drinking water and sanitary facilities are scarce, led to some of the highest recorded incidences of death due to this waterborne disease. The limited availability of early warning information on potentially heavy floods poses significant challenges for the formulation of plans and projects to deal with current and emerging risks health risks. Furthermore, poor information dissemination mechanisms within the key institutions responsible for risk monitoring to clinics and hospitals impede the use and application of available early warnings from agencies such as ACMAD (African Center for Meteorological Applications for Development). More cooperation between the health and meteorological sector may assist in developing such an early warning system, making sure that the warnings emerging from various agencies reach those who can respond. This should include training community health volunteers and *cases de santé* staff on the risks posed by intense rainfall, evaluation of water quality and disease prevention during floods, as well as providing improved methods for disease surveillance during intense rains.

Geographic health priority 2: Cholera, diarrheal disease and schistosomiasis in the center and northeast

Invest in improved weather and hydrologic monitoring base in order to:

- Improve early warning and detection of priority diseases under a changing climate, particularly in the center and northeast where data are sparse and the burden of disease high. Improvement in weather forecasts and possibly real-time decision support systems for operational response will require investments in hydro-meteorological observations and stations. This could improve the detection and therefore potential to respond to outbreaks of cholera, diarrheal disease and schistosomiasis, diseases that are clearly linked to extreme or heavy rainfall. The available evidence base suggests large gaps in the meteorological knowledge for the country, particularly in the rural areas of central Tambacounda and the northeast, focusing on areas where settlements and agriculture take place. Archives of non-digital data may in fact exist. There is a clear need to identify these, placing attention on restoring archived data, checking it for quality, and in some cases investing in improved technology for these stations in order to provide real-time information on climate-related health risks such as floods and droughts.

- Further the understanding of climate-relevant thresholds for emerging diseases such as meningococcal meningitis, which is projected to increase in conjunction with increased temperatures in the dry season, and for schistosomiasis, with improved understanding of the links between water and air temperature thresholds. The thresholds identified in this report are based on literature analysis and are not necessarily specific to Senegal or even certain regions of the country. More work is needed to understand these diseases and climate factors in a local context. This could assist with developing appropriate targets and monitoring sites for an effective health surveillance system for meningitis and schistosomiasis.

Programmatic priority:

Encourage inter-ministerial collaboration on disaster preparedness with the inclusion of the MOH in the development of plans and communications mechanisms for impending disasters in order to improve preparation and response of the health personnel. At the time of writing, no plans and strategies were being developed by the MOH to address the impact of climate change in Senegal. Increased inter-ministerial coordination and collaboration is needed with the MOH. Development of a Health National Adaptation Plan (HNAP) could catalyze MOH engagement and planning on climate change and health outcomes. Even if a HNAP is not the most effective or efficient way to focus MOH attention, other means should be identified to ensure that the MOH is informed about this issue. This would strengthen the communications between WHO/MOH contacts to build a common agenda around climate change and health impacts. While not specific to Senegal although certainly relevant, USAID engagement with recent World Health Organization (WHO) thinking about building resilient health systems could help develop the concept of health system resilience and what is needed to achieve it. This dialogue could also increase awareness of the health impact of climate change, which is not well-developed among public health practitioners. USAID could also encourage stronger coordination in the World Bank's program to support the Disaster Risk Management and Climate Change Adaptation project which will strengthen the capacity of the Civil Protection Agency (Ministry of the Interior).

C.2 SECOND-TIER PRIORITIES

Explore existing data and dissemination mechanisms to develop a Senegal (southern) specific early warning system for vector-borne disease. The Famine Early Warning Systems Network (FEWS NET) already provides forecasts for Senegal and other countries about climate, agricultural production and food security. Linked to a health indicators surveillance system, and taking advantage of this network of data and users could provide valuable information on emerging health issues. For example, the Malaria Early Warning System is currently making use of data already used in FEWS NET satellite data from the Terra–Moderate Resolution Imaging Spectroradiometer (MODIS), as a proxy for potential mosquito survival conditions in terms of humidity. Combining this with on the ground surveillance and seasonal forecasts provides a window into early identification of potential areas of vector- borne disease outbreaks such as malaria. Exploration of these tools could shed light on new early disease detection opportunities for Senegal's health sector.

Develop spatial mapping database and decision support tool to better detect, assess and respond to increased risk for diarrheal disease and cholera outbreaks, particularly in the south. There are volumes of information available in Senegal, which are often difficult to track, poorly curated, and in formats that pose significant challenges to the users who need this information most. Improved epidemiological understanding is clearly needed between diarrheal disease and periods of heavy rainfall or floods, particularly when coupled with other factors of vulnerability such as population density, infrastructure quality, and access to safe drinking water, among others. Understanding the spatial distribution of areas where hotspots of flooding intersect with inadequate drainage systems, water supplies, waste disposal, sanitation, overpopulation, and other factors can help to better target monitoring and response resources. This tool would aim to collate and make visual this information in order to better identify intervention and monitoring areas.

Invest in institutional capacity. Readiness and response, two functions of an effective risk management system, require functional, capable institutions and individuals. A useful starting point may be working with climate sensitive-health programs such as malaria control and other vector-borne diseases to integrate climate information into their planning efforts. Information about an impending disaster or a disease outbreak should prompt health staff to check supply inventories and obtain emergency stocks of oral rehydration salts (ORS), antibiotics, IV tubing, bandages, protective gear, etc. Facility managers have to check shift rotations to ensure qualified health providers are available to provide services to people affected by the emergency and those needing routine care. For example, training of health managers and health providers can be conducted to better prepare them to understand the link between seasonal trends and preventive measures for those most at risk.

Educate health staff on the diagnosis and treatment of neglected tropical diseases (NTDs), particularly those linked to climate and environmental changes such as lymphatic filariasis, schistosomiasis, trachoma, and soil-transmitted helminthes, which represent a major health burden given little attention in the CDCS. Continued support from USAID’s NTD Program will contribute to the GOS objective of eliminating those diseases. An improved surveillance system for NTDs would include both a baseline mapping of water bodies and sanitation infrastructure as well as identification of potential hotpots where the impact of extreme/heavy rainfall may lead to contamination and reduced water quality. This is especially true in the north and east of the country.

Support improved planning on the part of the MOH for the location and construction of health facilities. Clinics located in low-lying areas are flooded and damaged during periodic floods. USAID could support the MOH in conducting land surveys, relocating facilities out of flood zones, reviewing building standards, and retrofitting structures to make them more resistant to water penetration and damage. Generators at hospitals and health centers should be in covered spaces and placed on solid cement pads that are high enough to avoid inundation. This support should also help to coordinate investments by other donors including

USAID in infrastructure such as expanding and improving drainage systems, water supply and sanitation facilities in urban and rural areas in order to reduce flooding and waterborne diseases.

I. BACKGROUND

A. CLIMATE CHANGE AND HEALTH RISKS IN SENEGAL

Since 1990, when the Intergovernmental Panel on Climate Change (IPCC) published its First Assessment Report on climate change, there has been a substantial increase in research into the issue. In 2014, the Fifth Assessment Report (AR5) was published and included rigorous reviews of the scientific literature covering many aspects of climate change, including health. The report gave a qualitative confidence rating based on data, models, and consistency of evidence, among other criteria. Among the findings and conclusions presented in AR5 Chapter 11*, Human Health: Impacts, Adaptation, and Co-Benefits* (Smith, et al., 2014) are the following:

> Until mid-century, climate change will act mainly by exacerbating health problems that already exist[1][very high confidence]. New conditions may emerge under climate change [low confidence], and existing diseases (e.g. food-borne infections) may extend their range into areas that are presently unaffected [high confidence]. But the largest risks will apply in populations that are currently most affected by climate-related diseases. Thus, for example, it is expected that health losses due to climate change-induced undernutrition will occur mainly in areas that are already food-insecure. (p. 11)

The USAID Senegal Country Development Cooperation Strategy (CDCS) (2012-2016) articulates the links between climate change and economic growth and lays out strategies to integrate climate change adaptation into programs that aim to improve agricultural practices and natural resource management. With regards to health vulnerability, the Senegal CDCS states:

> Climate change threatens human health, both directly and indirectly, affecting all parts of society and the social support systems which aid that society. Attempting to mitigate the effects of climate change on human health is especially challenging in the developing world where populations and ecosystems are the most vulnerable. The extent of climate induced impacts will depend on the country and the existing public health system. (p. 27)

This study identified the following primary health risks for Senegal:

- *Vector-borne diseases (such as malaria and lymphatic filariasis).* These are reasonably strongly influenced by climate. Conditions suitable for mosquitoes are currently found across the country, but more so in the south, which provides favorable conditions in both dry and wet years. The climate in the north is less suitable for mosquitoes and only experiences conditions suitable for mosquito-borne diseases in normal to wet years.

1 Emphasis added

- *Cholera/diarrheal disease.* Currently largely concentrated in the densely populated coastal region. This may be a function of socio-economic factors more than the climate influence but there is an association between outbreaks of cholera/diarrheal disease and heavy rainfall events.
- *Schistosomiasis*. Infections appear to be most severe in the north and east, potentially corresponding to the generally warmer temperatures experienced in the interior and northeast.
- *Meningococcal meningitis*. Linked to the long, dry period experienced in the country in the last decade, creating favorable conditions for its spread.
- *Undernutrition*, the majority of which is concentrated in the south including the Ziguinchor and Kolda regions of Casamance, and in Kédougou and Kaffrine regions.

In addition to these specific diseases, natural disasters are highly associated with climate change and can trigger disease outbreaks and epidemics. The damage to critical infrastructure caused by natural disasters can also inhibit the ability of Senegal's health system to respond to urgent situations and maintain routine healthcare services.

Flooding in Senegal

Flooding is a serious problem in Senegal that affects both urban and rural areas. Flooding caused by a combination of heavy rainfall and lack of functional drainage systems occurs in urbanized areas such as Dakar, Kaolack, Fatick, and Saint Louis. Floods caused by rising river water level to heavy rainfall affect Matam, Tambacounda, and Kédougou. Between 1980 and 2009, floods affected more than 900,000 people, caused 45 deaths and damage estimated at more than USD $142 million (Government of Senegal et.al, 2010).

Approximately 25 percent of the population of Senegal lives in Dakar and its vicinity due to natural increase and migration from rural areas. Between 1988 and 2008, almost 40 percent of Dakar's population growth occurred in peri-urban areas that have a moderate or high hazard potential from inland flooding, coastal erosion, or sea level rise (Wang & Montoliu-Munoz, 2009).

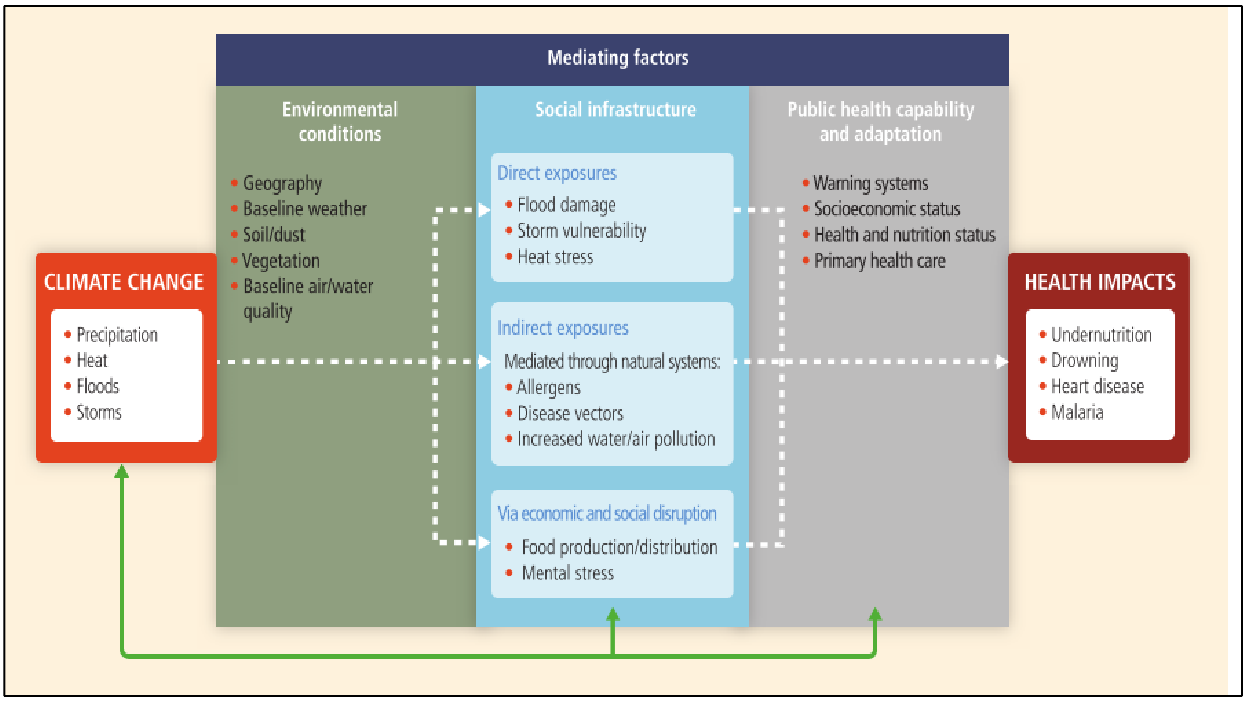
According to UN Habitat, development in Dakar "is characterized by a preponderance of informal settlements with limited access and poor transportation, and inadequate infrastructure and services. Two of every three newly-established households in the metropolitan region are sub-standard. Unplanned settlements have made it difficult to gain access to and to connect neighborhoods, and have put additional strain on the existing transportation network. Low income districts tend to be the most underserved; for example, in the central city 61 percent of households have piped water but this figure drops to 16 percent in the poor district of Rufisque." (as cited in Wang & Montoliu-Munoz, 2009 p. 15)

The vulnerability to flooding due to low-lying areas has been compounded by unplanned and uncontrolled building without adequate infrastructure such as storm drainage, and water and sanitation systems to support the burgeoning population. In the overcrowded urban areas of Dakar, Saint Louis, Thies, and Kaolack, drainage systems have become blocked by the haphazard construction of buildings and roads leaving excess water with no outlet. Around Dakar, the water table of the aquifer has risen due to inadequate pumping and infiltration of storm water and domestic wastewater. Groundwater in the area is not safe for drinking due to the high water table and lack of proper sanitation facilities. During floods, water swamps latrines and septic systems causing overflow and leading to contamination of drinking water supplies and food. The stagnant water, which can last for three to six months, becomes a breeding ground for mosquitoes. Floods in 2009 in Dakar, Saint Louis, Kaolack, and Thies caused over $100 million of damage and loss. Public infrastructure, including health centers, was badly damaged. Some 2,000 reported cases of diarrhea and 3,300 cases of malaria were reported. (Government of Senegal, 2010; British Red Cross, 2009).

The IPCC identifies multiple connections between health and climate, structured into three main categories (see Figure 2):

- *Direct impacts*: such as those arising from illnesses or damages due to increased frequencies of extreme weather events.
- *Environmentally mediated impacts*: those that are borne through other environmental systems such as air pollution, and changing patterns of vector, food, and waterborne diseases.
- *Socially mediated impacts*: those that occur via the interaction of climate with social systems, including health effects resulting from under nutrition, occupational heat stress, population displacement, and poverty reduction.

Figure 2: Exposure pathways between climate change and health



NOTE: Conceptual diagram showing three primary exposure pathways by which climate change affects health: directly through weather variables such as heat and storms; indirectly through natural systems such as disease vectors; and pathways heavily mediated through human systems such as undernutrition. The green box indicates the moderating influences of local environmental conditions on how climate change exposure pathways are manifest in a particular population. The gray box indicates that the extent to which the three categories of exposure translate to actual health burden is moderated by such factors as background public health and socioeconomic conditions, and adaptation measures. The green arrows at the bottom indicate that there may be feedback mechanisms, positive or negative, between societal infrastructure, public health, and adaptation measures and climate change itself. As discussed later in the chapter, for example, some measures to improve health also reduce emissions of climate-altering pollutants, thus reducing the extent and/or pace of climate change as well as improving local health (courtesy of E. Garcia, UC Berkeley). The examples are indicative. (Smith, et. al., 2014, p. 716).

The IPCC defines vulnerability as “a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity” (2001, p. 388) In essence, vulnerability has three dimensions: exposure, sensitivity and resilience/adaptive capacity. The magnitude to which one is vulnerable is variable, but almost everything and everyone is vulnerable to climate to some extent. When investigating the health sector climate vulnerability in Senegal, it is important to recognize that there will be influence from each of the above aspects of vulnerability. A change in any of those aspects will either increase or decrease the population's climate vulnerability in relation to health risks. In addition to this, the health sector in Senegal is influenced by a number of different stressors, only one of which is climate.

Table 2 outlines priority health risks in Senegal, with the climate and non-climatic influences on each health risk separated into different columns in order to place the climate component into context. Where possible, the climate thresholds of each health risk have been noted. These thresholds are used in the climate sections of this report to investigate the potential impact of future climate change on each of these health risks.

B. PURPOSE OF STUDY

This study was undertaken to identify the extent to which the health sector in Senegal is vulnerable to climate risks and to suggest ways to integrate a climate change perspective into USAID/Senegal's health portfolio. Specifically, the study examined the linkages between health system delivery and climate change. Where possible, links have been made between climate and primary health risks in Senegal.

Although there is a clear climate link with each of the health risks discussed, there is often insufficient information to be able to draw robust conclusions with regard to the extent of the climate influence. There are two reasons for this: firstly, there are seldom well-defined climate thresholds that can be investigated; and secondly, a significant portion of the vulnerability of the health sector lies in non-climatic, socio-economic factors such as population density, sanitation, access to medical facilities, nutrition and poverty. These non-climatic factors, in many cases, exacerbate the climate vulnerability but are all drivers of health risk in their own right.

Table 2: Priority health risks in Senegal and their associated climate and non-climate influences

HEALTH RISK	GEOGRAPHIC/TEMPORAL CONDITIONS OF SUITABILITY IN SENEGAL	CLIMATE(S) VARIABLE OF RELEVANCE (CLIMATE SENSITIVITY)	EXAMPLES OF NON-CLIMATE INFLUENCES	CLIMATIC THRESHOLDS
MALARIA	Mainly in the southern parts of the country throughout the summer	Increasing air temperature Rainfall	Human immunity Population movement Drug resistance	Parasite optimal temperature range: 16 – 35° C (Hales et al., 2014) Vector optimal temperature range: 15.4 – 35° C Vector maximum temperature value: 40° C (Lindsay and Martens, 1998) Vector minimum temperature value: 8-10° C 80mm rainfall per month
LYMPHATIC FILARIASIS	Varied geographic distribution, but also concentrated in the southeast	Air temperature Rainfall	Immune response Altitude Population density	Larvae within mosquito peak at 22 – 34°C (Slater and Michael, 2012) Optimal rainfall > 150mm per year (Slater and Michael, 2012)
DIARRHEAL DISEASE AND CHOLERA	Over-crowded urban and peri-urban areas near the coast as well as western parts of the country, more specifically the coastal zones	Extreme/heavy rainfall Air temperature Sea surface temperature	Algal blooms Sanitation	
SCHISTOSOMIASIS	Infections appear to be most severe in the north and east of the country - intestinal schistosomiasis is transmitted during the rainy season, while urinary schistosomiasis is transmitted during the dry season	Water temperature	Time of day Sanitation Water use practices	Snail (water) temperature range: 16-35°C (Moodley et al., 2003) Snail (water) optimal temperature: 27°C (Moodley et al., 2003)
MENINGOCOCCAL MENINGITIS	Predominantly in the southern half of the country outbreaks of meningococcal meningitis currently occur in the dry season with the risk increasing with the arrival of the seasonal winds (*Harmattan*) in November, reducing again in April	Air temperature Humidity	Dust Land cover type Population density Population movement Vaccination coverage	High temperatures and low humidity
UNDERNUTRITION	Concentrated in the south including the Ziguinchor and Kolda regions of Casamance, and in Kédougou and Kaffrine regions	Droughts* Heavy rainfall* *for crops in Senegal Imported crops excluded	Poverty Services Underlying population health (Hales et al., 2014)	Complex because more than a factor of crop growth and different crops will have differential responses to changed climate.

II. DETAILED ANALYSIS OF SENEGAL CLIMATE

Key Messages

- Regional rainfall is characterized by a high degree of variability that ranges from inter-annual to multi-decadal time scales. Although seasonal rainfall totals have remained relatively steady over the past few decades, they still have not returned to levels experienced prior to the serious drought taking place in the second half of the 20th century.
- High rainfall variability on multi-decadal time scales largely precludes strong conclusions regarding rainfall trends.
- An east-west temperature gradient is very evident (except during the rainy season, when there is more of a north-south gradient), with inland temperatures being much higher than those found along the coastal region. The highest temperatures occur during spring and autumn, with mid-summer temperatures moderated by clouds and rainfall.
- The rainfall distribution over Senegal displays a clear north-south gradient, with the south being wetter, containing more rain days and having a longer rainy season than the north.
- Historical analysis reveals that there has been a clear upward trend in temperature across the country since the 1970s. The magnitude and location of the warming varies across the country.

A. BACKGROUND

Senegal is located at the westernmost part of a transitional zone between the moist coastal regions to the south and the dry Sahara Desert to the north. The northern part of the country is part of the Sahel zone. The southern part is situated in the West African climatic zone called the Sudan, a transition zone between the dry Sahel zone and the very moist Guinean and equatorial coastal zone. The Sahel, in which the capital city of Senegal (Dakar) is located (Figure 3), is possibly the most documented region of West Africa in terms of climate, due to the impact of a multi-decadal drought towards the end of the 20th century. As noted by Giannini, Biasutti, Held, and Sobel (2008), changes in rainfall patterns experienced in the Sahel are "unparalleled globally, in magnitude, spatial extent and duration" (p.365).

The climate aspect of health risk in Senegal is founded on the climate dynamics of the region, which are favorable to certain diseases. The rainfall in Senegal is largely determined by the location and intensity of the *Intertropical convergence zone* (ITCZ) which demarcates a north - south gradient of rainfall distribution across the country. The meridional migration of the ITCZ determines the onset and duration of the rainy season. The wetter south has more rain days and a longer rainy season than the drier north. Conversely, temperature displays more of an east-west gradient with inland temperatures being higher than those found along the coast. This is particularly evident in the northeast which has the highest temperatures in the country. Highest temperatures occur during spring and autumn, with mid-summer temperatures moderated by clouds and rainfall.

The Senegal climate is characterized by a high degree of variability, and has recently experience a long drought period which started abruptly in the late 1960s and persisted into the 1990s. Rainfall began to recover in the 1990s, but this recovery slowed down in the subsequent decade. Given the short history of climate records and this rainfall variability, finding statistically significant rainfall trends across Senegal remains a challenging task. Temperature trends are clearer, revealing an upward trend in temperature across the country since the 1970s. Although there has been warming across the country, its magnitude and location vary spatially.

In order to explore how health risks may respond to future climate change, a foundation first needs to be made by creating an understanding of the current and historical climate and of health risks in the current context. Accordingly, this section provides a picture of the current climate for Senegal, looking at the mean climate as well as regional climate variability and observed changes.

B. MEAN CLIMATE CONTEXT

B.1 RAINFALL

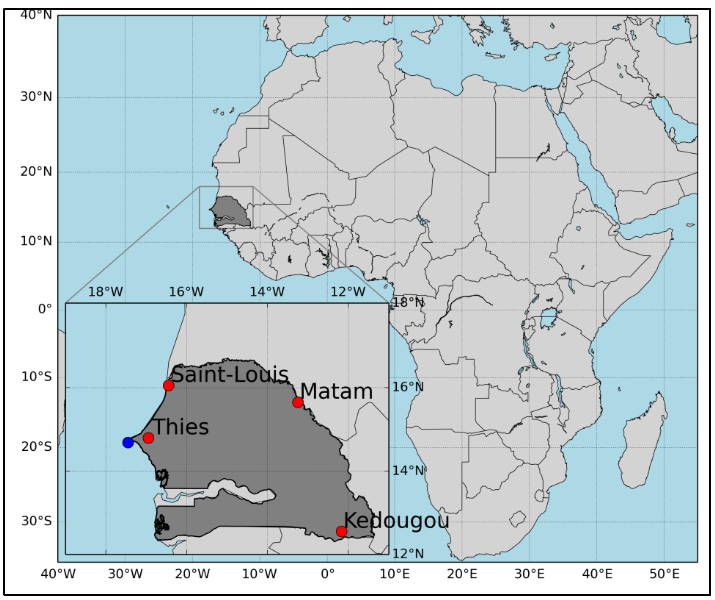
The climate of West Africa is considerably complex, with a distinct north-south rainfall gradient evident between the wet coastal /southern regions and the drier Sahel located further to the north. The climate of Senegal is influenced by both oceanic and continental processes. The lack of any significant topography is also thought to play a key role in regional climate processes, allowing a variety of air masses to move easily into the country (Fall, Niyogi & Semazzi, 2006). It is the convergence of these air masses that often brings rain to the region.

The dominant regional process behind the rainfall regime in West Africa is the West African Monsoon, which is driven by the seasonal cycle of radiative heating of the Earth’s surface. The classical picture of the monsoon involves southwesterly monsoon flow from the Atlantic converging with the dry, northeasterly *Harmattan* winds that originate in the Sahara. The northeasterly winds are associated with the Saharan Heat Low. This convergence zone is known at the Intertropical Convergence Zone (ITCZ), and is characterized by a band of cloudiness and rainfall. It migrates seasonally in a north – south pattern (Figure 4) in relation to the movement of the sun (albeit slightly delayed) and is directly related to the latitudinal gradient of rainfall over West Africa.

Like many other countries in West Africa, it is the migration of the ITCZ[2] that determines the onset and duration of the rainy season in Senegal. The onset of the rainfall typically begins in the southeast around May/June, and propagates northwest throughout the summer months (Figure 5). This results in Senegal receiving most of its annual rainfall from June to September. August generally receives the highest volume of rainfall, followed by September, July, and June (Figure 6). Highest seasonal rainfall totals are typically found in the southern parts of the country (in excess of 1000 mm during the rainy season), while the northern parts are drier (less than 400 mm). There is generally a strong correlation between rainfall totals and the number of rain days, with the south having more rain days (Fall et al., 2006).

The north experiences predominantly August to September rainfall compared to the southern part, which not only has a longer rainy season, but a more evenly distributed rainfall pattern. The rainy season ends with the southwards migration of the ICTZ, typically taking place around October. The remaining months of the year are generally dry, resulting in a dry season lasting for about six months in the south and eight months in the north.

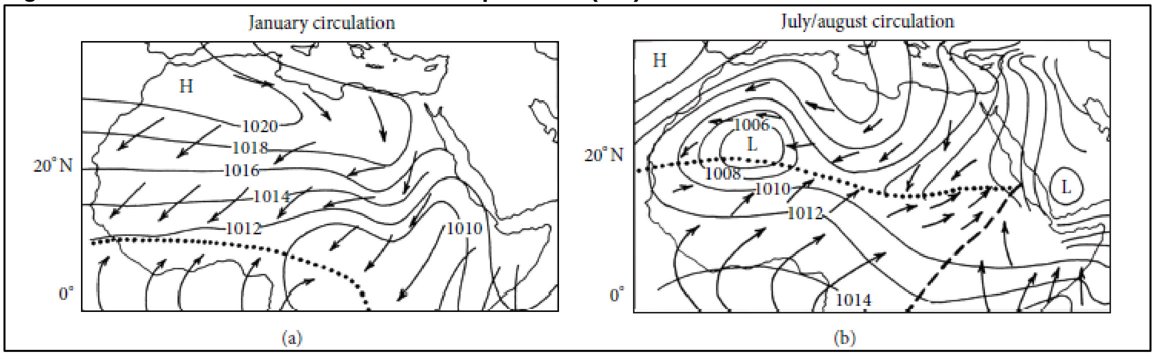
Figure 3: Senegal's location in Africa and the location of stations referenced in this report



NOTE: Stations are indicated with red dots. The capital Dakar is indicated with a blue dot.

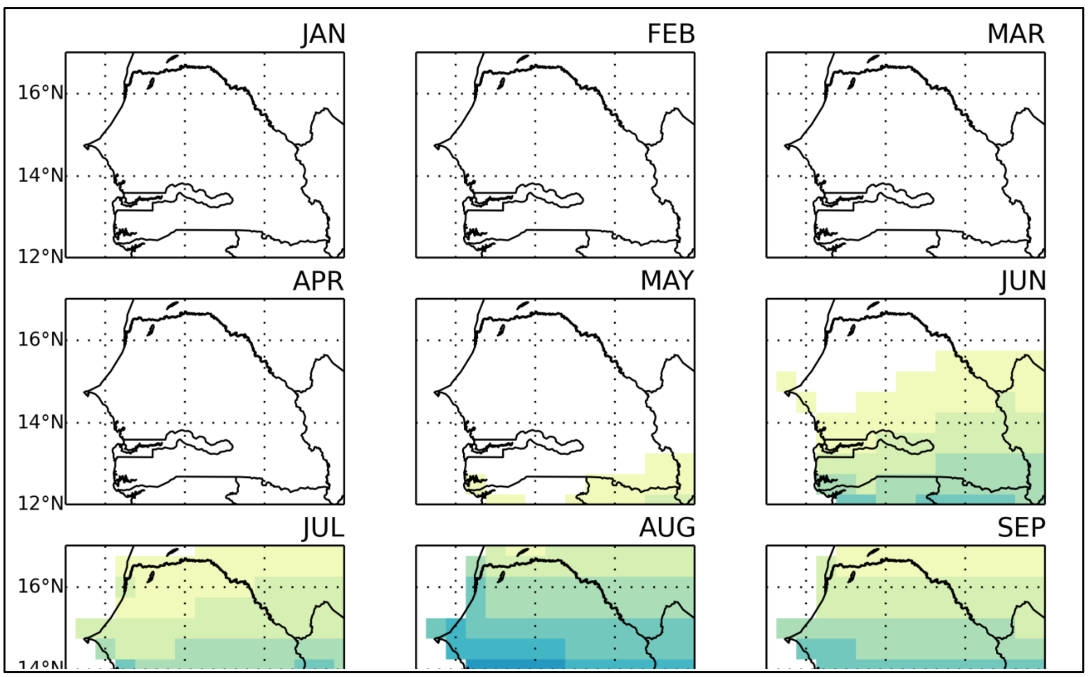
2 Over Senegal, the ITCZ is formed through the convergence of the northwest and southeast trade winds as well as the southwest monsoon winds.

Figure 4: Schematic of surface winds and pressure (mb) over West Africa



NOTE: Winter (left). Peak of the summer monsoon (right). The dotted line denotes the position of the ITCZ. (Nicholson, 2013, p3.)

Figure 5: The seasonal cycle of monthly rainfall (mm) across Senegal

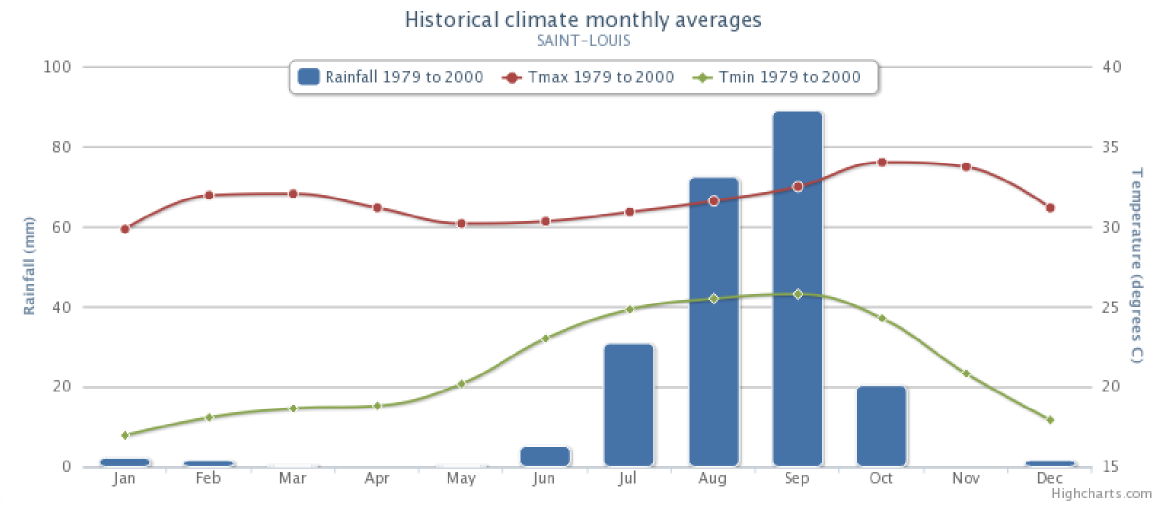


NOTE: Based on CRU TS3.21 data.[3] The month is indicated at the top right corner of each panel.

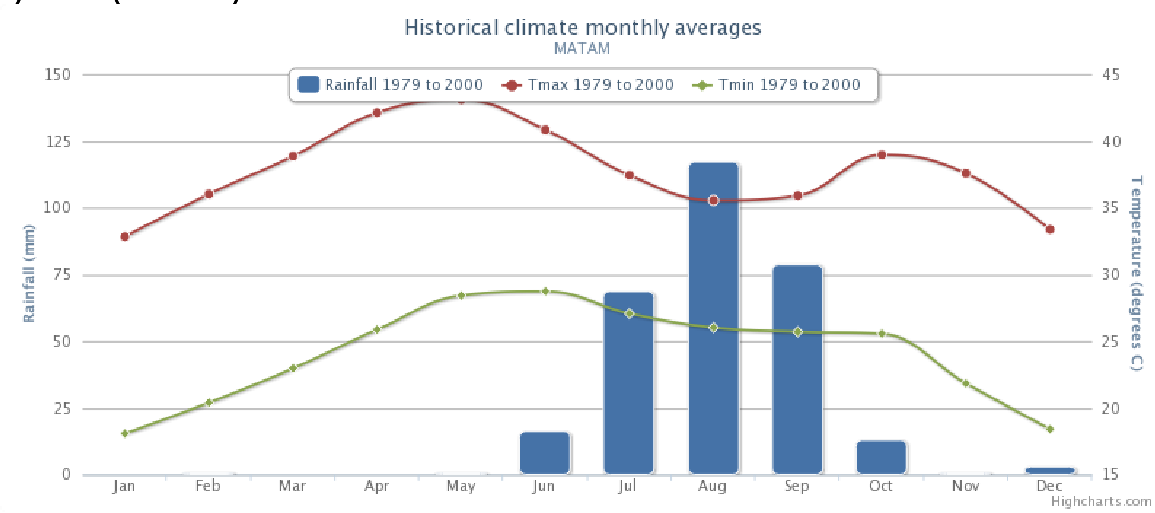
3 The Climate Research Unit Time Series (CRU TS) data is made up of monthly time series of various climate variables, which include maximum and minimum temperature and rainfall. The data, which is based on more than 4,000 global weather stations, is available for the period 1901 – 2012 and is gridded to 0.5 x 0.5 degree resolution. See Jones and Harris (2013) for more information.

Figure 6: Average monthly rainfall, maximum temperature, and minimum temperature for three areas

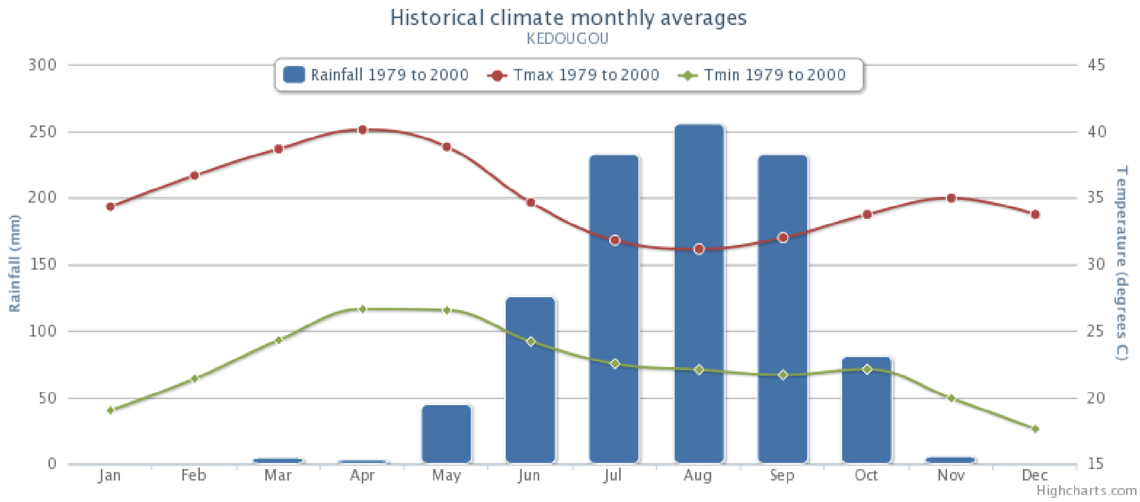
a) Saint-Louis (Northwest)



b) Matam (Northeast)



c) Kedougou (Southeast)

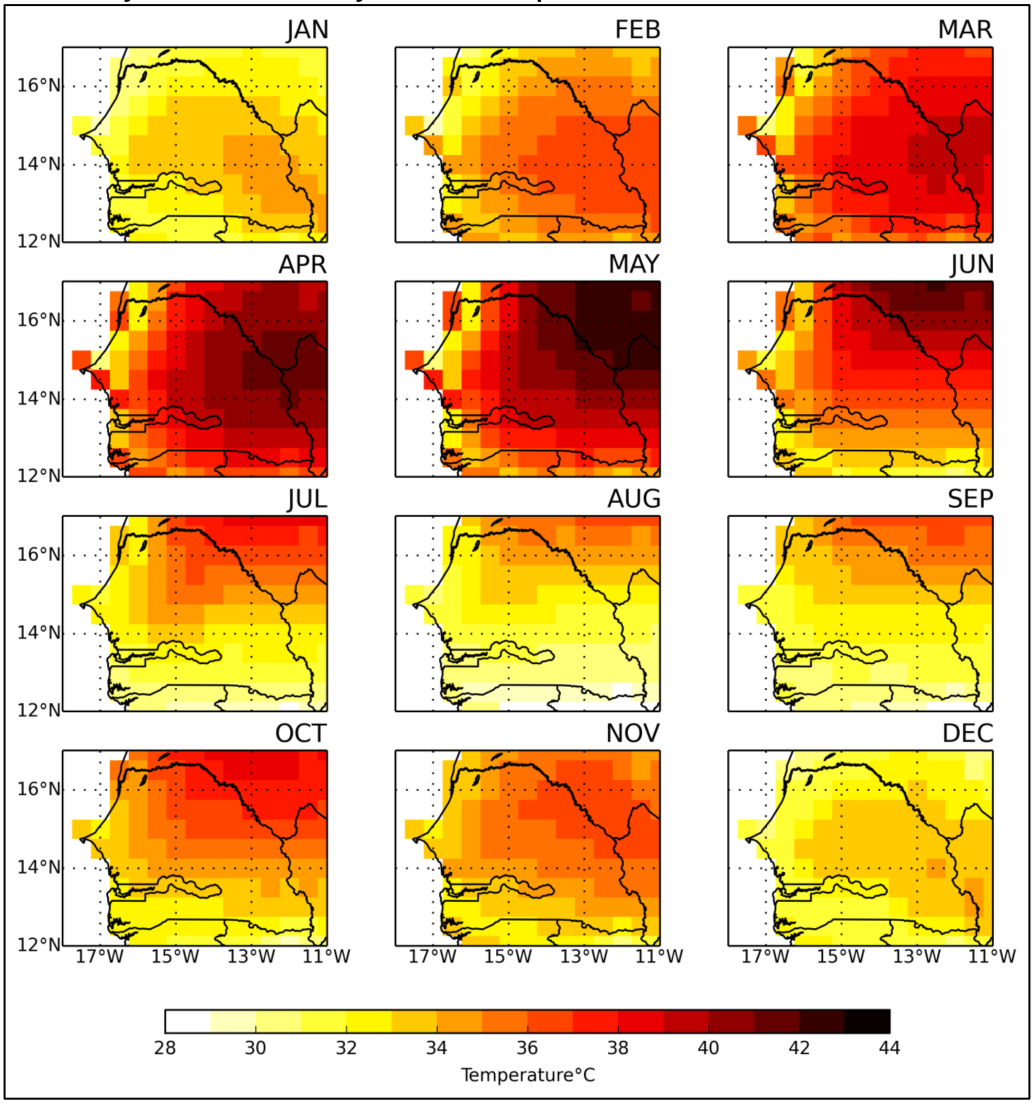


NOTE: Based on station data from 1979-2000 (see Figure 3 for station location). Rainfall in mm, blue bars. Maximum temperature in °C, red line. Minimum temperature in °C, green line. Note that the rainfall values on the y-axis are different for each plot.

B.2 TEMPERATURE

Many locations within Senegal experience two peaks in maximum temperature, the first being around April and the second around October (red line in Figure 6). There is an obvious east – west temperature gradient across Senegal (except during the rainy season, when there is more of a north-south gradient), with locations inland experiencing higher maximum temperatures (often exceeding 40 °C) than those along the coastal regions (typically below 35°C). Cooler maximum temperatures are often found during the core rainy season, which are attributed to the increased cloud cover and moisture during this period (e.g., see Figure 7). The coldest days of the year occur during the winter period (December and January), where minimum temperatures often drop below 20°C.

Figure 7: Seasonal cycle of mean monthly maximum temperature



NOTE: In °C based on CRU TS3.21 data. The month is indicated at the top right corner of each panel. Warmest temperatures are found in the northeast of the country during April to May.

C. REGIONAL CLIMATE VARIABILITY AND OBSERVED CHANGES

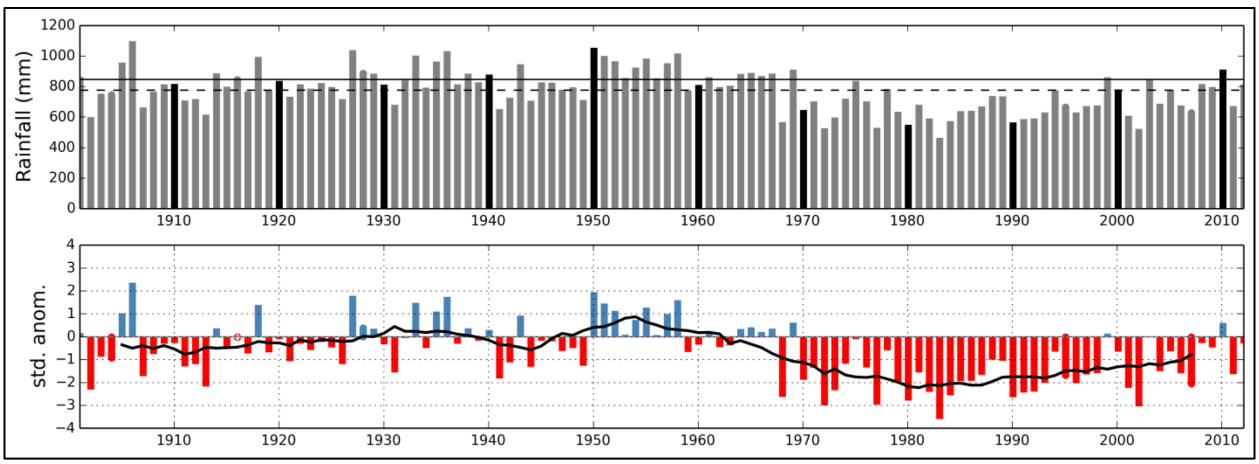
C.1 RAINFALL

On a regional scale, West Africa rainfall is characterized by a high degree of variability that ranges from inter-annual to multi-decadal time scales (i.e., from year to year and from decade to decade). It is the persistent anomalous rainfall conditions (e.g., anomalous wet periods [1930s, 1950s and 1960s] and dry periods [1970s and 1980s]) in the Sahel that have received the most attention in West Africa climate studies. The most recent dry period, which started abruptly in the late 1960s and persisted into the 1990s, was one of the most extreme observed. Rainfall remained below the long-term mean in every year during this period. The 1980s was considered the most intense dry period, with rainfall falling to below 60 percent of the long-term mean

(Nicholson, 2005). This prolonged dry spell is evident in station data across Senegal, which indicates that rainfall in the region declined rapidly between 1950 and the mid-1990s (Figure 6 and Funk et al., 2012). It began to recover in the 1990s, but this recovery has slowed down in the subsequent decade. Given this variability in rainfall, finding statistically significant rainfall trends across Senegal remains a challenging task (e.g., Fall et al., 2006).

Figure 9 shows various rainfall characteristics for a single station within Senegal.[4] Based on this station, there is very little information to suggest that the region has undergone any considerable changes in heavy rainfall. There is some evidence of increases in annual rainfall totals and extreme rainfall events at the station, but this increasing trend is not significant in either case. This result is not surprising given that the country has experienced extremely dry conditions at the start of this data record (i.e., the severe drought of 1980s). The lack of significance in trends of in rainfall characteristics is not unique, and has been documented in numerous studies across Africa (e.g., Aguilar et al., 2009; Mazvimavi, 2010; Ngongondo et al., 2011; MacKeller, New, & Jack, 2014). The variability in rainfall can often mask any meaningful statistical analysis.

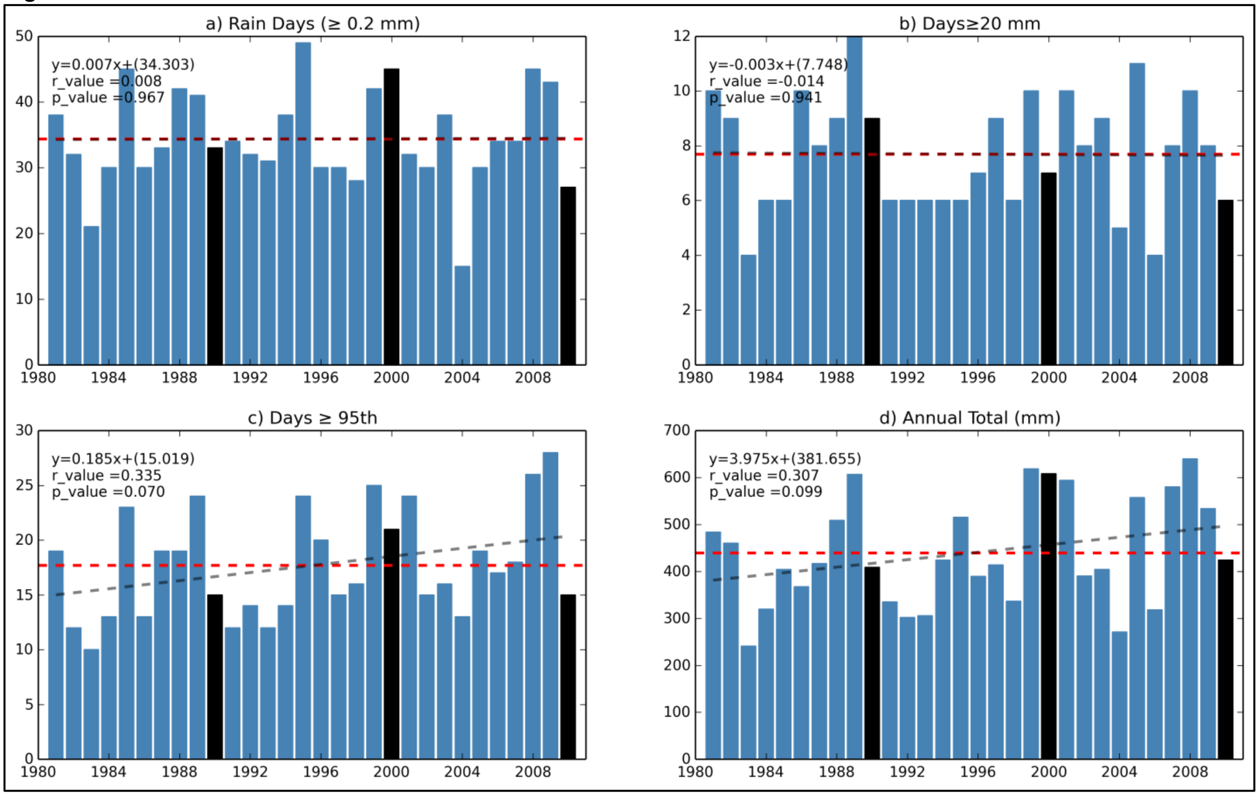
Figure 8: Historical rainfall variability in Senegal



NOTE: The top panel shows annual rainfall totals (bars, mm) from 1901 – 2012 (based on CRU TS3.21 data). The solid gray line shows the annual rainfall mean from 1920 – 1969, while the dashed line is for the whole period, 1901 - 2012. The black bars indicate the start of each decade. The bottom panel shows the standardized anomalies for the entire period, based on 1920 - 1969 being used as the reference climatology. The dark black line is a 10-year running mean.

4 The station at Thies has the longest record of data for stations across Senegal. All other stations have 20 years or less of data, which is too short for any meaningful analysis. However, using only one station does limit our understanding of any change on a regional scale.

Figure 9: Annual rainfall characteristics for the Thies station based on data from 1981-2010

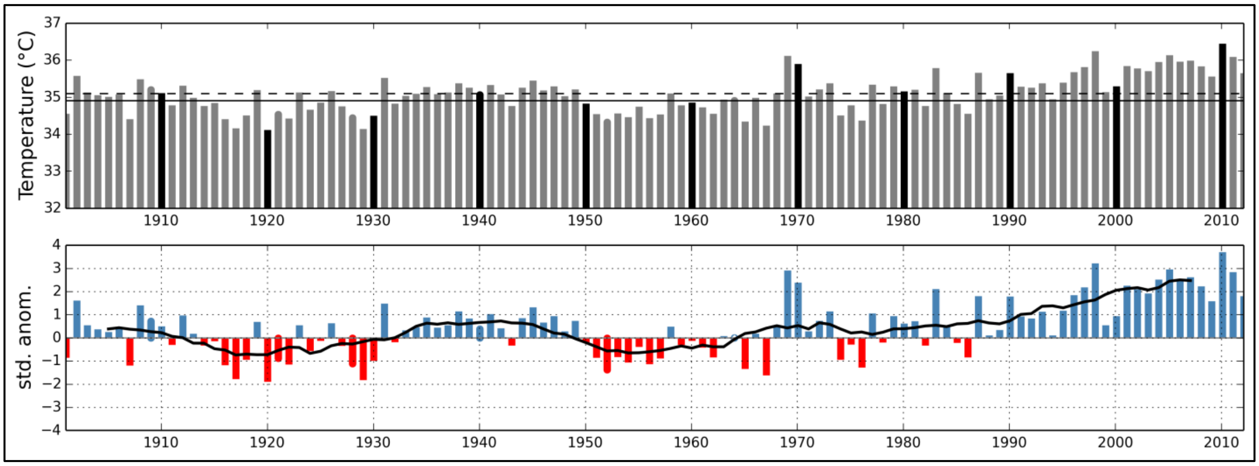


NOTE: See Figure 3 for station location. Panel a) the number of rain days per year, b) number of “heavy” rain days per year, c) the number of rainfall days exceeding the 95th percentile and d) the total volume of rainfall per year. The red line indicates the mean and the light black line the trend line from a simple linear regression (equation, r value and p value given in top left corner). For easier reading, the black bars indicate the start of each decade.

C.2 TEMPERATURE

Cooler temperatures are often associated with wet periods (e.g., 1950s) in Senegal’s climate, which can be explained by the increase in cloud cover and moisture. Warmer conditions have prevailed since the large drought that started in the 1960s. Since 1975, it has been calculated that temperatures have increased by almost 0.9° Celsius (°C) across much of Senegal (Funk et al., 2012). Most of the warming appears to have occurred November to May (based on data from 1971 -1998: Fall et al., 2006). The most obvious sign of the warming occurs from about the 1980s (Figure 10). The warming rate is not constant across the country, with some regions, such as central north and southwest Senegal, warming faster than the rest of the country (Fall et al., 2006).

Figure 10: Historical temperature variability in Senegal 1920-2010



NOTE: The top panel shows the annual mean maximum temperature (bars, °C) from 1901 – 2012 (based on CRU TS3.21 data). The solid gray line shows the annual mean from 1920 – 1969, while the dashed line is for the whole period. The black bars indicate the start of each decade. The bottom panel shows the standardized anomalies for the entire period based on 1920 - 1969 being used as the reference climatology. The dark black line is a 10 year running mean.

C.3 DRIVERS OF REGIONAL CLIMATE VARIABILITY

Given that most analyses of climate variability are focused on a regional scale and are not country specific, the following section documents drivers of variability within West Africa. As alluded to above, regions within West Africa, particularly the drier Sahel, display considerable rainfall variability at inter-annual, decadal. and multi-decadal time scales. Identifying the contribution of any one particular feature or climate driver to West African rainfall variability is difficult due to the complex nature of the interactions involved. It is likely that the influence of an individual driver may vary for different regions within West Africa and the times of the year, and due to effects of other drivers.

The oceans play a major role in moisture supply and in the generation of atmospheric circulation patterns. It was originally thought that monsoon variability (rainfall variability) was associated with sea surface temperature (SST) anomalies in the South Atlantic and Gulf of Guinea (e.g., Lamb, 1978; Hastenrath, 1984) or inter-hemispheric SST gradients between the North and South Atlantic (Folland, Palmer & Parker, 1986). Through observations and model-based studies, research has shown that SST anomalies on a near global scale appear to influence West African rainfall patterns. In particular, warming in the equatorial Indian Ocean (e.g., Bader & Latif, 2003) and tropical Pacific Ocean (e.g., Lu & Delworth, 2005) are thought to have played a dominant role.

In terms of atmosphere circulation, West African rainfall is closely associated with the strength and location of a few prominent zonal (east - west) jet streams positioned at various vertical levels in the atmosphere. There are two pronounced easterly jet streams over West Africa: the mid-level Africa Easterly Jet (AEJ; also known as the West African Jet) and the upper-level Tropical Easterly Jet (TEJ). The AEJ, transporting moisture from Central Africa to the west, has possibly received more attention due to its association with the development of phenomenon known as African Easterly Waves, which are often linked to rainfall in the region. Although the climate of West Africa may be predominantly driven by large-scale circulation patterns, it is very sensitive to regional scale feedback processes linked to properties such soil moisture and vegetation cover. Essentially, land surface feedbacks amplify the climate conditions brought about through changes in other large scale features (e.g., Zeng, Neelin, Lau, & Tucker, 1999).

III. CLIMATE AND LINKS TO HEALTH RISKS

Key Messages

- The influence of climate (rainfall, temperature, and humidity) on disease is complex. This complexity arises because numerous non-climatic factors also have to be taken into consideration, and because the details of the climate drivers are very complex (e.g., water ponding for a certain time period).
- The south of the country experiences conditions suitable for mosquito-borne diseases during both dry and wet years, so the variability of risk is likely low.
- The north only experiences conditions suitable for mosquito-borne diseases during normal to wet years. During dry years, rainfall is insufficient. The variability of risk in the north is likely significantly higher than for the south.
- Cholera and diarrheal diseases have been concentrated largely in the more densely populated western (coastal) part of the country, and are associated with periods of extreme/heavy rainfall or dry periods, leading to sanitation problems.
- Based on the climate element alone, the risk of meningococcal meningitis may increase in the future. The spatial distribution of meningitis is a function of the seasonal winds, and it is unknown how these winds may change in the future.
- Schistosomiasis infections appear to be most severe in the north and east, potentially corresponding to the generally warmer temperatures experienced in the interior of the northeast.
- The country has experienced a dry period in the last few decades, resulting in long and hot dry seasons, creating favorable conditions for the spread of meningitis.

A. CLIMATE AND HEALTH RISKS

There has for many decades been recognition of the association between climate variability and the development/spread of various diseases. The most common example in an African context is that between climate and malaria, for which information is thus more readily available than for other priority health risks. The availability of health-related data and research influences the level of detail provided for each of the priority health risks outlined below.

Based on the outline of the current and historical climate above, a picture of the influence of climate on the current health risks can start to form. The next section explores some of the priority health risks for Senegal in the context of the current and historical climate outlined in Section III.

A.1 VECTOR-BORNE DISEASES

Malaria remains the leading cause of morbidity and mortality in Senegal despite control efforts that have reduced the burden of disease. The mosquito vector of malaria is highly adaptive to insecticides and prophylaxis/treatment medications. It can also adapt to climate conditions of increased/decreased dryness or moisture by altering its life cycle and the period during which it transmits malaria. This section focuses on malaria, where the evidence base is more robust, but it could potentially inform the risk and distribution of other mosquito-borne diseases that occur in Senegal, such as lymphatic filariasis.

From a climate perspective, sufficient rainfall is required to provide sites for mosquito breeding, while temperature plays an important role by regulating the development rate of mosquito larvae and influencing the survival rate of adult mosquitoes (see Table 2). Warmer temperatures are often preferred by mosquitoes because in such conditions they generally develop faster and feed earlier in their life cycle. Another factor is humidity, with mosquitoes generally not living long enough to complete their transmission cycle in areas with low humidity.

How do climate variability and change alter what is known about vector-borne diseases?

- By extending the viable range of vector species to new geographic areas where population immunity is absent.
- By altering the known duration of typical malaria transmission. In the north, for example, wet periods increase the number of months of viable malaria transmission while dry periods decrease these.

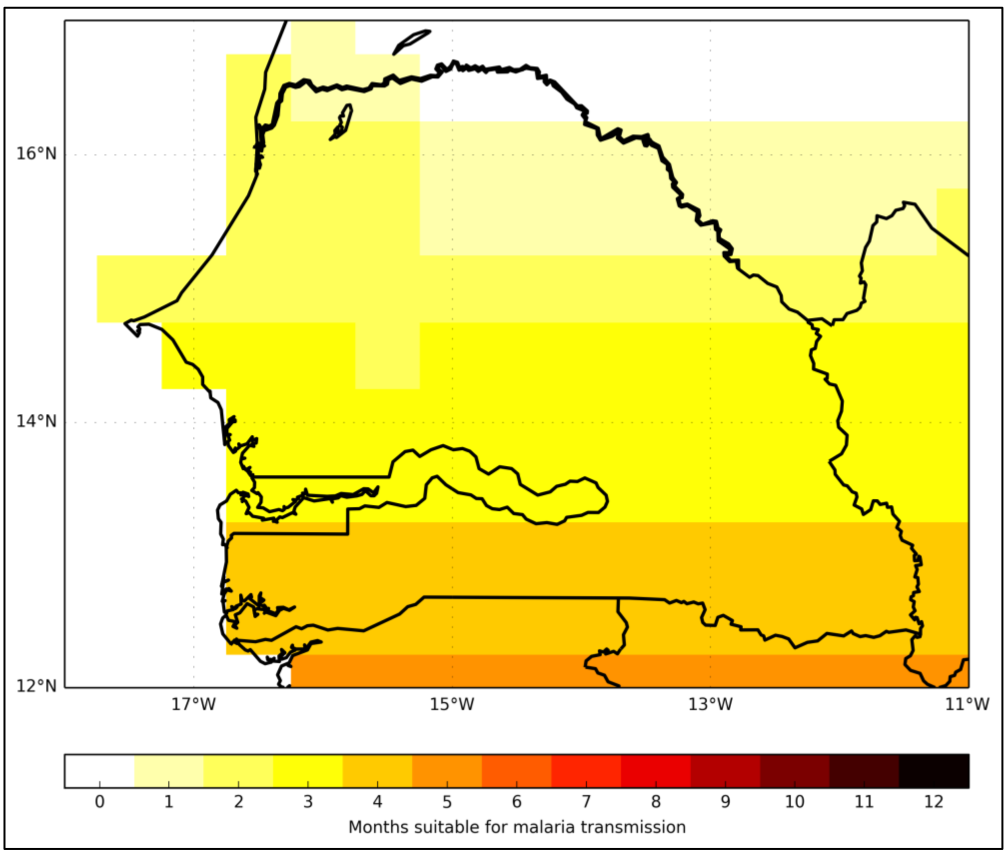
Some locations on the continent satisfy all three climate thresholds regularly, while areas bordering these favorable locations typically lack one or more of the thresholds. It is these border locations where malaria epidemics are likely to occur because an individual's exposure to malaria is infrequent and therefore, has not developed immunity to the disease (Grover-Kopec et al., 2006). Without immunity present in the population, any shifts or changes in climate would leave these areas more exposed to a malaria epidemic. It needs to be emphasized that the difficulty in evaluating the influence of climate on the spread of a disease is due to the fact that factors influencing the disease are not only limited to climatic factors, but extend to socio-economic factors (e.g., population density, sanitation, access to medical facilities, etc.), as well as anthropic/human-induced changes (e.g., changes in the environment, land use, deforestation, etc.).

In Senegal, from a climate perspective, favorable malaria transmission conditions are found mainly in the southern parts of the country throughout the summer months (Figures 11 and 12). Favorable conditions for transmission begin around the start of the rainy season in the south and extend northwards, following the rain. The central and northern parts of the country typically have 2 to 3 months of the year with favorable conditions, whereas southern parts have 4 to 5 months.

Senegal is known to undergo drastic shifts in climate on decadal and multi-decadal timescales. Thus, the favorable areas for malaria transmission shown in Figure 11 would likely shift with a change in climate. During wet periods, a northward shift in rainfall generally occurs, while warmer temperatures retreat to the extreme northeast of the country. Numerous factors would play a role in this, with the most prominent being the location and intensity of the ITCZ. The opposite occurs during dry periods, with rainfall retreating southwards and warmer temperatures encroaching from the northeast and penetrating further into the country. This results in changes in the number of months per year with favorable climate conditions for malaria transmission. Figure 12 indicates that during wet periods, there is an increase in the number of months in northern Senegal that are favorable, while during dry periods there is a decrease. The southern parts of the country do not show as much variation as that found in the north.

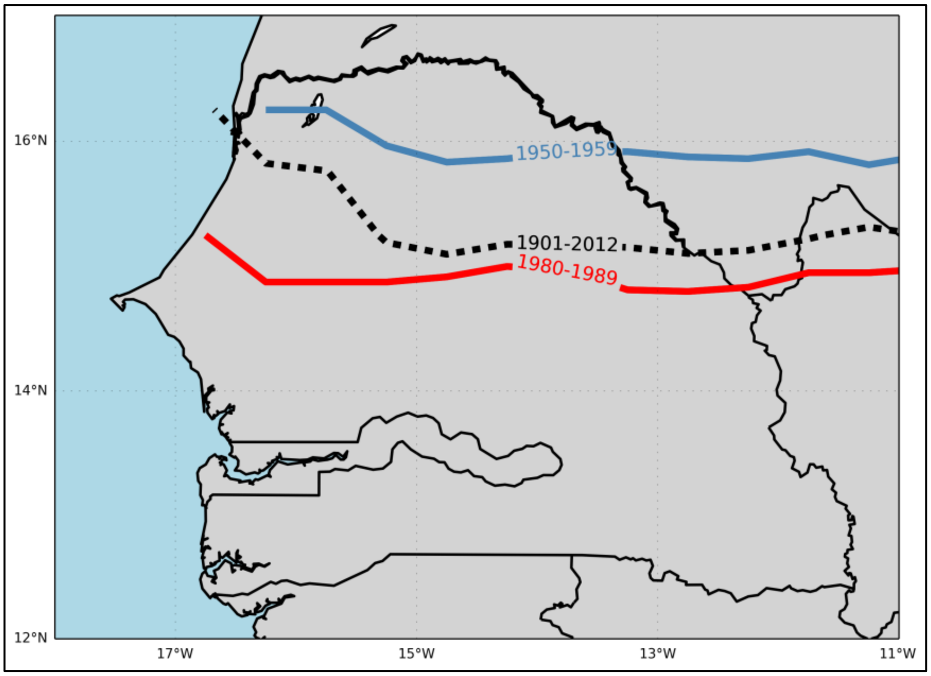
By understanding past climate variability, both in terms of spatial change and magnitude, measures could be put in place to assist in limiting the scale of epidemic malaria outbreaks. However, the influence of climate (rainfall, temperature, and humidity) on mosquitoes is a considerably complex relationship. For example, an increase in rainfall can provide more breeding sites for mosquitoes, but if the rainfall is too heavy or excessive, it can wash out breeding sites. Extreme weather conditions will likely add even more complexity to the relationship. This is compounded by many other non-climate factors that influence the location and spread of mosquito-borne diseases.

Figure 11: Current number of months per year where locations have conditions favorable for malaria transmission



NOTE: Based on climate thresholds depicted Table 2, where temperature is between 16 – 35 °C and monthly rainfall is greater than 80mm.

Figure 12: Favorable climate conditions for malaria transmission over selected decades



NOTE: The lines in the figure represent where the two-month mark of favorable climate conditions for malaria transmission extends under different climate conditions of a select few decades (i.e., everything south of the line receives two or more months per year of favorable conditions for malaria transmission during that decade). The 1950-1959 (blue line) corresponds to a wet/cool period, the 1980-1989 (red) a dry/warm period and the 2000-2009 (black) is the last full decade.

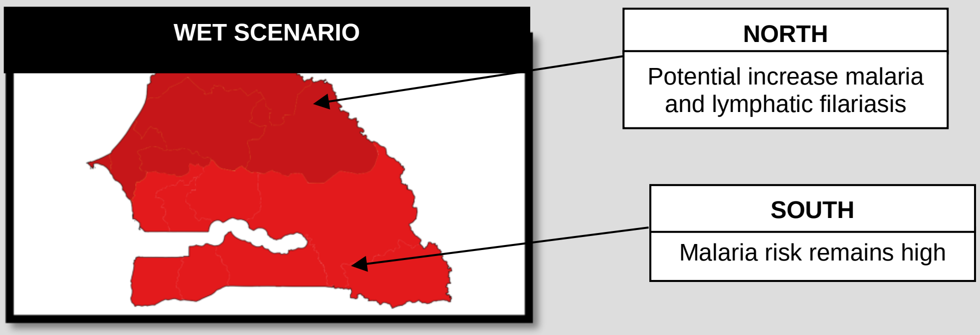
A.1.a Vector-borne diseases under a changing climate

As outlined in Table 2 of this report, mosquitoes are a primary driver of two of the major health risks in Senegal: malaria and lymphatic filariasis. Mosquitoes are also vectors for other diseases of less prominence, such as dengue fever. For these reasons, it is worth investigating the viability of the mosquito habitat under future climate conditions in order to make inferences about the changing risks of these diseases.

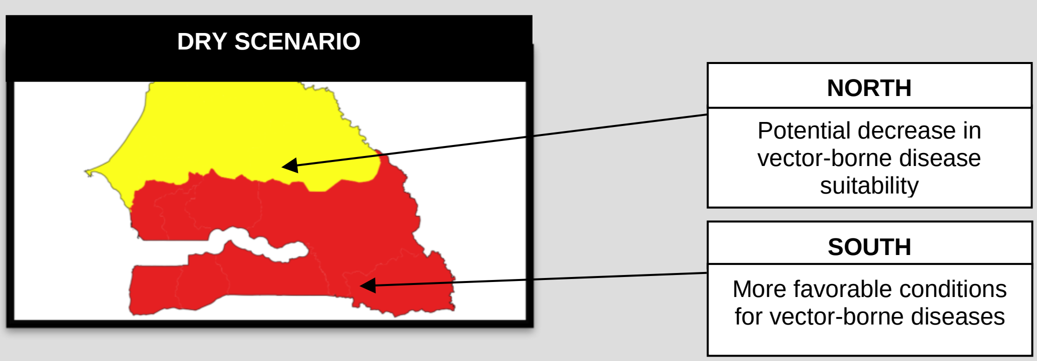
General thresholds for mosquitoes suggest a requirement of a minimum of 80mm of rainfall per month and a maximum temperature tolerance of 40°C. Using these two requirements, preliminary analysis can be undertaken on the potential change in the spatial health risk of mosquito-borne diseases under future climate conditions.

Summary: Potential changes in key diseases under a wet or dry future climate scenario

Under the "wet" future scenario, there would be ample rainfall for the proliferation of mosquitoes across the country. The "wet" scenario is also associated with slightly lower increases in temperature, which, particularly in the south, would remain within a range of temperatures viable for mosquito survival. Given the reduced temperature increase in the "wet" scenario, it is likely that the north may either remain suitable for mosquitoes or become more suitable because of the increased rainfall. Therefore, it is concluded that, under the "wet" scenario, the risk of malaria and lymphatic filariasis in the country will remain high with a minor potential that the risk may, in fact, increase in the north.



Under the "dry" future scenario, the south may remain at risk of mosquito-borne disease because, even under the driest scenario, the average monthly rainfall does not fall below 80mm. This threshold, combined with the projection of average maximum temperature of between 35 and 38^{o}C, means that the south may not reach the upper threshold temperature limit for mosquitoes either. In fact, a slight increase in temperature may be favorable for mosquitoes because, in such conditions, they generally develop faster and feed earlier in their life cycle. The north of the country exhibits a different message under the "dry" scenario. The projections indicate that, in a dry year, there may not be sufficient rainfall in the north of the country to support mosquitoes every year. This, combined with the potential for the maximum temperatures in the north to exceed the 40^{o}C threshold for viability, means that the risk of these diseases under a dry scenario may, in fact, decrease in the north but remain stable (or increase) in the south.



A.2 DIARRHEAL DISEASE AND CHOLERA

Diarrheal disease and cholera mainly spread through contaminated water or food. While diarrheal disease is caused by a host of bacterial, viral, and parasitic organisms, cholera is caused by a specific bacterium, *Vibro cholera*. Non-climatic factors, including inadequate sanitation, poor hygiene, and overcrowding, play a major role in the spread of both. Yet climatic factors also play an important role, both in the spread and by creating favorable or unfavorable conditions for the bacteria to multiply. As stated in the USAID Water and Development Strategy 2013-2018 (n.d.-b):

> Lack of access to safe water and sanitation services has direct health implications as nearly two million people – the vast majority of whom are children under five – die from diarrhea each year. Nearly 88 percent of diarrhea is attributed to unsafe drinking water, inadequate sanitation, and poor hygiene, and is preventable by known interventions. (p. 3).

Diarrheal diseases account for more than 40,000 deaths annually and are the second leading cause of death of children under the age of five in Senegal (USAID, n.d-a). The leading causes and areas where these diseases occur are:

- Lack of access to clean drinking water and improved sanitation facilities is compounded by poor hygiene practices, e.g., lack of handwashing, and improper food preparation.
- Overcrowded urban and peri-urban areas near the coast are particularly vulnerable to floods that cause sanitation facilities to overflow and lead to outbreaks of cholera and diarrhea.
- Rural areas where more people rely on unsafe water sources and do not have improved sanitation facilities are highly vulnerable to outbreaks of cholera and diarrheal disease which spread quickly. In 2005, a cholera epidemic affected more than 75,000 people in West Africa. Senegal reported 31,719 cases and 458 deaths (WHO, 2010).

Water supply, sanitation, and hygiene, given their direct impact on infectious disease, especially diarrhea, are important for preventing malnutrition. Malnutrition and inadequate water supply and sanitation are linked to poverty. The impact of repeated or persistent diarrhea on nutrition-related poverty and the effect of malnutrition on susceptibility to infectious diarrhea are reinforcing elements of the same vicious circle, especially amongst children in developing countries (FAO, IFAD, & WFP, 2014).

Senegal has made progress on improving access to clean water supplies and sanitation facilities but much improvement remains to be done, particularly in rural areas. As of 2011, 73 percent of the population had access to an improved source of drinking water: 93 percent of the urban population had an improved source while 59 percent of the rural population had access. Improved sources include piped water on premises, public standpipes, and covered wells with a pump. Some 27 percent of the total population still relies on unimproved sources such as uncovered wells and surface water (WHO & UNICEF, 2013).

Progress on improving sanitation facilities, however, has not fared as well. Nationwide 51 percent of the population has an improved sanitation facility: 68 percent of the urban population and 39 percent of the rural population had access to improved sanitation (WHO & UNICEF, 2013). **On the climate side, both temperatures and rainfall have been associated with an increase in cases of diarrheal disease and cholera:**

- Heavy rainfall can lead to flooding, which increases the chance of fresh water being contaminated.
- Dry periods, on the other hand, can lead to stagnant water in ponds and rivers, creating more favorable conditions for bacterium to grow.

If flooding or drought takes place in overcrowded areas, where proper hygiene and sanitation is lacking, it can be very hard to manage and contain outbreaks. A good example is the 2005 cholera outbreak, the largest in Senegal's history, for which it was found that the temporal dynamics of precipitation – sudden and heavy rain – was one of the likely driving factors (de Magny et al., 2012). The two worst hit regions, Dakar and Diourbel, are also the most densely populated out of the affected regions.

Episodes of cholera reported in Senegal since 1971 are largely concentrated in the western parts of the country. While western areas, more specifically the coastal zones, have somewhat lower maximum temperatures than the rest of the country, rainfall totals during the rainy season vary greatly from the north coast to the south coast. Climatic driving factors are thus more likely linked to episodes of heavy rainfall and dry periods, together with socio-economic aspects such as population density, hygiene, and sanitation.

A.2.a Diarrheal disease and cholera under a changing climate

Arguably, these diseases are primarily driven by sanitation with climate playing a relatively minor role in influencing the risk. However, the minor part played by climate is likely due to episodes of extreme/heavy rainfall or dry periods leading to stagnant or polluted water sources. As the projections indicate, these dynamics may become more frequent and pronounced and therefore may increase the burden of waterborne diseases, with implications for improving monitoring and surveillance during known climate episodes. The projections of change in the 95th percentile rainfall, as shown in Figure 21, suggest (with a fair amount of uncertainty) that at least one of the rainy season months may exhibit an increase in heavy rainfall events. In turn, this may exacerbate the sanitation problems, leading to an increase in the risk of these waterborne diseases.

This potential change in extreme rainfall events is a consistent message across the country, with little distinction between the north, the south, the interior, or the coast. However, the best scientific evidence on rainfall changes suggests that the total average rainfall is projected to increase in the south more than the north, and therefore the risks of these waterborne diseases may display a greater prominence in the south.

A.3 SCHISTOSOMIASIS

Referred to as "neglected tropical diseases" (NTD), schistosomiasis, lymphatic filariasis, trachoma, and soil-transmitted helminthes are endemic in Senegal. Schistosomiasis and lymphatic filariasis are transmitted by vectors sensitive to seasonal weather variation. Disease vulnerability is also affected by control measures, drug resistance, environmental factors, and climate change. Schistosomiasis is transmitted by a fluke that requires a snail host, which is sensitive to changes in air and water temperature. The snail population, which is also influenced by other water conditions, increased in Senegal as a result of irrigation and dam projects built to improve agricultural production and generate electricity. In Senegal, intestinal schistosomiasis is transmitted during the rainy season, while urinary schistosomiasis is transmitted during the dry season.

The Government of Senegal established a national integrated NTD program in 2010, with a dedicated NTD focal point within the Ministry of Health's Directorate of Disease Control (DLM). Senegal is a focus country for USAID's global NTD Program, which provides critical support for control and treatment activities for schistosomiasis as well as lymphatic filariasis, trachoma, and soil-transmitted helminthes. The DLM organizes mass treatment campaigns that are carried out by a nationwide network of community health service delivery points (USAID, 2014a).

In addition to the USAID NTD Program, Senegal receives support from the Schistosomiasis Control Initiative (SCI), a program operating in several sub-Saharan African countries to undertake national schistosomiasis control programs. In 2013, Senegal and five other countries – Burkina Faso, Liberia, Senegal, Sierra Leone, Togo and Zimbabwe – reached the threshold treatment of at least 75 percent of in school-age children.

The proliferation of schistosomiasis is dependent on two primary factors: habitat suitability and water temperature. Arguably, the more dominant driver is habitat suitability, which is influenced by factors such as hygiene, water use practice, population density, and sanitation. Without these elements, the climatic element is redundant. However, Senegal currently suffers from outbreaks of schistosomiasis so the climate element is worthy of investigation.

Moodley et al., (2003) define the hospitable water temperature range for growth and development of the host snails as between 16 and 35°C. However, they suggest that a water temperature of 27°C appears to be near optimal for the proliferation of the disease (Table 2). Unfortunately, it is not possible to define a straightforward relationship between air and water temperature, as the correlation will depend on the depth and overturning of the water source. However, in general, air temperature and water temperature are causally linked.

Based on the Global Health Atlas of Helminth Infections (see Figures 13a and b), current schistosomiasis infections appear to be most severe in the north and east of the country. This may correspond to the generally warmer temperatures currently experienced in the interior and northeast but may also be a function of the water supply and sanitation of those areas. It may be that the lower rainfall experienced in the north makes the area more susceptible to sanitation problems. The location of the majority of the water bodies may also have an influence on the spatial distribution of infections across the country.

A.3.a Schistosomiasis under a changing climate

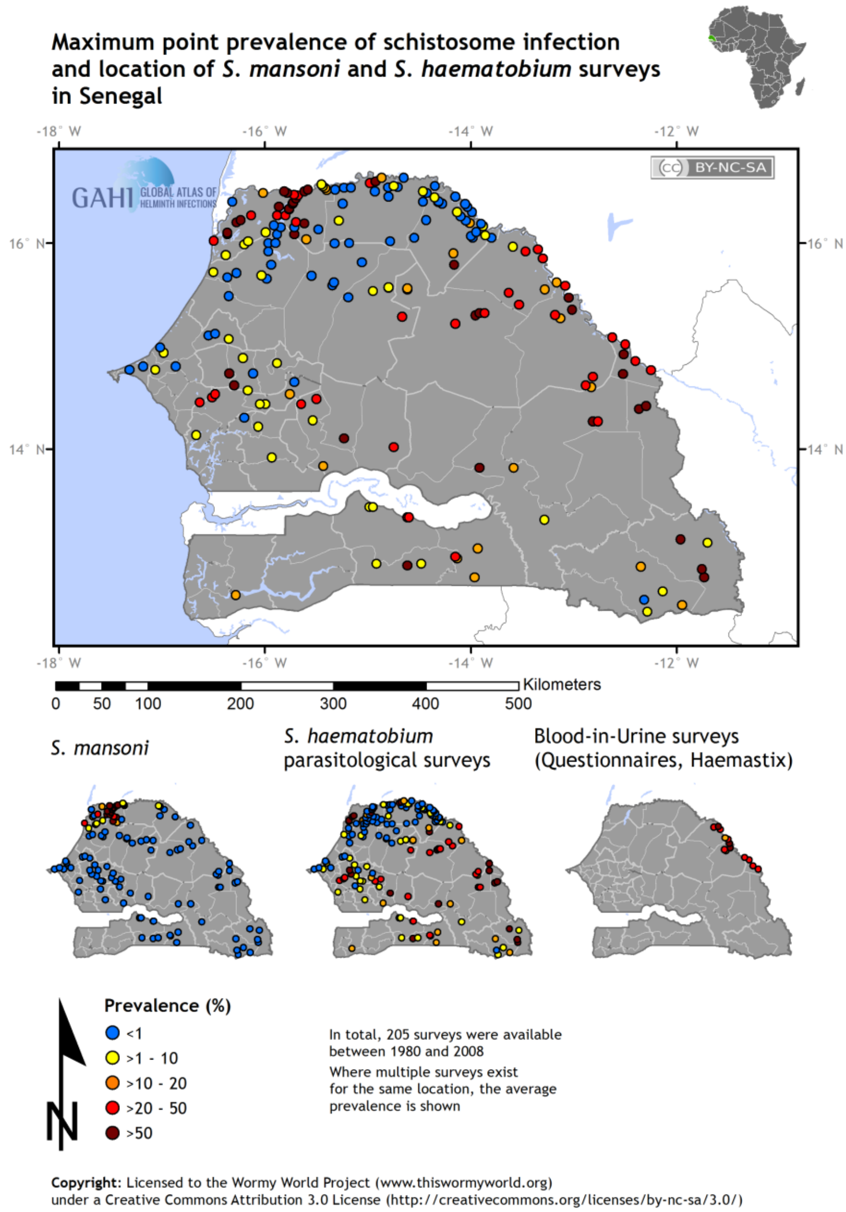
As schistosomiasis is spread via a parasitic snail that lives in a water environment, the only available information on climatic thresholds for the spread of the disease are those of water temperature. There is a not a straightforward correlation between water temperature and air temperature, and it is therefore challenging to make inferences about the potential change in the disease risk based on air temperature projections. However, one can assume that there is a casual relationship between air temperature and water temperature, and as air temperature increases, so will water temperature. But it is not possible to assess when the upper water temperature threshold may be reached based on air temperature projections alone.

Given a lack of knowledge regarding an upper air temperature threshold for the schistosome vector snail, it can be inferred that the risk of schistosomiasis may increase across the country under both a “wet” and a “dry” future scenario because both scenarios project an increase in temperature. This assumes that the warming does not result in the water temperature exceeding the upper threshold of 35°C (see Table 2). This statement also assumes that, under the dry scenario, there is enough rainfall to maintain the water bodies. This may only be a consideration in the north.

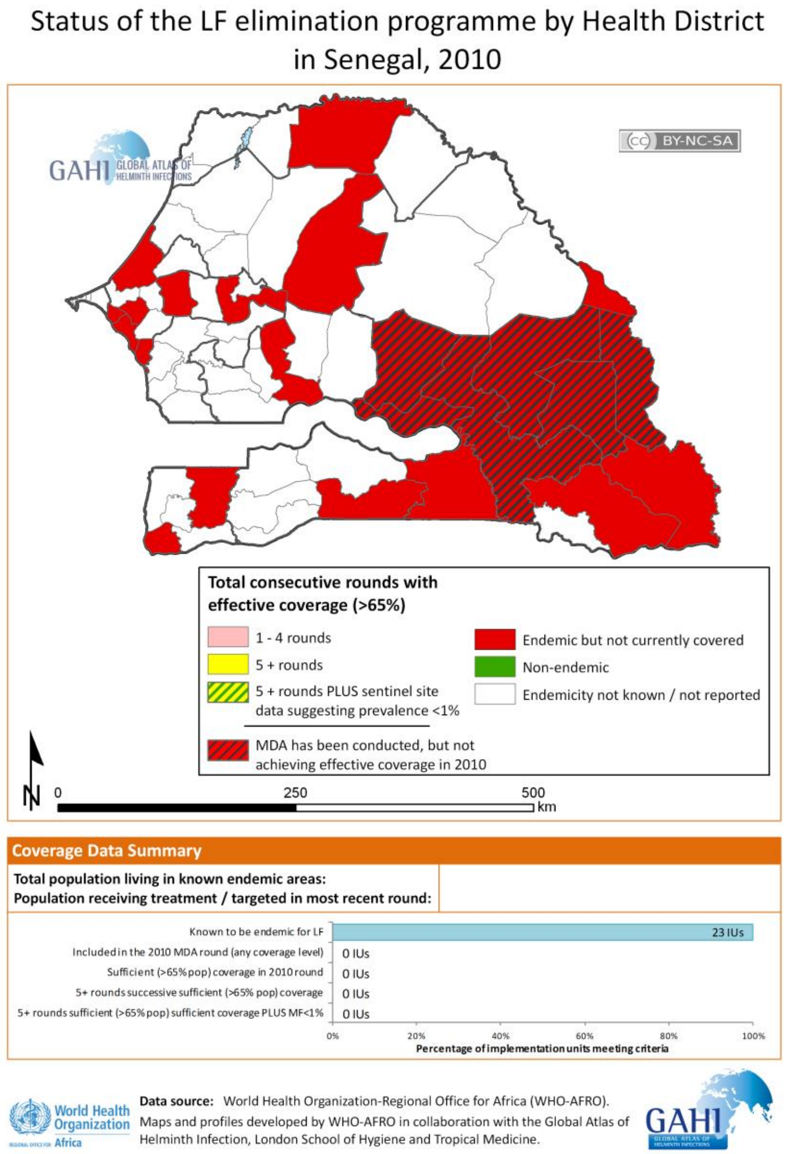
Under both scenarios, there is a projected increase in extreme/heavy rainfall in at least one month of the rainy season. As outlined in the section on cholera (above), this may exacerbate water quality and sanitation problems. As sanitation is a primary non-climatic driver of schistosomiasis, this may result in an increase in this waterborne disease.

Figure 13: Detail on schistosomiasis and lymphatic filariasis in Senegal

a. Distribution of schistosomiasis survey data in Senegal



b. Status of lymphatic filariasis elimination program in Senegal



NOTE: Maps from the Global Health Atlas of Helminth Infections**,** showing the prevalence of the schistosome infection across Senegal (a) and the areas of endemism and intervention in the lymphatic filariasis program in Senegal (b). (London School of Hygiene and Tropical Medicine, 2015).

A.4 MENINGOCOCCAL MENINGITIS

Senegal is part of the "meningitis belt" (Figure 14) that extends across Africa from Senegal to Ethiopia. Although meningitis is endemic in Senegal, the country is not considered "hyperendemic" for the disease. After a decline in meningitis immunization coverage, the Ministry of Health is making concerted efforts to scale up meningitis immunizations again. Changes in periods of dryness could affect the transmission pattern of meningitis.

Figure 14: Africa's meningitis belt. (MenAfriVac, 2015)

Meningococcal meningitis thrives in hot, dusty, and dry conditions. Therefore, outbreaks of meningococcal meningitis currently occur in the dry season with the risk increasing with the arrival of the seasonal winds (*Harmattan*) in November, and reducing again in April when the humid air returns prior to the rainy season. Wind is a primary driver for the spread of the virus, so windy conditions exacerbate the disease spread.

The dry conditions experienced in the country over the past few decades, which can prolong the dry season, would have provided conditions suitable for the spread of meningitis. Mapping of the meningitis belt suggests that meningitis risk does not currently extend to northern Senegal, with the result that the spread of the disease is only found in the southern half of the country (WHO practical guidelines, 1998). This is fortunate as the longer dry seasons found in the north and northeast would be conducive to a longer period of exposure to the risk, if/when the disease were found in the north.

A.4.a Meningitis under a changing climate

Outbreaks of meningococcal meningitis currently occur in the dry season, with the risk increasing with the arrival of the seasonal winds from the Sahara in November and reducing again in April when the humid air returns prior to the rainy season. The disease requires hot and dry conditions which are projected to increase in the dry season under the future projections. Therefore**, based on the climate element alone, the risk of meningococcal meningitis may increase in the future. The spatial distribution of meningitis is a function of the seasonal**

winds, and it is unknown how these winds may change in the future. Currently, the meningitis belt does not extend to the north of the country (WHO, 1998). It is unknown whether this may change under the future climate.

A.5 UNDERNUTRITION

Undernutrition refers to the deficiency of calories or of essential nutrients, and is thus essentially about the lack of food and/or the lack of the appropriate food. Many inter-linking drivers, both socio-economic and climatic, shape people's food intake. Agricultural productivity, in relation to current climatic factors such as climate variability, droughts, and floods, is just one aspect which shapes people's ability to put food on the table. People's ability to access food are also shaped by numerous other factors, including poverty and access to services.

Agriculture in Senegal is predominantly rain-fed, however adaptation measures such as improved seed varieties and irrigation, albeit limited, have been introduced. In recent years, recurrent food crises have been attributed to agricultural disruption caused by poor rain in some areas and flooding in others as well as market factors and fluctuations in food prices. 2013 was generally a good year for agricultural output but in 2014 Senegal had late and erratic rainfall and a 40 percent decrease in cereal production. Pastoralists also had a lean season because of the late onset of rains (IRIN, 2014; WFP, n.d.).

Good food availability in the northeast and central areas of the country normally extends from October through June. However, decreased cereal production and deterioration of livestock in 2014, combined with low income, is predicted to expose poor households to acute food insecurity "Stressed" level (IPC Phase 2) as of March 2015. This situation could involve more households in the coming months (FEWS NET, 2014).

Closure of the border with Guinea due to the Ebola epidemic interfered with trade flows and markets and hurt the local economy. Border restrictions have been lifted but the income of households from many typical sources remain below average, considerably reducing their purchasing power and limiting access to food for poor households that depend on the market for food purchases. As food stocks from last year's harvest decline, more households in the area may become "Stressed" (IPC Phase 2) for food insecurity and possibly move to "Crisis" level (IPC Phase 3) later in 2015 (FEWS NET, 2014).

The majority of cash crops grown in Senegal are cultivated in the south (WFP & IRI, n.d.) away from the dry Sahel zone. While the south experiences the highest seasonal rainfall totals in the country, an excess of 1000 mm during the rainy season, high inter-annual and multi-decadal rainfall variability and dominance of rain-fed agriculture can be challenging for food production.

A.5.a Undernutrition under a changing climate

As noted in Table 2, undernutrition is a complex subject because it is a factor of several inter-linking socio-economic drivers. Based on the available climate projections it is possible to provide commentary on the impact that climate change may have on locally grown crops. As the majority of cash crops are grown in the south, this analysis focuses on southern Senegal.

There is a consistent message of warming across all Coupled Model Intercomparison Project Phase 5 (CMIP5) models. This higher temperature and associated evapotranspiration may lead to added pressure on the water supply for irrigation during dry periods. The projected increase in extremes under climate change (droughts and floods) may also lead to added pressure on the agricultural sector, either reducing crop yields or destroying crops all together. The agricultural sector in Senegal is already stressed by the significant climate variability of the region and climate change is only likely to exacerbate this. In order to provide a detailed and comprehensive assessment of changes in nutrition under future climate changes, a full agricultural research study would be required.

A.6 FOOD SECURITY AND MALNUTRITION

The FAO defines food security as **"**a situation that exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, n.d.).

There are three components of food security: availability, access and utilization:

- *Availability* refers to the amount, type, and quality of food a unit (such as community, household, and individual) has at its disposal to consume. It can be further broken down into production, distribution, and exchange.
- *Access* to food refers to the ability of a unit to obtain access to the type, quality, and quantity of food it requires. The subcomponents of access are affordability, allocation, and preference.
- Food *utilization* refers to the individual or household capacity to consume and benefit from food. The three subcomponents are nutritional value, food safety, and social value. (Erickson, et al., 2011)

Food insecurity may be short-lived or chronic**.** The drivers of short-lived and chronic food insecurity are often different: short-lived results from variability in production, food prices, or incomes; chronic is the result of systemic or structural failure such as poverty or political marginalization. Ericksen et al. (2011) note that:

> Chronic food insecurity results from one or a series of transitory shocks causing very vulnerable households to lose the ability to cope with any future shocks. Chronic food insecurity, such as high malnutrition rates or low household incomes, can make populations much more vulnerable to severe transitory shocks like a price increase…Climate change will have longer term impacts on production trends but in the short term it will increase variability and extreme events. Food insecurity is always due to multiple stressors, so the impact of climatic shocks has to be in the context of this multiple exposure. (p. 9)

Food security and poverty are intertwined as people who do not produce their own food (or enough of their own food) must buy what they need to eat. At the end of 2014, there were reports that more people were slipping from being moderately food insecure to facing acute food insecurity and livelihood losses. People who are moderately food insecure are able to use coping mechanisms to get through it but with acute food insecurity negative coping mechanisms (taking out a loan, eating seeds intended for next year's planting, and reducing daily food consumption) come into play (IRIN, 2014).

The Government of Senegal's Poverty Reduction Strategy has had some success: over the decade from 2001 to 2011 the proportion of the population living at or below the national poverty line declined from 55.2 percent to 46.7 percent (World Bank, 2015). However, rural households are more likely to be poor than urban ones: 33 percent of rural households are in the lowest wealth quintile versus 1 percent in urban areas.

In Senegal, the west outranks other regions by having the highest percentage of households in the highest wealth quintile while the south has the highest percentage of households in the lowest wealth quintile. In the north and center, the percentage of households in the lowest and highest quintiles is almost the same (ANSD & ICF, 2013).

Table 3: Lowest and highest wealth quintiles by major region

Region	% Population in Lowest Wealth Quintile	% Population in Highest Wealth Quintile
West	5	**41**
North	23	9
Center	24	10
South	**40**	6

Source: ANSD & ICF, 2013

Low income curtails purchasing power, which exposes many households to food insecurity either on a temporary or long-term basis. Even if there is food *available* for purchase, poor households don't have *access* to it.

Access to markets is critical to food security in Senegal. Two interrelated climatic impacts could affect the ability of households to access food during critical months. First, if the lean season intensifies due to climatic variability (e.g., delay in the onset of the rainy season) it is likely that households would have to purchase more food during the lean season. Second, under a scenario of increasingly erratic rainfall, extreme climate events such as floods could destroy or severely affect infrastructure (roads, transport, markets) reducing the ability of households to purchase food.

Senegalese households rely heavily on markets for most of their food: 87 percent of rural households and 97 percent of urban households purchase much of the food they consume. Consumption from own production is the second most common food source and accounts for approximately 10 percent of all food in rural households. The remaining food is obtained from credit/borrowing, and in-kind gifts (WFP & IRI, n.d.). Reliable infrastructure therefore is critical, especially in the southern parts of the country (WFP & IRI, n.d.).

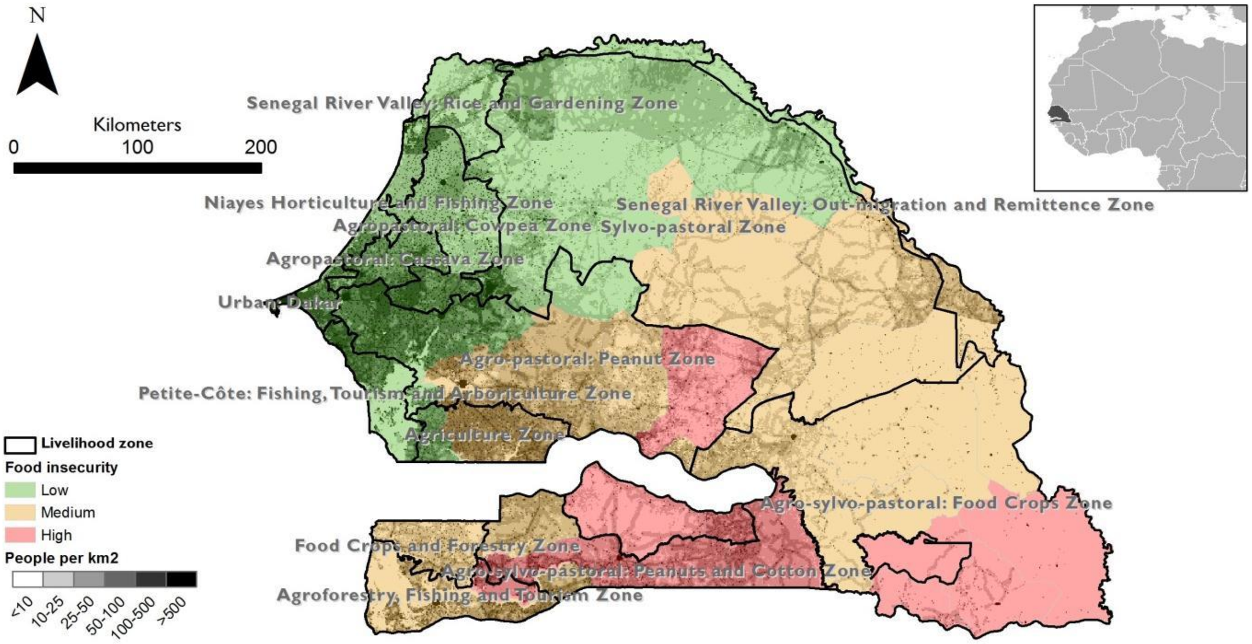
In Senegal, markets, and especially rural markets, play an important role in the food security of households. They contribute to the family savings as a source of income (sale of agricultural production and livestock) and for the purchase of food products and production inputs. During lean periods poor households that cannot cover their cereal needs generate revenue by selling small ruminants and wild fruits. Thus, market access is essential for the food security of poor households. Access to the market is dependent on factors such as options to transport products to market, the existence and quality of road infrastructure, the physical distance to the market, the frequency of market days, product availability, and price fluctuations (USAID, 2014b).

Access to markets is thus an important adaptation element for the households in the face of climate change. Physical inaccessibility is a characteristic of rural food insecurity because it interrupts the food supply chains. In addition to the impact on food production, extreme weather events such as floods, strong winds, and temperature increase can damage already poor transport infrastructure.

The time that it takes for food to reach markets affects the ability of consumers to buy and the ability of producers to sell. Food that has spoiled during lengthy transport cannot be sold. Although West Africa has more urban centers with markets than East and Central Africa, poor roads and lack of transportation add to the time and cost of getting to markets. The time to markets in Senegal can take anywhere from two to 16 hours depending on location of origin and location of market (USAID, 2014b).

Food security, poverty, and undernutrition are closely linked. Figure 15 shows an overlap of areas with high prevalence of food insecurity, areas with high rates of global chronic malnutrition, and areas with high poverty incidence, providing a more comprehensive picture of food security trends in the country. The map shows that food security problems are concentrated in southern and central areas, particularly in the Ziguinchor and Kolda regions of Casamance, and in Kédougou and Kaffrine regions.

Figure 15: Overlap of food insecurity, poverty, and undernutrition (WFP & IRI, n.d. p.30)



Food insecurity is shown in this map through three proxies: prevalence of food insecurity, poverty incidence and global chronic malnutrition as measured by the CFSVA (2009/2010).
A department is considered to have high food insecurity when prevalence of food insecurity is >20%, poverty incidence is >60% and GCM is >30%.
A department is considered to have medium food insecurity when prevalence of food insecurity is 15-20%, poverty incidence is 40-60%, and GCM rates are 20-30%.
A department is considered to have low food insecurity when prevalence of food insecurity is <15%, poverty incidence is <40%, and GCM rates are <20%.

Malnutrition is an underlying factor for much of the burden of disease in Senegal. WHO has defined four categories of nutritional status: “acceptable,” “precarious,” “alarming,” and “critical.” Using those categories, the preliminary survey results show the nutritional status of children under five to be “alarming” in Thies, Louga, Saint Louis, Tambacounda, and Kedougou and “critical” in Diourbel and Matam (Ministere de la Santé et de l’Action Sociale, 2014). Undernutrition among children under five is more prevalent in rural areas (19.1 percent) than in urban areas (12.2 percent) (UNICEF 2014).

Certainly not all malnutrition is due to food insecurity; suboptimal practices of breastfeeding and Infant and Young Child Feeding (IYCF) are also important factors. However, lack of availability and access to appropriate foods for young children between six and 23 months could be factors in poor IYCF practices particularly in rural areas. The preliminary results of a SMART survey found that food insecurity in rural areas has increased: from 15.1 percent in 2010 to 25 percent in 2014.

Table 4: Breastfeeding and IYCF practices in Senegal

Early initiation of breastfeeding	Exclusive breastfeeding <6 months	Introduction to solid and semi-solid foods at 6-8 months	Minimum acceptable diet 6-23 months
48%	39%	67.2%	9.2%

Source: UNICEF, 2015

- Stunting (height for age) is more prevalent in central Senegal and least prevalent in the west.
- Wasting (weight for height) is more prevalent in the north and least prevalent in the west.
- Underweight (weight for age) is more prevalent in the south and least prevalent in the west. Boys are more likely than girls to be wasted (10 percent versus 8 percent respectively) and underweight (17 percent versus 14 percent respectively). Children living in rural areas are at greater risk for all forms of malnutrition.

Table 5: Prevalence of malnutrition by area of country

Area[5]	Underweight	Stunting	Wasting
Center	2	**4**	2
West	1	1	1
North	3	2	4
South	**4**	3	3

Ranking 1 to 4 with 1 = least; 4 = most
Source: Ranking based on Continuous Demographic Health Survey 2013 (ANSD & ICF, 2013)

As of February 2015, the UN Office for Coordination of Humanitarian Affairs (UNOCHA) estimated that of Senegal's 13.7 million people, approximately 3.8 million (28 percent) are food insecure (2015). These figures are considerably higher than those of the 2013 national food security and nutrition survey that reported 2.2 million people as being food insecure.

Recognizing the complexity of undernutrition, and its multiple and inter-linking drivers, further unpacking of the issue is beyond the scope of this study.

5 Center = Diourbel, Fatick, Kaolack, Kaffrine; South = Ziguinchor, Sédhiou, Kolda, Kédougou, Tambacounda; North = Matam, Louga, Saint-Louis; West = Dakar, Thiès

IV. CLIMATE-LINKED APPROACHES TO HEALTH SYSTEMS STRENGTHENING

Key Messages

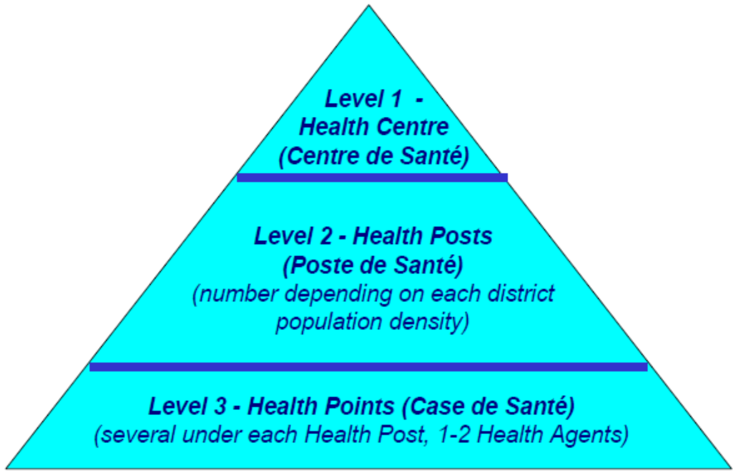
- Inter-ministerial and inter-departmental coordination and communication are essential for reducing water-related disease transmission and for improving the national capacity to forecast, prepare for, and respond to an impending event or escalating disease outbreak and developing health system resilience.
- Health personnel at all levels of the system – including community health workers – need to be adequately trained for emergency response and have the resources needed to provide care for injuries and treatment for diseases such as cholera, diarrhea, malaria, etc. that may occur during or after an extreme event.

A. THE HEALTH SYSTEM IN SENEGAL

The Ministry of Health governs the policies and standards for the health sector in Senegal. At the national level, the MOH sets policy, develops and oversees strategic and operational plans, and negotiates budget allocations. Each region of the country operates under a health management team that carries out national policies and programs, supervises district health services, and liaises with counterparts of other government ministries and the regional administration. Likewise, at the district level, there is a health management team that oversees health services and provides supervision and support to the community health committees.

In addition to the public health system, private sector health providers operate outside the direct supervision of the MOH but are required to abide by national policies for standards of care. The public health service is the largest provider of health care in Senegal and is organized in a pyramid structure as shown in Figure 16.

Figure 16: Health system pyramid in Senegal (Heyen-Perschon, 2005, p.8)



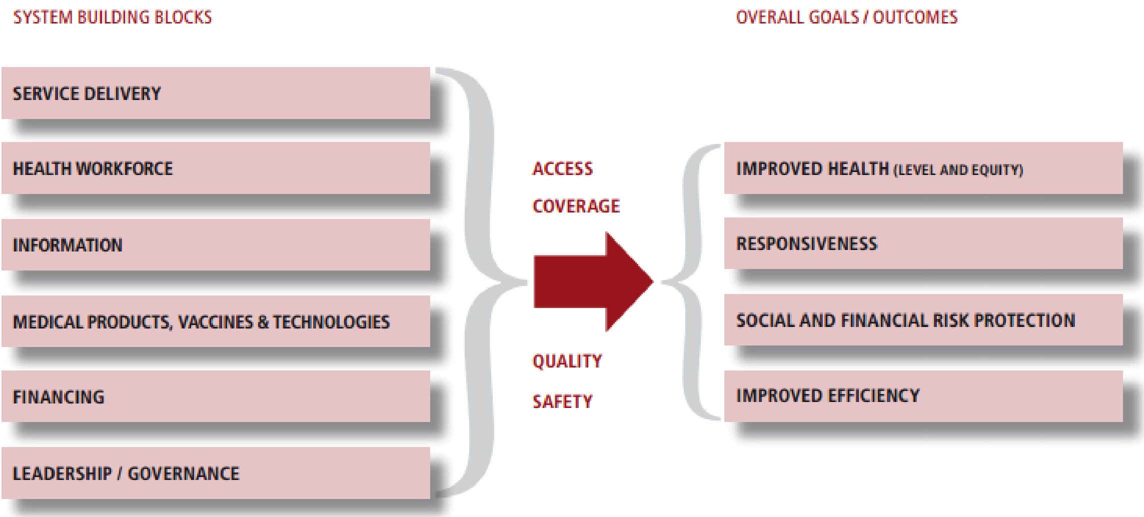
At the top level are university hospitals and regional hospitals, which offer tertiary and emergency care, surgery, consultations, and labor/delivery. Regional health management teams coordinate with regional government administrators and supervise district health teams. At the district level, Health Centers offer consultations, maternity care, minor surgery, and non-surgical emergency care. Each district has multiple Health Posts located in peripheral areas to provide primary care. Private clinics also operate at the district level. At the community level, *Cases de Santé* (Health Huts) are managed by local health committees in collaboration with the district or sub-district health management team. The *Cases* are in rural areas and staffed by health workers who provide basic health care services such as immunizations, antenatal care, diagnosis and treatment of malaria and other common ailments, and well-child clinics. In addition to the *Cases*, there are community health volunteers that do not have formal education in health/clinical care. They make household visits, provide health education, and distribute products (e.g., ORS, condoms). Ideally, the community health volunteers and *Cases de Santé* staff should be functioning as part of the surveillance network to identify and report suspected cases of disease and malnutrition.

The Senegalese Ministry of Health faces many of the same challenges as those in other countries in sub-Saharan Africa: insufficient personnel, inadequate infrastructure, weak supply chain, and poor information management. Many activities are being undertaken to address the challenges such as: m-Health applications to improve surveillance and data management; the Push model to improve contraceptive commodity management; training of health workers at all levels, etc. Scale-up of successful pilots and application to other supplies (in the case of Push for example) should be fostered to improve operating systems and human resource capacities nationwide.

B. BUILDING BLOCKS OF A CLIMATE-SMART HEALTH SYSTEM

The WHO health systems strengthening "building blocks" can help guide development of the MOH's capacity and resilience to plan for and respond to changing disease trends due to climate variation to urgent situations (WHO 2007). These are discussed below, under two general categories: 1) issues absolutely critical under increased climate stresses and 2) those that are important from a resilience perspective.

Figure 17: Building blocks of a health system: aims and desirable attributes. (WHO, 2007, p.3)



B.1 CLIMATE-CRITICAL COMPONENT OF HEALTH SYSTEMS:

- *Leadership and governance*: Access to safe drinking water and improved sanitation are significant factors in prevention and control of diarrheal diseases, neglected tropical diseases, malaria, and others. Planning and development of water and sanitation facilities is the responsibility of the Ministry of Water and Sanitation, not the Ministry of Health. Similarly, although the MOH must respond to emergency situations, responsibility for disaster preparedness and management is not housed in the MOH but rather in the Ministry of the Interior. Other ministries such as Water and Natural Resources, and Agriculture have responsibilities for disaster response over the long term (such as redeveloping the agriculture sector and improving food security following a drought). Thus **inter-ministerial and inter-departmental coordination and communication are essential for reducing water-related disease transmission and for improving the national capacity to forecast, prepare for, and respond to an impending event or escalating disease outbreak and developing health system resilience.**

B.2 COMPONENTS OF A RESILIENT HEALTH SYSTEM:

- *Health workforce*: Severe shortages of health personnel are a major constraint to providing quality routine care as well as to being able to provide urgent care at time of an emergency. Health personnel at all levels of the system – including community health workers -- need to be adequately trained for emergency response and have the resources needed to provide care for injuries and treatment for diseases such as cholera, diarrhea, malaria, etc. that may occur during or after an extreme event.

- *Service delivery*: Related to issues of the health workforce, planning and procedures are needed to make rapid decisions about when, how, and where to refer sick or injured people or where to redirect people needing routine care if local health facilities are not available. In addition to health facility managers, community involvement and education is needed for effective response during emergency situations. From a climate perspective, evidence from other countries suggests that lack of awareness between climate risks and certain diseases such as dengue or malaria often lead to misdiagnosis and ineffective treatments.
- *Health information systems*: Good surveillance and a robust health information system are critical for early identification of disease outbreaks and emergency planning and response. Understanding what diseases will occur when and in which areas of the country can improve the supply chain and deployment of health workers.
- *Medical products and technologies:* Ensuring the availability of medicines and supplies is critical for the provision of quality care for routine and emergency services. For example, facilities in an area of possible cholera outbreak need to have adequate stocks of ORS and IV fluids. Building flexibility into the supply chain management system is important to adjust for seasonal variation in disease incidence (for example, periods of disease transmission in different parts of the country) or to facilitate transfer of supplies and stocks from one region to another in the event of an emergency.
- *Health systems financing*: High out-of-pocket expense for health care can delay care-seeking by people who may infect others thereby increasing the scope of an outbreak. Increasing health insurance coverage and micro-insurance (*mutuelle)* participation can help households grapple with the expense of health care.

In addition to these issues, much of the existing public health system infrastructure and equipment is inadequate, dilapidated, and non-functional. The number of vehicles needed for supervision and monitoring and ambulances for transferring patients to higher level facilities is insufficient. Already, poor roads and areas inaccessible during the rainy season or due to flooding further complicate the provision of quality health care. Increased intensity, short-term events may impede access further (Heyen-Perschon, J, 2005).

Table 6: Current status and some climate-proofing suggestions for the health system in Senegal

Local government function	Current status	Suggestions for climate-proofing based on analysis findings
Service delivery	• Inadequate # of facilities • Inequitable regional distribution of facilities • Poorly equipped	Identify infrastructure at risk from damage to floods and/or with limited access during flooding due to poor transportation network.
Health workforce	• Poorly trained especially at community level • 14 doctors/100,000 people • Shortage of more than 3000 health workers	Promote resilience through education, empowerment and engagement to reduce vulnerability to health impacts of climate change
Supplies and technology	• Shortages and stock outs • Counterfeit products	Review and modify as needed stocking protocols based on changing dynamics of diseases during wet/dry periods.
Information system	• Working to strengthen; m-Health pilots • Trying to catch-up on backlog of service stats	Include environmental and climate parameters in traditional surveillance to better understand and respond to climate-related outcomes.
Financing	• 18% of population has insurance • Health expenditures increased from 4.5% GDP to 6% GDP between 2001-2011	Conduct a cost analysis of potential impacts of climate change on key sectors and modify plans to address key immediate gaps.
Leadership and governance	• Despite health system deficits, life expectancy increased; infant and maternal mortality decreased • Insufficient inter-sectoral planning • Plans and strategies exist	Encourage inter-sectoral planning and response, particularly in water and sanitation and disaster management.

V. FUTURE CLIMATE PROJECTIONS

Key Messages

Projections:

Messages for the 2040 -2059 period (relative to a 1986-2005 baseline) for RCP 8.5 include:

- Some models show increased rainfall, particularly in the southern regions. This is possibly linked to an intensification of the West African monsoon.
- Temperatures are expected to increase more in the interior than at the coast, and increases are higher in the dry season compared to those found in the rainy season.
- Projections of increased rainfall are generally associated with lower projected increases in temperature, and decreased rainfall is associated with higher temperature increases.
- Some models show an increase in extreme/heavy rainfall in at least one month of the rainy season.

Changing future health risks:

- Under both a wet and dry future scenario, there will remain a risk of malaria and lymphatic filariasis in the south. Under the “wet” future scenario, the risk of malaria and lymphatic filaria may increase in the north. However, under a “dry” scenario the risk of malaria and lymphatic filariasis may decrease in the north.
- The risk of cholera, diarrheal diseases, and schistosomiasis may remain high across the country, in association with the increase in extreme/heavy rainfall. However, the risk may become more acute in the south.
- Meningococcal meningitis risk is likely to increase in association with increased temperatures in the dry season.
- Undernutrition may be exacerbated by increasing climate stress on agricultural production.

Uncertainties and limitations:

- By its very nature, projecting the future is uncertain, therefore it is important to incorporate a range of future projections into decision-making.
- The climate of West Africa is complex and characterized by multiple drivers. The suite of GCMs present in the CMIP5 experiment exhibit widely divergent performance when it comes to capturing these particular aspects of the regional climate. This contributes strongly to the wide spread of future projections and hence the uncertainty around these projections.

A. UNCERTAINTIES AND LIMITATIONS

Before inferences are made about how health risks may respond to future climate change, it is important to be fully aware of the caveats associated with the climate change projections. This section outlines these uncertainties and limitations as a basis for interpretation of the projections.

A.1 MODELING UNCERTAINTIES

For all areas of the world, all future projections of climate include a range of uncertainties. It is important to understand that the climate is changing, however there is a range of uncertainty in the *magnitude* of change because of limitations in our scientific understanding of the climate system and hence methods used to project future climate. As spatial scales become finer, there are more uncertainties introduced into the modelling, therefore the range of possible climate response widens.

Projecting future climate is a complex subject and the focus of much ongoing work worldwide. Progress is being made on understanding the underlying sources of uncertainty, and how best to manage these. These sources of uncertainty include:

- *Natural variability:* It is not possible to accurately define the limits of the natural variability, both due to the relatively short time historical records have been kept, but also because the climate system is chaotic. This source of uncertainty cannot effectively be reduced, meaning that users need to evaluate a range of possible futures.
- *Future emissions:* The range of possible societal development pathways will have significant impacts on the greenhouse gas emissions and other environmental forcing factors. Two dominant emission scenarios used in planning are Representative Concentration Pathway 4.5 (RCP 4.5) and Representative Concentration Pathway 8.5 (RCP 8.5). RCP 4.5 represents an emissions pathway that stabilizes before 2100 with emissions peaking around 2040. RCP 8.5 represents a high emissions future where emissions continue to increase into the future.
- *Uncertainty in the science:* Current knowledge and understanding of the dominant physical processes controlling the regional climate system and how these processes might change in the future.
- *Structural uncertainty:* Imperfect tools and methods, including their inappropriate application.
- *Observational uncertainties*: Errors in the information used as input into the climate modelling, as well as that used to test the results.

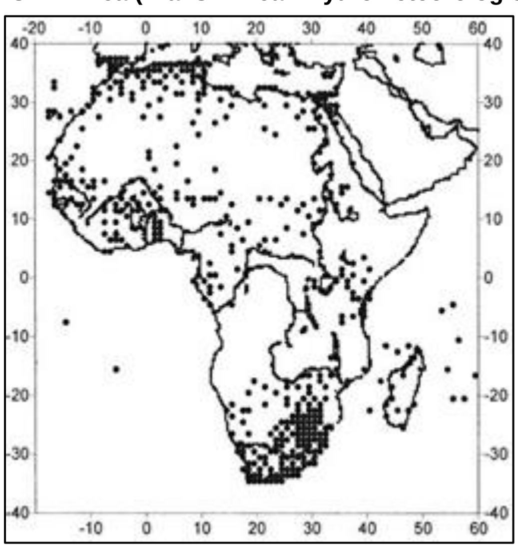
Some aspects of uncertainty can be addressed through improved methodologies. However, some proportion of uncertainty will always remain. Each climate modeling center around the world is addressing these sources of uncertainty in slightly different ways. Nevertheless, the best available science suggests that using one climate model is insufficiently robust to understand future climate impacts on health outcomes, and that combining as many models as reasonably possible under one emissions pathway can avoid dangerous oversimplifications or point forecasts that lead to maladaptive practices. What results from this combined model approach is a range of likely change in the desired variable, be it temperature, precipitation, or another. This allows the user to have a more defensible projection of the direction of change, even though the size of projected change is less certain.

For the reasons stated above, where we provide projections of change in this report (Figures 19 and 20), we have incorporated a subset[6] of CMIP5 GCMs used in the IPCC 5th Assessment Report. This shows the spread of projections across the models, rather than taking a best-guess approach. Because the grid resolution of a GCM is very coarse, it is necessary to apply a procedure whereby finer-scaled information can be produced. This scale conversion is referred to as downscaling. Downscaling proposes that the local scale climate is largely a function of the large scale climate modified by some local forcing factors, such as topography, continentality, and proximity to oceans and lakes. There are two main types of downscaling: dynamical and empirical/statistical. This projection employs the latter type which utilises a statistical technique to approximate the regional scale response to the large scale forcing. The technique used is called Self-Organizing Map based Downscaling (SOMD) developed at the Climate Systems Analysis Group. This downscaling technique provides meteorological station level (or gridded) response to global climate change forcing (see Hewitson and Crane (2006) for methodology).

A.2 LIMITATIONS IN SIMULATING THE CLIMATE IN SENEGAL

A full understanding of the climate of Senegal, and indeed, the African continent in general, is hindered by sparse station coverage and the lack of long, continuous sequences of observed climate data (Figure 18). This is of concern as it limits understanding of regional climate change and variability which takes place over multiple decades.

Figure 18: Meteorological stations in Africa (Trans-African HydroMeteorological Observatory, n.d.)



6 The subset of models consists of all models that provide daily time resolution surface and atmospheric thermodynamic variables required for downscaling

The climate of West Africa is complex and characterized by multiple drivers, which play a role in variability on inter-annual to decadal time scales. It is the poor representation of these climate drivers in models that add to the uncertainty in future projections. For example, Global Climate Models have trouble simulating the tropical Atlantic sea surface temperatures, which are critical to accurately simulating the West African monsoon system. In addition, the sensitivity of models to the parameterizations used and the choice of boundary conditions can also lead to diverse results.

B. FUTURE PROJECTIONS OF CHANGE

B.1 TEMPERATURE

This report focuses on the wet season temperatures because they are likely to have the greatest impact on health. However, although the temperature projections for the wet season are shown here (Figure 19), it should be noted that temperature increases may be more acute during the annual dry season.

Figure 19 shows the observed temperatures in the upper left hand panel followed by projections of average maximum temperature change across each of the subset of CMIP5 models, for 2040-59 for Representative Concentration Pathway (RCP) 8.5[7]. Although each of the models shows a different magnitude of change, there is a consistent message of warming across the models and across the country. However, there is a general indication of greater warming in the interior of the country as opposed to the coastal areas. The coastal areas are projected to show an increase in maximum average temperature of between 0.75 and 2°C by the middle of the century, whereas, the interior may show an increase of between 0.25 and 3°C in the same time period.

If these temperature changes are then overlaid on to the observed baseline of the country, one can see that the north of the country may begin to see average maximum temperatures of more than 40ºC in the rainy season. The south of the country may see average maximum temperatures of between approximately 35 and 38°C in the rainy season.

B.2 RAINFALL

In contrast to the maximum temperature projections, the projections of rainfall show more varied projections across the range of CMIP5 models. Figure 20 shows that the model spread is such that some models show a drying across the country during the rainy season, whereas others show increased rainfall across the country. Some models show increased rainfall, particularly in the southern regions. This is possibly linked to an intensification of the West African monsoon.

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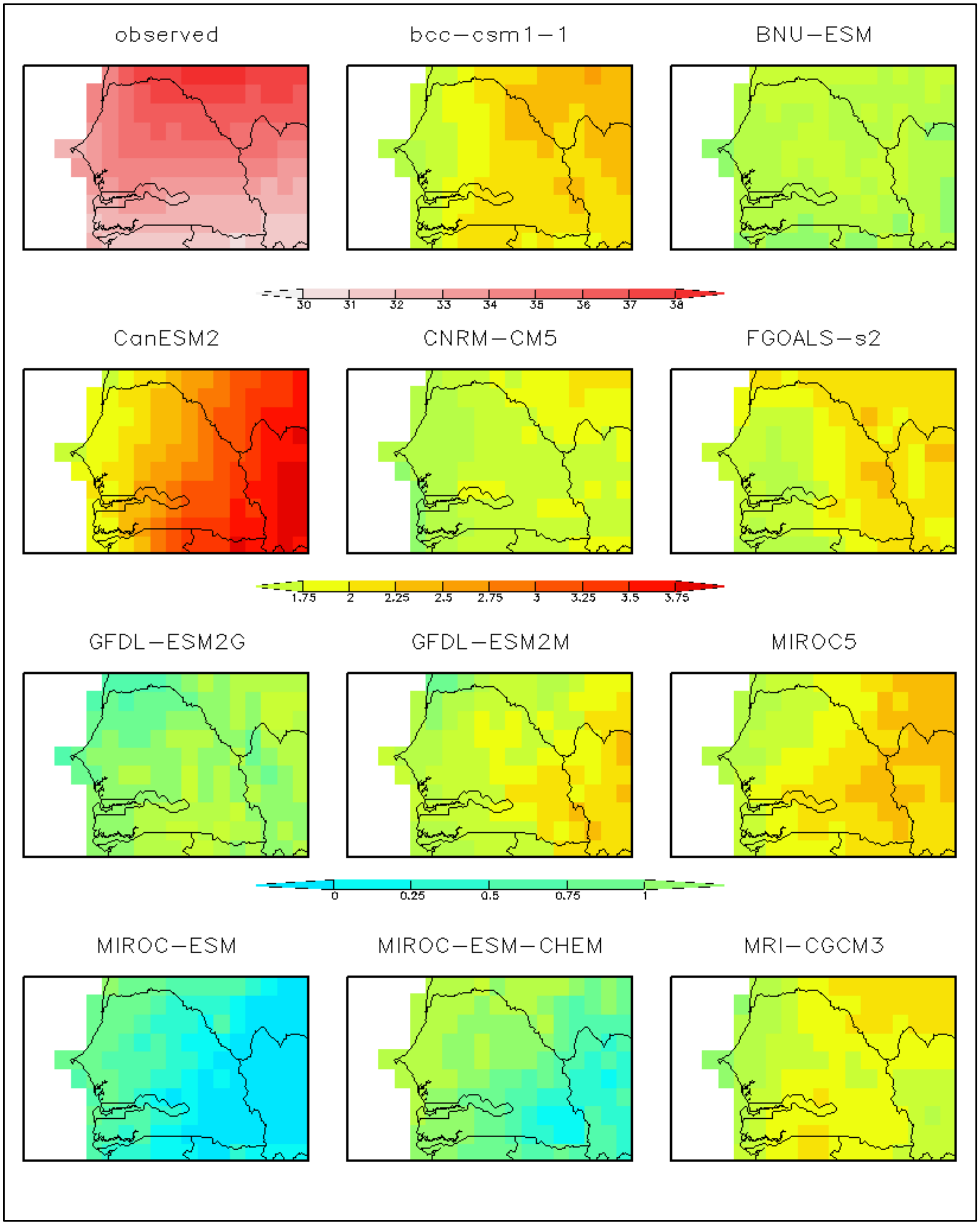
7 In CMIP5 climate projections are driven by concentration or emission scenarios known as “Representative Concentration Pathways” (RCPs). RCP 8.5 means that at the end of the 20th century, the radiative forcing will be 8.5 $W.m^{-2}$. This is considered to be a “high” (pessimistic) scenario.

B.3 EXTREME RAINFALL

A number of health risks in Senegal are susceptible to and/or exacerbated by heavy/extreme rainfall, which makes this variable worthy of investigation. Unfortunately, the gridded downscale used to produce Figures 19 and 20 below is based on monthly data, so daily statistical analysis is not possible. Therefore, in order to investigate extreme rainfall, statistically downscaled data for two stations have been chosen for analysis (data accessed on the Climate Information Platform: http://cip.csag.uct.ac.za). The two stations, Thies and Matam (Figure 21), represent the coastal and inland areas of Senegal, respectively.

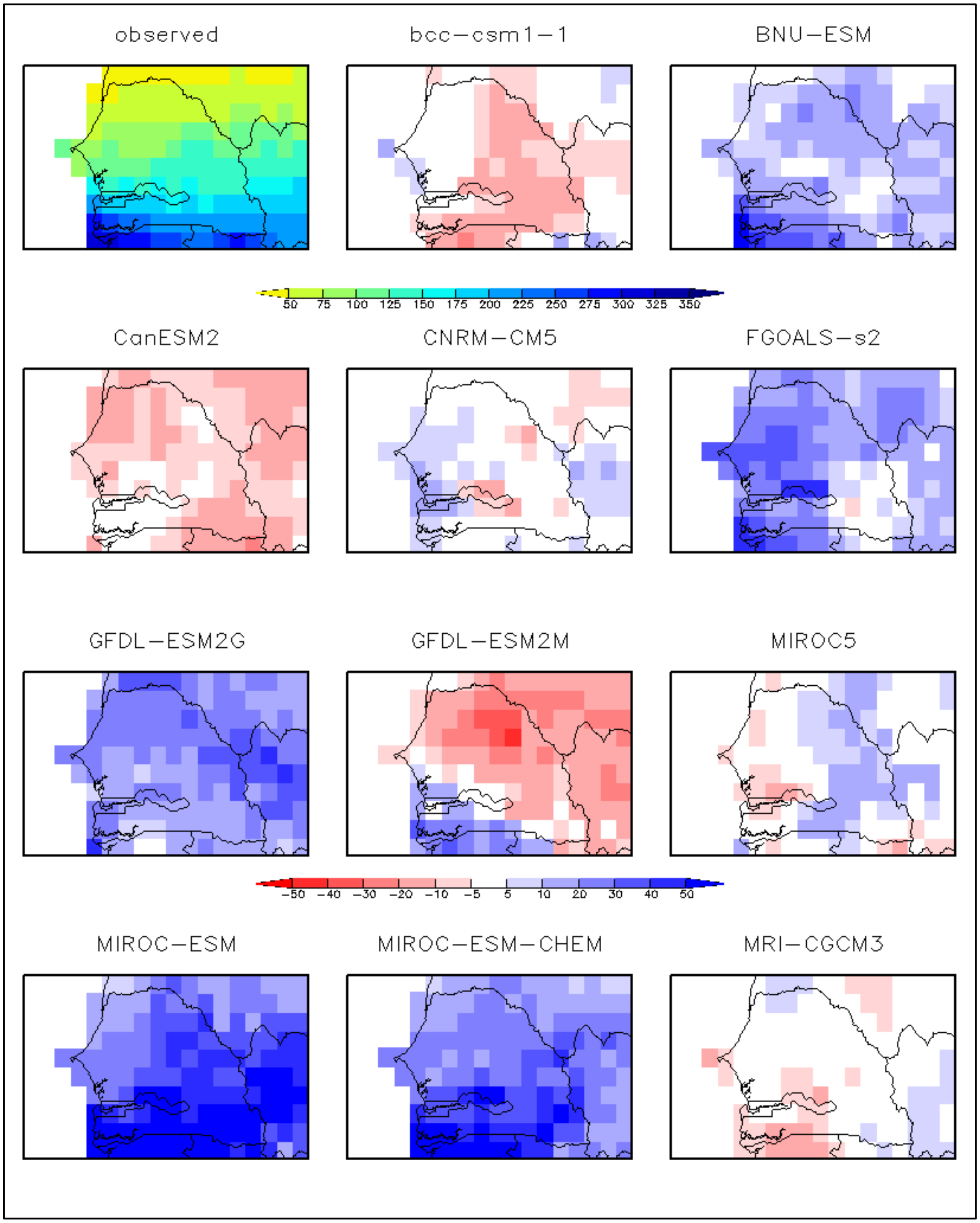
From these two stations, it can be seen that during the rainy season, there is a spread of projections from a potential decrease in extreme wet days to an increase in extreme wet days. However, the greater proportion of models point to an increase in extreme rainfall. For both stations, the potential increase in extreme rainfall forms a substantial addition to what is currently observed, for at least one month in the rainy season.

Figure 19: Downscaled projections of changes in average summer maximum temperatures.



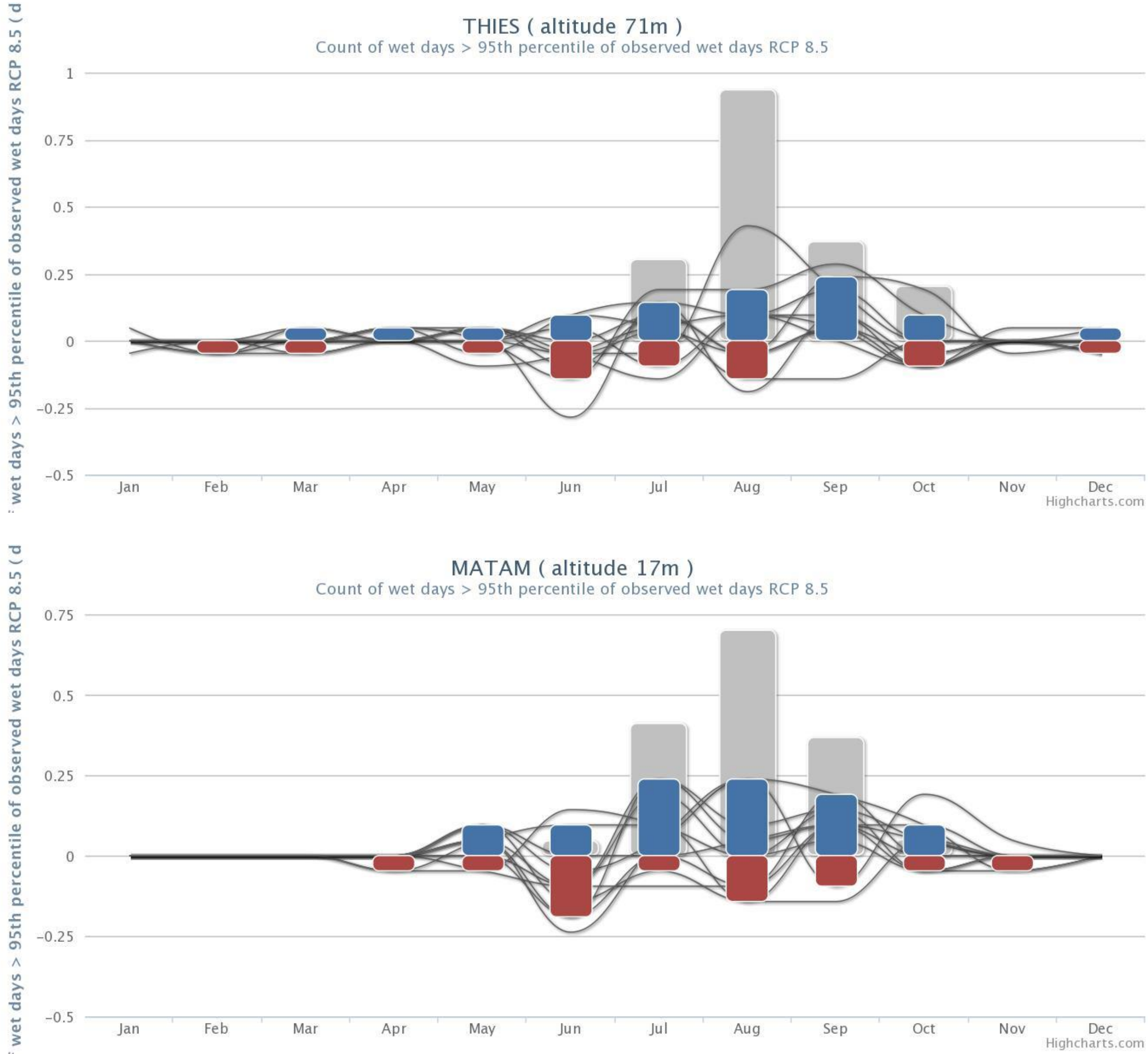
Note: Downscaled projections of changes in average July, August, and September (summer rainy season) maximum temperatures (in °C) between the 2040-2059 and 1986-2005 periods. These are from models (name is on top of each Figure panel) run with RCP8.5 scenario. The observed is shown in the top left panel (the top color bar applies to this panel only).

Figure 20: Downscaled projections of changes in average summer rainfall



NOTE: Downscaled projections July, August, and September (summer) showing total average rainfall change (in mm) between the 2040-2059 and 1986-2005 periods. The name above each panel indicates the GCM, using RCP 8.5 that was used for the downscaling procedure. The observed is shown in the top left panel (the top color bar applies to this panel only).

Figure 21: Projected changes in wet days above the 95th percentile of observed wet days in two areas



NOTE: The range of projected future changes in the count of wet days above the 95th percentile of observed wet days**,** across 10 different statistically downscaled CMIP5 GCMs, for RCP 8.5 pathway for a) Thies (west) and b) Matam (northeast). The gray bars represent the observed climate (1979-2000) and the blue and red bars indicate the projections for an increase or decrease in the variable, respectively.

C. STORYLINE APPROACH

Due to this inconsistent message in rainfall projections, a storyline approach has been taken to represent the potential changes in the country's future climate. Storylines offer a way of describing two plausible descriptions of what the future – in this case of climate – may hold, based on a physically sound evaluation of climate dynamics for the region. Two scenarios are presented when discussing potential changes in health risks. These are:

C.1 MODERATELY WARMER AND WETTER

Cooler maximum temperatures are often found during the core rainy season in Senegal, which are attributed to the increased cloud cover and moisture during this period. In this "*moderately warmer and wetter"* scenario, an increase in rainfall in the future would result in the change in temperature only being moderately higher than that currently observed. This is particularly true for southern areas, which are projected to be wetter than the rest of the country. The wetter conditions in the south could either arise from a more intense monsoon or due to the duration of monsoon being prolonged. The dry season will still experience the greatest increases in temperature.

C.2 STRONGER WARMING AND DRYING

In contrast to the previous scenario, with the drier conditions (i.e., less cloud cover and rainfall), the country would not experience, to as great an extent, the relatively cooler temperatures often found during the rainy season. The seasonal variation in temperature would also be much greater than that currently observed across the country. The inland regions (especially the northeast of the country) would experience greater temperature increases than the coastal regions. Given the low rainfall totals experienced in today's climate across the north, this region could be more vulnerable to a decrease in rainfall in comparison to the south.

VI. INSTITUTIONAL ASSESSMENT

Key Messages

- Senegal is vulnerable to drought and flooding, sometimes both in the same growing season, with devastating results for livelihoods and food security. Capacity to anticipate and manage climate risks could be improved with vulnerability assessments, early warning systems, risk assessment, and monitoring systems.
- The MOH in Senegal has an ambitious plan to strengthen the functioning of the public health system and improve health status but the ministry alone does not have the mandate, human resources, expertise, or funding needed to sufficiently address climate risks and their health impact. Coordination is needed with other line ministries and departments working on, for example, flood control and water and sanitation.
- The Post Catastrophe Assessment Report and the survey on managing natural hazards in Dakar include recommendations about needs construction, coordination, and management across sectors.

A. EXISTING INSTITUTIONS AND STRATEGIES TO SUPPORT A CLIMATE SMART HEALTH SYSTEM

The MOH has an ambitious plan to strengthen the functioning of the public health system and improve health status but the ministry alone does not have the mandate, human resources, expertise, or funding needed to sufficiently address climate risks and their health impact. Several ministries and departments, including the Civil Protection Directorate in the Interior Ministry, are working on flood control and water and sanitation facilities. The national water company (and asset holding company), Société Nationale des Eaux du Senegal (SONES) manages the country's water resources and contracts operations out to a private operating company, Sénégalaise des Eaux (SDE). In urban areas, the primary institutions involved with water include the Ministry of Agriculture and Water Resources; Ministry of Economy and Finance, which oversees WSS programs and projects financed by the Government; the Higher Water Council (including its Water Technical Committee), which sets policy; SONES, the asset holder which holds the concession for urban water resources; and SDE, a private company that manages the urban water service. SONES is responsible for managing sector assets, planning and financing investments, and for quality of service regulation. Sanitation falls under the jurisdiction of the Ministry of Prevention, Public Hygiene and Sanitation (MPHPA) and its Sanitation Department (DAS), which defines strategy, sets rates, and implements sanitation programs. The National Office of Urban Sanitation (ONAS) is an autonomous public agency in charge of operation and maintenance of sewer networks as well as collecting, treating, and recycling both wastewater and storm water in urban and peri-urban areas. In rural areas, sanitation is organized around regional sanitation divisions under the MPHPA. Rural communities and local authorities also play a role, in the form of decentralized cooperation and in collaboration with non-governmental organizations. Building on these partnerships collaboration with MOH in planning and communication could increase the resilience of the country's health system. Some relevant assessments and strategies available for this area are listed in Table 7.

Senegal is vulnerable to drought and flooding, sometimes both in the same growing season with devastating results for livelihoods and food security. Capacity to anticipate and manage climate risks could be improved with vulnerability assessments, early warning systems, risk assessment and monitoring systems (WFP & IRI, n.d.).

B. GOS READINESS TO ADAPT TO CLIMATE CHANGE

The Government of Senegal is aware of the risks that climate change poses especially to the agriculture sector and for long term economic growth. Development of the National Adaptation Program of Action (NAPA) indicates that there is dialogue and planning at high levels of government. However, the absence of health considerations in the NAPA suggests that a comprehensive approach for addressing climate change and developing resilience across sectors is missing. Review of available information for this analysis did not turn up documents that show health sector involvement in discussions about climate change. That is not to say they have not occurred, only that documentation to that effect was not found during this analysis. Interviews with MOH officials might reveal that discussion and planning for climate change and health are in fact on-going.

If the MOH has not begun incorporating climate change into their plans, the documents and strategies noted in Table 7 could provide a starting point for consideration helping to identify a role for MOH in supporting adaptation. For example, the Post Catastrophe Assessment Report and the survey on managing natural hazards in Dakar include recommendations about needs construction, coordination and management across sectors. Development of a Health National Adaptation Plan to complement the NAPA would focus MOH attention on climate change risks and foster a larger, multi-sectoral dialogue (WHO, 2014).

Table 7: Available strategic plans of relevance for climate change screening

National and Regional Strategies	Overview
Ministry of Economy, Finances, and Planning	Plan d'Actions Prioritaires 2014-2018 National sector and budget priorities
Ministry of Health and Social Action	The National Health Development Program (PNDS) 2009 – 2018 articulates the health policy of the Government of Senegal and provides a medium-long term planning framework.
Ministry of Health and Social Action	The Sector Investment Program (PIS) 2011-2015 sets out the operational and cost plans for PNDS priorities.
Ministry of the Environment and Sustainable Development	Published the National Plan for Climate Change Adaptation (NAPA) in 2006 which identified the vulnerabilities of the country's various regions to the negative effects of climate change. Key factors for the country's economy, i.e., water resources, agriculture and coastal areas are the focus of the plan. (Support for NAPA implementation is included in DO1 of the USAID Senegal CDCS.)
Urban	
Rapport d'Evaluation des Besoins Post Catastrophe *Inondations urbaines à Dakar 2009*	An assessment of 2009 flood damage primarily in Dakar and vicinity. Calculates cost of damage and impact on multiple sectors (education, health, agriculture, etc). Makes recommendations about action needed to mitigate flood impact in the future.
Disaster Preparedness, Prevention and Response	
Ministry of the Interior/Civil Protection Agency **Disaster Risk Management and Climate Change Adaptation project.**	The project complements the recently signed US$55.5 million World Bank International Development Association credit agreement with Senegal for storm water drainage in Dakar's suburban neighborhoods. By the end of Phase one the Government is expected to have launched a roadmap for disaster risk management and will have set up coordination mechanisms for early warning, preparedness and response. In addition, a state-of-the-art Civil Protection Agency headquarter building will be constructed adding to the modernized infrastructure. Phase two of the project will consolidate the country capacity to manage risk through the development of Geographic Information Systems (GIS) tools, a functioning early warning system, implementation of a risk awareness campaign, strengthening of a DRM financing mechanism and support to the National Strategy for the Protection of Coastal zones.
Preparing to Manage Natural Hazards and Climate Change Risks in Dakar, Sénégal. A Spatial and Institutional Approach. World Bank. 2009	Report describes a pilot study of natural risk hazards in the peri-urban areas of the Dakar. Used new tools for spatial and institutional analyses and proposed dissemination and awareness-raising tools to inform stakeholders about the general parameters of the natural hazard risks facing the Dakar area. The pilot study concludes with a broad action plan for Dakar, to foster disaster management practices, as motivation for a stakeholder debate to define subsequently a set of specific and viable actions.
Sectoral Plans	
AMCOW Country Status Overview. Water Supply and Sanitation in Senegal. Turning Finance Into Services for 2015 and Beyond	Report of the second country status overviews (CSO2) commissioned by the African Ministers Council on Water (AMCOW). The analysis aims to help countries assess their own service delivery pathways for turning finance into water supply and sanitation services in each of four subsectors: rural and urban water supply, and rural and urban sanitation and hygiene.

National and Regional Strategies	Overview
	The CSO2 analysis has three main components: a review of past coverage; a costing model to assess the adequacy of future investments; and a scorecard which allows diagnosis of particular bottlenecks along the service delivery pathway. The CSO2's contribution is to answer not only whether past trends and future finance are sufficient to meet sector targets, but what specific issues need to be addressed to ensure finance is effectively turned into accelerated coverage in water supply and sanitation. In this spirit, specific priority actions have been identified through consultation. A synthesis report, available separately, presents best practice and shared learning to help realize these priority actions.

Table 8: Author's evaluation of the Government of Senegal health system readiness to adapt to climate risks

Category	Questions	Yes	Somewhat	No
Information	Do appropriate systems for gathering and analyzing information exist (air photos, neighborhood charts, maps)?		√	
	Are data publicly available and accessible? (is information sharing a problem?)			√
	Have vulnerability assessments been done?			√
	Do the vulnerability assessments mention climate change?		√	
	Are the Health System actors aware of the most vulnerable areas?		√	
	Does an early warning system exist for major health risks?			√
Institutions	Does the GoS have a designated person or main contact on climate change?			
	Are there any other institutions/individuals who are familiar with climate change adaptation issues?	√		
	Are there institutional 'focal points' to bridge the communication challenges?	√		
	Does the GoS have the capacity to coordinate sectoral specialists?	√		
	Are people aware of the risks and how variability will continue to impact them?		√	
	Do Health Strategies and plans mention climate change?			√
Planning	Are the Health plans kept up to date (i.e. updated every five years?)	√		
	Is climate change addressed/included in the official plan's policies?			√
	Are Health priorities in climate change clearly articulated?			√
	Have key Health services been identified as vulnerable where coordination is required?			√
	Is there a body/person/organization responsible for climate adaptation?			√

VII. OPTIONS ANALYSIS AND RECOMMENDATIONS

All of the health conditions included in this analysis that are impacted by climate variability and change are linked positively or negatively to water. Whether from heavy rains that cause flooding, unreliable rainfall that causes crop failure, use of unsafe water for domestic use, or bodies of water that are vector breeding grounds, water is a cross-cutting factor. Most, although not all, of these health conditions are also linked to inadequate sanitation. It is clear that climate change will in these cases act as a multiplier of existing health problems or change the location of health concerns of import in Senegal.

A. OPTIONS ANALYSIS

Responding to these risks requires efforts categorized as incremental, transitional, and transformational.

- *Incremental* actions focus on improving health and health care services for climate-related health outcomes without necessarily considering the possible impacts of climate change.
  - For example, in Senegal, this includes continued investment in access to clean water and sanitation, especially in rural areas. As the second leading cause of death among children under five, prevention of diarrhea through increased access to clean water and improved sanitation, and proper hygiene practices (especially hand-washing with soap) would contribute to reducing infant and child mortality.
  - Malnutrition is also associated with recurrent bouts of diarrhea, thereby providing additional argument to invest more in water and sanitation.
- *Transitional* actions include those that focus on shifts in attitude and perceptions, leading to initiative such as vulnerability mapping, making better use of early warning information, setting up surveillance efforts in areas of high risk, and ensuring the health sector is at the table in planning adaptation.
  - Better disaster planning and early warning would allow the MOH to more effectively prepare for emergency situations. The danger of floods in Senegal should be seriously considered. Floods are harbingers of injury and disease. In addition, floods damage and destroy public infrastructure including health centers, which disrupts the availability of vital health care services.
  - Taking climate change into consideration as a factor in developing national health plans can help build on core health system functions (leadership and governance, health workforce, service delivery, etc.), and strengthen essential coordination 00mechanisms with other sectors and actors to ensure synergies in efforts and

responses. Developing the resilience of the MOH in the face of climate change will require time and investment.

- *Transformational* actions are those that warrant fundamental changes in health sector systems. In Senegal, these are not warranted at this time without a more in-depth review of current available data and institutions.

Table 9: Adaptation options to reduce the health impacts of climate change

Health Outcome	Policy and Planning	Investment	Coordination
Injuries, illnesses, deaths and changing environmental conditions related to extreme weather events	• Disaster management, particularly on urban floods, including the preparation of a master plan for storm water management in Dakar and the vicinity • Develop an urban development plan including maps of flood risks • Building guidelines for areas in zones of high risk for floods	• Disaster early warning systems that include evacuation plans and flood risks maps • Establishing a system for storm water drainage in priority areas around Dakar e.g., Pikine and Guédiawaye • Establish evacuation plans and surveillance in rural areas and inland cities including St. Louis, Dagana, Kaolack, Kaffrine, Mbour, Kolda, Thies, Tambacounda and Sédhiou • Scale up humanitarian assistance capacity to cope with increasing numbers of people impacted by extreme events	• Ministry of the Interior and Public Security • Ministry of Water and Sanitation • Ministry of the Environment and Sustainable Development • Ministry of Public Works • Ministry of Urban Renewal, Housing, and Living Environment
Undernutrition	Explore crop insurance or employment guarantee schemes that merge with social protection measures, particularly in the South	• Drinking water and sanitation infrastructure improvement • Surveillance for food security and malnutrition • Diagnosis and treatment for Moderate Acute Malnutrition and Severely Acute Malnutrition	• Ministry of Agriculture and Rural Equipment • Ministry of Economy, Finances, and Planning
Vector-borne diseases	Integrated Vector Management (IVM) strategies implemented using targeted interventions to remove or control vector breeding sites, disrupt vector lifecycles, and minimize vector-human contact, while minimizing effects on other ecosystem services	• Water and sanitation • Evaluation of micro-dams and IVM such as space spraying, improved household quality, insecticide treated materials	• Ministry of Agriculture and Rural Equipment • Ministry of the Environment and Sustainable Development • Ministry of Energy
Waterborne diseases	• Watershed protection • Water quality regulation, particularly in urban	• Water and sanitation • Early Warning Systems • Surveillance	• Ministry of Water and Sanitation • Ministry of Public Works

Health Outcome	Policy and Planning	Investment	Coordination
	and peri-urban areas, integrated vector management strategies	• Institutionalized water testing for key infestation sites	

B. RECOMMENDATIONS

To define MOH readiness to address current and projected climate risks, three parameters are considered: (1) the available information base, (2) institutions and staff, and (3) planning mechanisms. Potential interventions that could be implemented to help the country's health system become more prepared to deal with current and projected future risks can be grouped in several intervention focal areas:

- Information base: an effective information base to support decision making should be available to the public, providing an institutional memory to enable re-adjustments of priorities and actions as circumstances change
- Institutions and staff: technically competent institutions and staff will better assume the necessary tasks of coordination during emergencies or under changing circumstances and can provide incentives for improved planning mechanisms across relevant organisms.
- Planning mechanisms: adaptation requires first the recognition that climate change may alter the long-term development goals of the government.

B.1 INFORMATION BASE

Improve response and contingency plans for natural disasters such as floods. The limited availability of information on natural hazards poses significant challenges for the formulation of plans and projects to deal with current and emerging risks. Poor information dissemination mechanisms within the key institutions responsible for risk management also further impede the use and application of available studies. More cooperation between the health, meteorological, and civil protection entities may assist in guaranteeing a timely and effective response to disasters.

Strengthen existing disease surveillance systems to better diagnose and respond to climate-related health outbreaks. The reduction in cholera outbreaks suggests that surveillance mechanisms have improved but this needs to be assessed. Disease surveillance is a traditional public health function but linking these to climate variability, including weather information, can improve both detection and response mechanisms, offering targeted insights to clinical analysis and vector biology. Training community health volunteers and *Cases de Santé* on the health impacts of climate change could contribute to improved surveillance of both water and vector-borne disease outbreaks and the deteriorating nutrition status.

Targeted research on appropriate methods and tools to better detect, assess, and respond to emerging vector, water and food borne diseases is required. This is particularly true for diseases such as cholera and diarrheal disease that are linked to an increasingly variable climate. In addition, improved epidemiological understanding is clearly needed between diarrheal disease and periods of heavy rainfall or floods. A better understanding of climate thresholds and disease is required, particularly for priority diseases of high impact in already vulnerable areas. These thresholds possibly could be region specific, which means that more work is needed to understand these diseases and climate factors in a local context. This could assist with developing a health early warning system.

Strengthen the weather and hydrologic monitoring base, especially in areas where divergent risks are projected based on different storylines of climate evolution. Improvement in weather forecasts and possibly real-time decision-support systems for operational response will require investments in hydro-meteorological stations. Archives of non-digital data exist and more attention could be placed on restoring archived data and checking it for quality. Given that certain diseases are linked to climatic factors, primary locations for new weather stations should be around areas of human settlements and agricultural areas. FEWS NET already provides forecasts for Senegal and other countries about climate, agricultural production, and food security. Linked to a health indicators surveillance system, it could provide valuable information on emerging health issues. Early work in Tanzania and Malawi is being conducted under the Global Framework for Climate Services (GFCS) Adaptation Program in Africa to help health authorities obtain accessible and accurate climate service information and progress on these efforts should be monitored (See Box 1: Africa and Climate Data).

Build a public education program that helps to raise awareness of the risks from a changing climate that highlights salient insights on emerging threats. This should be linked to a detailed analysis of the impacts on health from the disruption of health services and other life supporting systems in poorer areas of the country.

B.2 INSTITUTIONS AND STAFF

The following recommendations highlight institutional shortfalls which need to be addressed.

Invest in institutional capacity. Readiness and response, two functions of an effective risk management system, require functional, capable institutions and individuals. The GOS/MOH strategic plan notes severe shortages of health personnel in most areas of the country and includes provision for recruitment of new personnel. The plan also notes that much of the existing infrastructure and equipment is inadequate, dilapidated, and non-functional. The plan includes budget provisions for building and upgrading of facilities, which is essential to improve access to services especially in under-served areas that bear a heavy burden of disease from malaria, undernutrition, anemia, and diarrheal disease.

Encourage inter-ministerial planning with the inclusion of the MOH in the development of plans and communications mechanisms for impending disasters in order to improve preparation and response of the health personnel. For example, USAID could encourage stronger coordination in the World Bank’s program to support the Disaster Risk Management and

Climate Change Adaptation project, which will strengthen the capacity of the Civil Protection Agency (Ministry of the Interior). By the end of the first phase, the Government is expected to have launched a roadmap for disaster risk management and set up coordination mechanisms between the agencies responsible for disaster management and others for early warning, preparedness, and response. Phase Two of the project will consolidate the country capacity to manage risk through the development of Geographic Information Systems (GIS) tools, a functioning early warning system, implementation of a risk awareness campaign, strengthening of a DRM financing mechanism, and support to the National Strategy for the Protection of Coastal Zones.

Inform, educate, and empower health workers about the health impacts of climate change so that they are to better prepared to understand and cope with climate risks – primarily risks they have already experienced. Training of health managers and health providers is also needed to better prepare them for disaster response. Information about an impending disaster or a disease outbreak should prompt health staff to check supply inventories and obtain emergency stocks of ORS, antibiotics, IV tubing, bandages, protective gear, etc. Facility managers have to check shift rotations to ensure qualified health workers are available to provide services to people affected by the emergency and those needing routine care.

Educate health staff on the diagnosis and treatment of neglected tropical diseases, particularly those linked to climate and environmental changes such as lymphatic filariasis, schistosomiasis, trachoma, and soil transmitted helminthes, which represent a major health burden given little attention in the CDCS. Continued support from USAID's NTD Program will contribute to the GOS objective of eliminating those diseases.

B.3 PLANNING MECHANISMS

Support improved planning on the part of the MOH for the location and construction of health facilities. Clinics located in low-lying areas are flooded and damaged during periodic floods. Investments in health infrastructure in partnership with the MOH should include support in conducting land surveys, relocating facilities out of flood zones, reviewing building standards, and retrofitting structures to make them more resistant to water penetration and damage. Generators at hospitals and health centers should be in covered spaces and placed on solid cement pads that are high enough to avoid inundation.

Support for development of a Health National Adaptation Plan for Senegal. The MOH seems largely absent in discussions, plans and strategies that are being developed to address the impact of climate change in Senegal. Increased inter-ministerial coordination and collaboration is needed with the MOH. Development of a Health National Adaptation Plan (HNAP) could catalyze MOH engagement and planning on climate change and health outcomes. Even if a HNAP is not the most effective or efficient way to focus MOH attention, other means should be identified to ensure that the MOH is informed about this issue. While not specific to Senegal although certainly relevant, USAID engagement with recent WHO thinking about building resilient health systems could help develop the concept of health system resilience and what is needed to achieve it. This dialogue could also increase awareness of the health impact of climate change, which is not well-developed among public health practitioners. This is an important first step towards improving knowledge, and actions to identify problems related to climate change, and improving the capacity to manage risk and to plan and implement climate change actions.

Support and coordinate investments by other donors including USAID in infrastructure such as expanding and improving drainage systems, water supply and sanitation facilities in urban and rural areas in order to reduce flooding and waterborne diseases.

Box 1: Africa and Climate Data

Rainfall is one of the key components of the hydrological cycle, playing a vital role in sustaining life on Earth. It also plays a central role in socio-economic activities, such as agriculture, transportation, etc. Surface temperatures, particularly extreme maximum and minimum, plays a similarly crucial role. It is for these reasons that there is such a demand to understand the past, current, and future climate. A fundamental part of understanding the climate is through observations. However, the paucity of spatial and temporal coverage of climate data over Africa remains one of the limitations in fully grasping the possible effects of a changing climate. This restricts or limits any form of meaningful adaptation or mitigation strategies.

In terms of surface-based weather observation platforms (i.e. rain gauges, radar, etc.), Africa is a data sparse region, which generates a problem for monitoring climate characteristics. In the case of Senegal, very limited station data is available for analysis, with the biggest constraint being the timeframe of the data. For example, in this report, many stations available for analysis in the region have data covering the 1980–2000 period, which is a known dry period in the history of the country. Thus, establishing any meaningful statistics regarding the mean climate from this data would have a dry bias. Not only are there issues with spatial and temporal availability of data, but data can be further limited due to the lack of quality control. Data that has not been through stringent quality control tests may produce misleading climate signals and thus, have negative consequences when assessing new policies. However, these issues are not confined to the region, but are problematic worldwide.

The introduction of satellites has significantly increased data observations over the region (e.g., Multi-satellite rainfall estimates (RFE2) from NOAA CPC [Xie and Arkin, 1996]). The earliest introduction of rainfall estimation from satellites to global datasets is around the early 1980s. However, the full utilization of satellite-based rainfall datasets is hindered by the uncertainty and reliability associated with the rainfall estimates. Given the limitations of rain gauge datasets within many regions of the world, the use of satellite rainfall products appears to be a feasible solution to fill the void.

As alluded to above, the main limitation with the current station data set of Senegal is not that it is limited spatially, but rather it does not cover a long historical period. In many cases within Africa, data has been captured for stations but has not yet been digitally logged. Given that certain diseases are linked to climatic factors, primary locations for new weather stations should be around areas of human settlements and agricultural areas. However, adding more weather stations probably isn't the most efficient use of resources. Resources should rather be expended on restoring data archives (i.e., generating digital copies of data) and checking it for quality or complementing the current dataset with alternatives sources such as satellite data. Satellite data also has its limitations, such as poor estimates in mountainous areas and near coastlines. It would be worthwhile conducting an evaluation of satellite products specifically for Senegal.

A better understanding of climate thresholds and disease is also required. These thresholds could possibly be region specific, which means that more work is needed to understand these diseases and climate factors in a local context. This could assist with developing a health early warning system. More cooperation between the health and meteorological sector may assist in developing such an early warning system.

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