BRIEFING NOTE

SHIFTING BURDENS: MALARIA RISK UNDER RISING TEMPERATURES IN BOTSWANA

February 2020

This document was produced for review by the United States Agency for International Development. It was prepared by Chemonics and the University of Florida for the Adaptation Thought Leadership and Assessments (ATLAS) Task Order No. AID-OAA-TO-14-00044, under the Restoring the Environment through Prosperity, Livelihoods, and Conserving Ecosystems (REPLACE) IDIQ.

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Cover Photo: Rick Scavetta. April 2010. Army medical researchers in Kenya mark World Malaria Day 2010.

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Prepared for:

United States Agency for International Development

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INTRODUCTION

This briefing note provides health practitioners and development planners with information on the shifting pattern of malaria incidence nationally and regionally in Botswana as temperatures rise. The analysis aims to improve understanding of changing malaria seasonality across the country and the implications for malaria management and programming.

THE BIG PICTURE

CLIMATE OVERVIEW

The landlocked country of Botswana has a semi-arid climate with a short rainy season. The country of roughly 2.2 million people experiences periodic droughts and related environmental challenges, including desertification and limited fresh water. Botswana's landscape is dominated by its location on a high plateau approximately 1,000 meters above sea level, the Okavango Delta in the northwest, and substantial tracts of desert, including the Kalahari in the southwest. It has a dry season from April to October, with temperatures reaching 35°C+, and an erratic rainy season from November to March that is often punctuated by long dry spells and periodic droughts. The annual average temperature is 22°C and annual average rainfall during the rainy season ranges from 295 mm in the southwest to 540 mm in the northeast. Historical climate trends point to a small but significant temperature increase of +0.11°C per decade from 1901–2013; no substantial change in precipitation has been observed for the same time period. Projected changes to the country's climate under the RCP 8.5 pathway include a rise in mean annual temperature by 6.2°C from 1990 to 2100 and an increase in the number of days of dry spell conditions from 110 days in 1990 to ~113–150 days by 2100 The majority of models predict a decrease in annual total precipitation, with the largest decrease in the dry season. (GERICS 2015; Chihanga et al. 2016; Chihanga et al. 2013; WHO 2015)

Current malaria incidence in Botswana is limited to the north of the country, where it is seasonal in the northern and northeastern regions and where it differs from year to year depending on both rainfall and temperature. Incidence has fluctuated significantly in recent years, ranging from 686 cases in 2005 to 10,993 cases in 2006, and with relatively higher number of cases in 2014 (1,346), 2016 (716), and 2017 (1,900). Despite these variations, the country overall has significantly reduced its malaria burden over the last two decades (102,000 cases in 1997 to 533 in 2018) owing to malaria control and elimination initiatives. While Botswana has made great progress controlling malaria, projected increases in both temperatures and rainfall variability (more frequent heavy rainfall events, in particular) may impact the geographic and seasonal incidence of malaria nationwide (Chihanga et al. 2016; Chihanga et al. 2013; Chirebvu et al. 2016; WHO 2015; WHO 2019; WHO 2020).

As temperatures rise, even within the next 12 years (by the 2030s), changes are anticipated in the suitability of *Anopheles gambiae* malaria transmission. First, the number of months suitable for infected mosquitoes' range in large parts of the country will increase. In hotter parts of the country, rising temperatures may exceed the thermal limit of mosquitoes' tolerance, causing a decline in the months of mosquito suitability. Changes to malaria incidence countrywide is dependent on the combination of rising temperatures, changing rainfall patterns, and changing humidity as well as ecological, environmental, and social factors. It is important to note that this analysis focuses on temperature only, not on rainfall or humidity. Therefore, rising temperatures without increased rainfall or humidity may not lead to increased malaria incidence. Further analysis should consider the complex interactions between these three parameters in determining Botswana's shifting malaria burden.

HIGHLIGHTS OF THE ANALYSIS

- Between the 2030s and 2060s, rising temperatures will likely extend the seasonality (months of suitability) for *Anopheles* mosquitoes in many parts of Botswana.

- The large increase in people newly at risk in Botswana comes with an extension in the months of seasonality for malaria transmission, whereby areas currently moderately or marginally suitable (1–6 months) become seasonally suitable (7–9 months) (see Figure 3 below). This will make 348,000–569,000 people newly at risk by the 2030s under the less hot future model (Figure 3A), and 652,000–1.08 million people under the hotter scenario (Figure 3B). By the 2060s the increase is 253,000–584,000 people under the less hot model, and 340,000–1.6 million people under the hotter scenario. However, interestingly, it is the hotter model under the RCP 4.5 climate pathway that leads to the largest increase of people newly at risk, suggesting that under other scenarios the conditions may get too hot in some months to support year-round transmission suitability (see Figure 4 below).

- Addressing the changing risk profile of malaria due to temperature increases combined with other drivers will require modifying current interventions and programs and potentially implementing new programs that can adapt to changing climate. With these challenges come opportunities for improving observation, surveillance, and response, including detailed geographic targeting, optimizing strategies, and aligning interventions to changing seasonality.

PATHWAYS OF RISK

1. **Temperature drives suitability.** Higher temperatures are projected under all climate pathways (RCP 4.5 and RCP 8.5). In some regions, temperature rise may limit transmission when temperatures go beyond the optimal range for the *Anopheles gambiae* mosquito.

2. **Suitability drives the number of people at risk.** As temperatures rise, more people will be at risk in different geographic areas, and the portfolio of responses will need to be modified.

METHODS

Areas of malaria suitability were mapped in a model combining temperature change projections and current knowledge about the life cycles of malaria-carrying mosquitoes and the malaria parasite. Malaria suitability was examined across two time periods the 2030s (representing the period between 2015 and 2044), and the 2060s (representing the period between 2045 and 2074); two climate models ('less hot' and 'hotter'); and two climate pathways (RCP 4.5 and RCP 8.5) . Details of the methodological approach, summarized in Figure 1, are available in the Shifting Burdens: Malaria Risks in a Hotter Africa report.

Figure 1: Summary of analysis parameters

Mosquito species: *Anopheles gambiae*

Malaria pathogen: *Plasmodium vivax*

Climate models: two regional climate models representing the range of possible outcomes from an available ensemble – a 'hotter' and a 'less hot' model

Climate pathways: RCP 4.5 and RCP 8.5

Time period: 2030s and 2060s

MALARIA BASELINE IN BOTSWANA

Most of the country has seasonal (7-9 months) and moderate (3-6 months) suitability, while the southwestern edge has marginal (1-3 months) suitability. As of 2019, an estimated 1.93 million people (87 percent of total population) live in areas with one or more months of transmission suitability, with the majority (1.64 million, 75 percent of total population) living in areas suitable for moderate transmission (Figure 2).

DEFINING SUITABILITY

- Seasonal: 7- 9 months
- Moderate: 4-6 months
- Marginal: 1-3 months

Figure 2: Areas of current malaria suitability in Botswana: seasonal (7–9 months), moderate (4–6months), and marginal (1–3 months)]

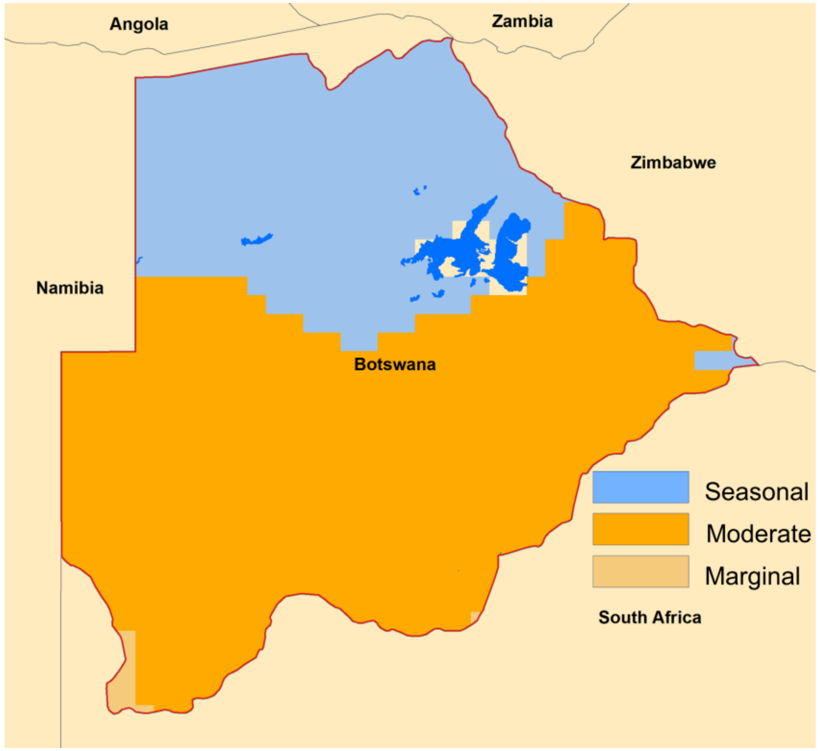


Figure 3: Areas of Botswana currently moderately or marginally suitable (1–6 months) which become seasonally suitable (7–9 months) under RCP 4.5 and RCP 8.5 for 2030s and 2060s time horizons, for (A) the less hot model and (B) the hotter model

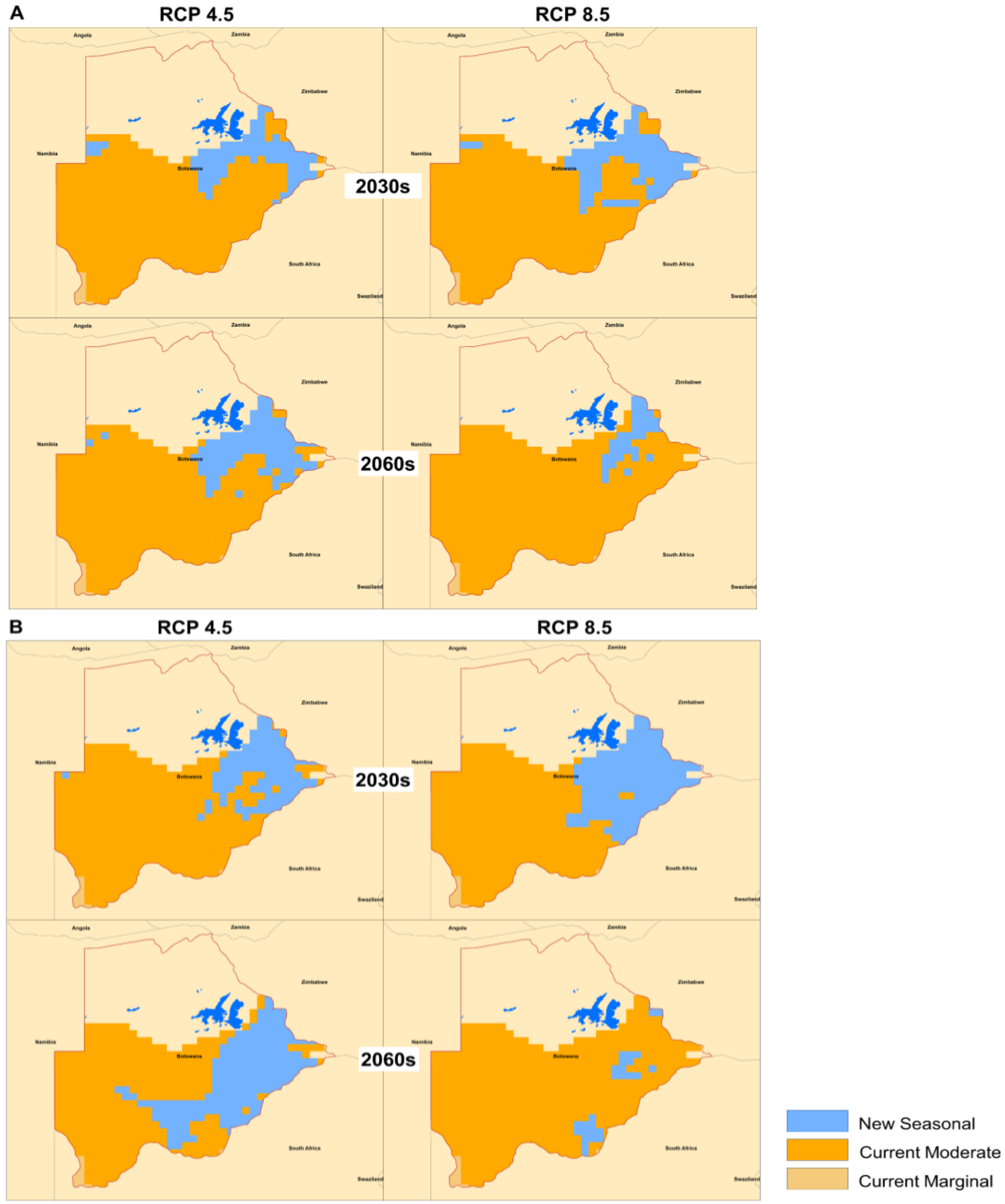
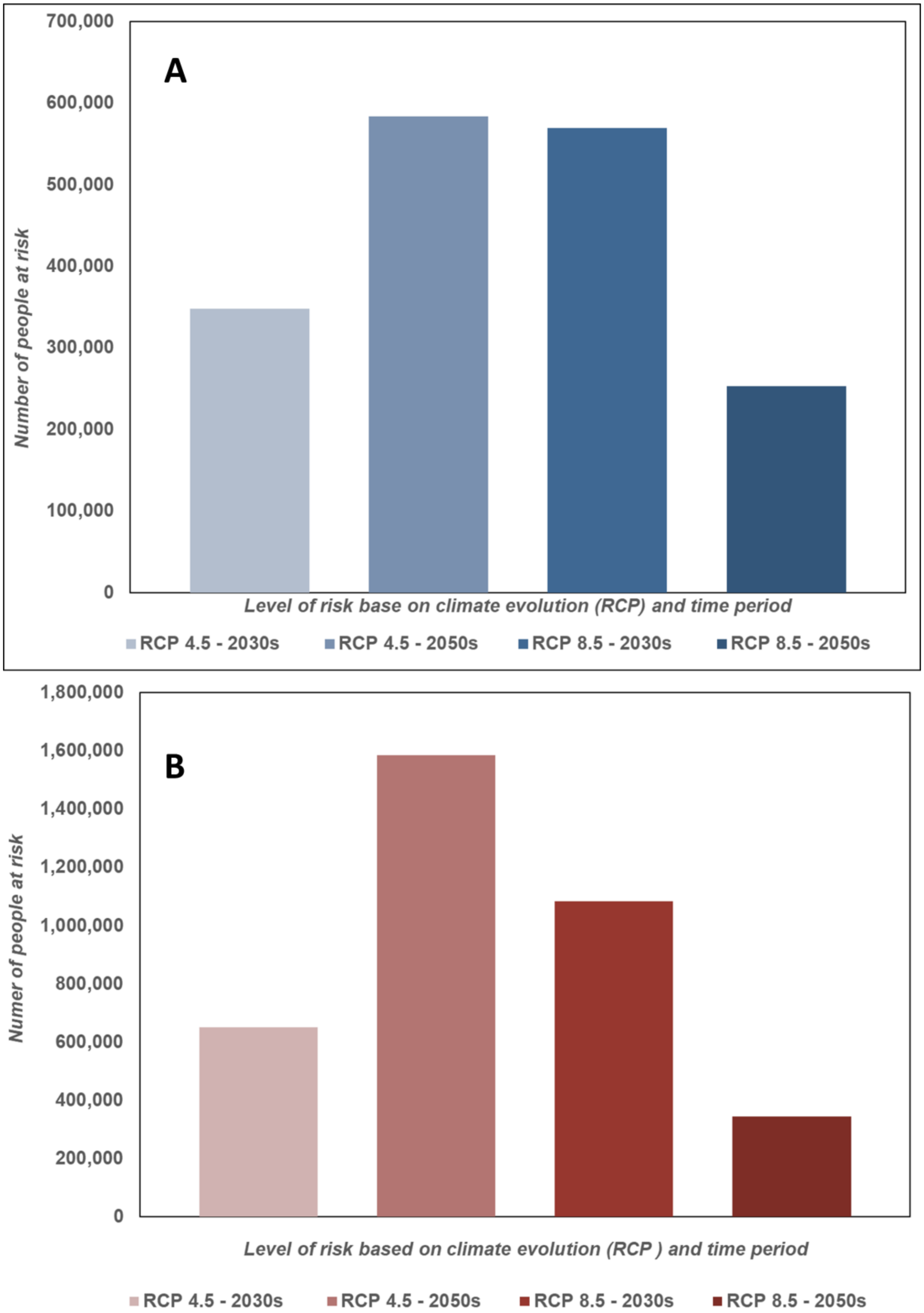


Figure 4: People in Botswana newly at risk as areas with moderate and marginal suitability (1–6 months) become seasonally suitable for transmission (7–9 months), for RCP 4.5 and 8.5 climate pathways , in the 2030s and 2050s time horizons, for (A) the less hot model and (B) the hotter model



RECOMMENDATIONS AND OPPORTUNITIES FOR ACTION

This analysis offers an initial view of potential changes in malaria seasonality due to projected rising temperatures. This study alone is not meant to guide programmatic decisions. Additional field studies testing these findings are needed for the findings and the underlying methodology to be used as predictive tools.

This methodology and the analytical results use temperature as the primary driver of malaria incidence and do not take into account shifting rainfall patterns and changing humidity. These factors combined with Botswana's semi-arid climate may also have implications for malaria incidence. It is therefore important to consider the role of temperature as a driver of malaria burden when combined with many other likely drivers, i.e., other environmental and social factors that could influence outcomes, such as migration, changes to landscape, and new technologies to control malaria vectors. Some of the implications for action and decision-making of this research for Botswana are discussed below.

TARGET ON-THE-GROUND SURVEILLANCE AND RESPONSES TO CHANGING EPIDEMIOLOGY

- **Targeted and informed on-the-ground surveillance:** Knowing where and when changes in malaria incidence are likely to take place offers the opportunity to geographically target monitoring programs with the goal of guiding interventions to achieve the highest impact with limited resources.
- **Addressing the risk of epidemics:** Where malaria suitability in Botswana is likely to shift from moderate or marginal to seasonal, the appearance of new risk is critical. When communities have little or no immunity, changes in malaria suitability can often lead to epidemic conditions, especially among vulnerable groups such as pregnant women, children, and the elderly. Surveillance data allow preparation of a timely response before the outbreak of epidemics and can guide decisions around distribution of malaria services and their use by impacted communities.
- **Adjusting current management and control interventions:** Surveillance information provides the evidence base to adjust the investment time frame (seasonal to year-round, or vice versa), optimize vector control, and improve case management. Pinpointing regions where transmission could be reduced lowers the cost of interventions and provides an opportunity to reach pre-elimination or elimination.
- **Addressing malaria elimination:** In areas where the months of malaria suitability will decrease (Figure 3), the opportunity exists to invest in targeted surveillance and response systems to identify, track, and respond to malaria cases and any remaining transmission foci (e.g., infected mosquitoes or affected patients).

IMPROVE A COUNTRY'S CAPACITY FOR COLLECTING AND USING INFORMATION AT THE NATIONAL LEVEL

Understanding how rising temperatures could impact vector ranges, and thus have the potential to alter disease dynamics, is an important first step in building the knowledge base required to evaluate how climate may impact malaria incidence and inform investments. This analysis indicates that, as temperatures rise, even by around 2030, important changes are anticipated in *Anopheles* transmission suitability in Botswana, in both seasonality and range of malaria vectors. Importantly, temperature-driven changes in vector dynamics are themselves mediated by direct and indirect environmental and societal factors, such as changes to ecosystems and land use, that may reduce or amplify the vulnerability of certain groups to malaria risks. For Botswana, new methods of data collection, integration, and analysis will require cross-ministry investment in information collection and information-sharing. This proactive collaboration will be critical to understanding the complexity of malaria incidence dynamics.

Public health observatories, many already operational around the world, could help pave the way for the timely use of remotely derived weather and climate information to inform investments and strategies in malaria control by:

- Formalizing agreements that encourage interdepartmental and interministerial collaboration and data sharing
- Leveraging information technology
- Building a community of practice
- Advancing research on critical outstanding questions with respect to the use of climate information to inform malaria planning

BUILD CAPACITY IN HEALTH SYSTEMS

In spite of the significant advances Botswana has made in reducing malaria incidence and outbreaks, weak health systems—including understaffed health posts, lack of skilled human capacity, and the need to improve supply chain management across the spectrum of services and programs—continue to slow progress toward malaria control goals and targets. For example, health posts are understaffed, skilled human capacity is lacking, and supply chain management is unreliable. For malaria programming and health services to respond to climate risks, the following investments need to be made in building the skills and capacity of health workers to understand and address the health risks posed by climate:

- Training health workers on the links between health and climate change
- Streamlining supply chain management
- Promoting research on applied, service-oriented health services questions

REFINE COUNTRY SELECTION AND STRATEGIC BUDGETING FOR INTERNATIONAL PROGRAMS

New country selection for international programs investing in malaria interventions is complicated and often dictated by many factors, including available funding, national capacity to implement programs, ability to work across agencies, and the ability to work with country-specific partners, donors, and stakeholders. However, the potential impacts of increased temperature on malaria burden are too great to be ignored during country selection and strategic budgeting. While there are many drivers of malaria burden at a national scale, increased temperature may contribute to putting large populations within Botswana at risk of seasonal malaria where the burden was previously significantly less. As a result of this potential risk, it is important to include projected temperature increases during strategic discussions for country selection in the near and medium term.

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