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Assessment of Climate Change Impacts on Dengue Fever

Summary for Policy Makers

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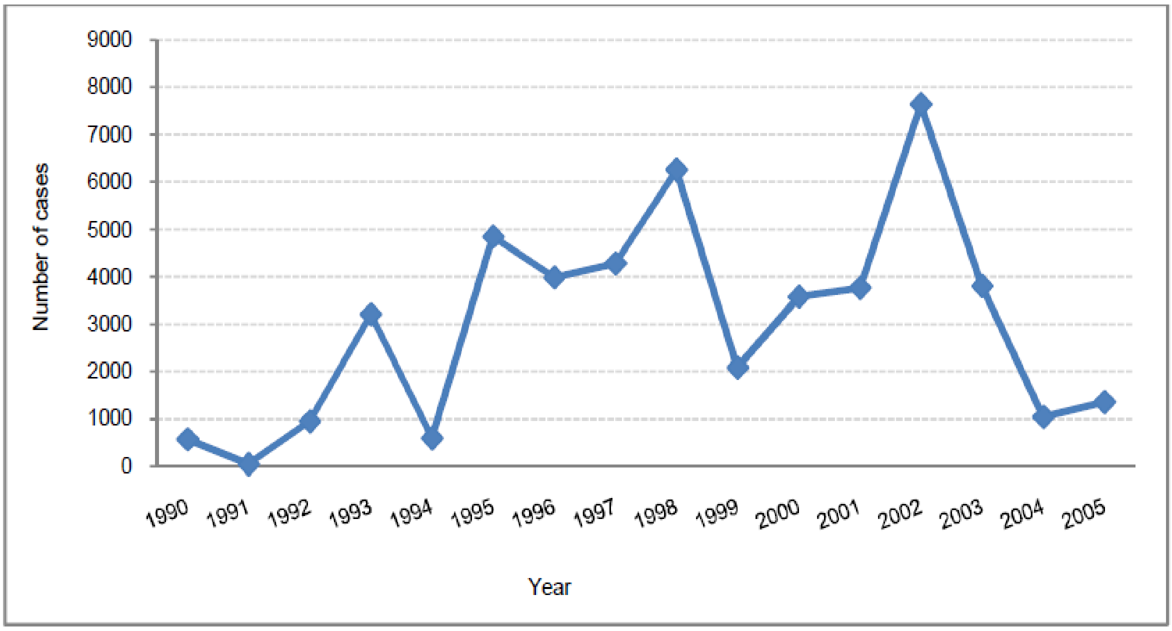
1 Importance of the Sector to National Sustainable Economic Development

It is anticipated that the adverse effects of future climate variability and climate change (weather extremes, warming trends, increased intensity and frequency of storms) will likely lead to increases in health related risks and vulnerability especially vector and water borne diseases. There is great concern for developing countries particularly small Island developing states (SIDS) such as those in the Caribbean region, since the region is considered especially vulnerable to the negative impacts of climate change and faces adverse effects of climate variability daily, monthly and seasonally. Risks such as a rise in the incidence of existing and emerging climate sensitive diseases, health impacts from lack of potable water supplies and lack of proper nutrition leading to an unhealthy population threatens the region's health and development.

Dengue fever (DF) has garnered much attention in the region since the burden of the disease in the present climate conditions is already substantial and is expected to increase in an altered future climate. Aggregate DF cases for 12 countries in the Caribbean, from the period 2000-2005, shows a general upward trend as seen in figure 1 below.

Figure 1 Aggregate dengue fever cases in the Caribbean for the period 1990-2005



According to Clarke et al. (2013), the aggregate cases in the figure above represents data from the following countries: Antigua and Barbuda, the Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, and Trinidad and Tobago.

Source: Caribbean Epidemiology Centre[1] (CAREC) dataset 2012 (as cited in Clarke et al. 2013)

[1] Although CAREC is no longer functional, its work was assumed by CARPHA (Caribbean Public Health Agency)

In the Americas, costs related to DF was valued at approximately US $2.1 billion per year on average (in 2010 US dollars)[2] of which 60% of these costs correspond to productivity losses (Shepard et al. 2011). Furthermore, the number of DF cases in the Caribbean for the same period, taking into consideration underreporting, is estimated at 448, 412 cases with around 11 cases per capita. According to Shepard et al. (2011), the annual economic burden of DF in the Caribbean was less than or equal to US $0.3 billion (or US $321 million) in US 2010 from 2000-2005 and increased slightly to approximately US $0.5 billion in 2006 and 2007 (in US 2010). The figure for the Caribbean may be underestimated since vector control program costs among others was not included in the study. Additionally, the cost per capita, according to Shepard et al. (2011), was found to be highest in the Caribbean at around US $8.29 in US 2010.

Given these historical economic burden of DF, it is likely that these costs will increase in the Caribbean in the future. The results in the Belize District can be used as a snapshot to depict what will likely occur in the country of Belize and on a larger scale, the wider Caribbean region, in the future. Findings from the dengue fever case study in the Belize District conforms that temperatures and rainfall variability will likely increase in the future which is consistent with greater DF occurrence in the district, which means that annual DF costs might also increase in the future. As such, the Health sector plays a crucial role in delivery of health and wellness services to Caribbean peoples including Belizeans as it relates to the prevention and control of dengue fever. Through its efforts, the sector maintains a healthy, productive population and by extent a strong workforce which is the driving force for better economic standing; however, this can be in jeopardy based on the increase projections for DF occurrences.

The risk of an unhealthy nation can impact development and the productive development sectors. The tourism sector, which is the region’s major source of foreign exchange, can be affected by cancelled visits or reduced tourist arrivals. The labour and education sectors may experience increased absenteeism which negatively affects the country’s GDP because of reduced productivity. In the advent of increased disease incidence, the Health sector will be challenged by increased costs of health care delivery and outbreak control. As such, the health sector’s policy and strategies in all Caribbean countries remain vital for the delivery of proper healthcare services to safeguard vigorous, productive nation states.

Some of the policy implications regarding dengue fever in the future include:

- Projected decreases in mean wet day precipitation from May-September suggest that there will be less natural breeding grounds for DF vectors in the future, which may result in lower DF occurrence. Conversely, decreases in total rainfall could lead to more water storage, which would potentially lead to higher DF transmission rates if containers are improperly covered.

- An increase in projected rainfall and rainfall variability in October and November could result in the availability of more natural and artificial breeding sites, which can lead to more DF occurrence. There is also the possibility that

[2] Currrency details- http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3029168/

heavy rainfall can decrease DF transmission by destroying or flushing larval habitats.

- Warmer conditions in the future, as shown by increases in Tmax and Tmin WG outputs, has been found to accelerate the biology (reproduction and lifecycle) of DF virus and vectors (Taylor et al. 2009). As a result, mosquito feeding rates would intensify and hence, increase the risk of greater DF occurrence in the 2050s. These altered conditions places previously unaffected areas at risk of becoming infected with the disease.

- Results of the threshold detector shows a decrease in the number of days when Tmax exceeds 20^{o}C, but does not exceed 32^{o}C. This suggests a decrease in DF occurrence; however, decision makers and the public at large should maintain caution because there is still a substantial amount of days conducive to the proliferation of DF. Furthermore, attention should be given to the influence of the upper end of the joint threshold condition (Tmax <32^{o}C), which is significantly driving the overall decrease in the specified condition.

- The TD outputs show an increase in the number of days when Tmin exceeds 18^{o}C, which implies an increase conditions suitable for the transmission of DF.

- It is also important to recognize that non-climate related factors such as social and economic conditions contribute to the spread of DF. Efforts to improve these existing conditions in the future can influence the number of DF cases.

2 Application of the Tool to determine Outputs

The Caribbean region attracts a large influx of visitors annually. Although the movement of visitors to the region is a major contributor to GDP, it also facilitates the movement and spread of diseases. Furthermore, poor health infrastructure places the region at a disadvantage and thus, vulnerable to health related risks particularly DF occurrence.

There is tremendous concern regarding DF in the region because it is considered one of the most important diseases in tropical countries. The apprehension is justified since countries in the Caribbean region share similar characteristics, including a rainy and dry season which may influence DF rates. The situation is the same in Belize where most of the country’s rainfall occurs from June to November (the rainy season), with average rainfall ranging from 60 inches (1524mm) in the north of the country to 160 inches (4064mm) in the south (BNMS 2014). There is evidence suggesting that climatic variables including rainfall and temperature can affect vector and virus reproduction cycles, consequently increasing DF transmission rates. The Belize dengue fever case study shows an association between DF and two climatic conditions namely, rainfall and minimum temperature (Tmin). The Weather Generator (WG) and Threshold detector (TD) provide projections for these important variables associated with the proliferation of DF for the 2050s. Additionally, a study in Mexico discovered that Tmax greater than 20^{o}C is associated with increased DF incidence while Tmax greater than 32^{o}C shows a decreasing effect on DF transmission (Colón-

González et al. 2013). Findings of the same study showed that Tmin greater than 18°C has an increasing effect on DF occurrence.

The TD improved the analysis of the case study by projecting the number of days satisfying the threshold conditions that were based on figures found in the Mexico study (see Colón-González et al. 2013). The results of the DF case study conducted in the Belize District show increases in the number of days where Tmin is greater than 18°C in the 2050s, which implies more favourable conditions for DF occurrence in the 2050s. On the other hand, the joint Tmax condition - Tmax exceeds 20°C, but does not exceed 32°C - is projected to decrease in the future, which is consistent with less favourable conditions for DF in the future. Nevertheless, there is still a considerable number of days favourable to DF transmission rates. As such, the costs to healthcare and other indirect effects such as work absenteeism leading to productivity losses may increase in the future in Belize, and other Caribbean territories. Equally important, an unhealthy nation in the future can discourage international visitors to the region and thus, negatively impact the tourism sector which is known as the largest contributor to GDP and foreign exchange earner in the Caribbean region.

Given the implications associated with increases in DF occurrence in the Caribbean region, the WG and TD tools were developed to provide projections for various important climate parameters, including the main parameters known to facilitate the proliferation of DF. The results of both tools can be used to give health related stakeholders an indication of likely future dengue fever occurrence, which can be utilized to plan interventions accordingly. For example, a positive statistical correlation between Tmin and DF validated a relationship between the two variables. Keeping this association in mind, the increase in Tmin as calculated by the WG, indicates that DF occurrence will likely increase in the future. Consequently, health related stakeholders can use this information to develop strategic DF control actions based on the projected DF increase. The potential solutions may include an intensification of public awareness efforts in order to reduce DF morbidity in the 2050s. Additionally, governments may use the information provided by the tools to improve preparedness and response systems, strengthen enforcement efforts, and build capacity to cope with the rise in the number of DF cases in the future.

3 General Issues Emerging from the Application of the Tool

There was a need for technical guidance to properly interpret the various outputs from the WG and TD tools in order to provide a meaningful assessment. It was also helpful to have had the opportunity to attend the final stakeholder consultation workshop in Barbados because it provided a forum for further insights into the background and limitations of the tools.

In order to investigate both Tmax and Tmin thresholds, the opportunity to utilize the TD tool was provided. At first, manually entering the inputs in the text document was confusing and complicated. However, the update to the internet interface, which automatically generated the "ini file" enabled the file to be more easily copied to the text document. Furthermore, the opportunity to select other inputs including the control, scenario, model and time series, made the interface more user-friendly.

On the other hand, there seemed to be some sort of discrepancy, possibly in the tool itself, since the results varied. The first trial at the consultation was used in the final case study report since the results were consistent with increases in Tmin in the future. To validate the initial results, the case study supervisors suggested another trial. At this juncture, there was a series of issues which ranged from the tool not responding, to significant differences between the researcher's results and the developer's results. More specifically, there were some instances where the results for the control and a model for my trial were reverse in the developer's trial. It was suggested that the source of the issue was due to a corrupt file resulting from zipping and unzipping the folder. Having the necessary support from the developers to detect and solve problems related to the TD tool was important for the completion of the case study.

In terms of the WG, there were no outstanding issues. The developer emailed the plots of the results, which were separated by model type. It was also helpful that the actual data was made available so that the plots could be adjusted to include both models in one single graph for easier interpretation and comparison.

4 Other Sectors to which the Tools can be Applied

The application of the tool is relevant to almost all sectors in the Caribbean community (CARICOM) countries including:

- **The Agriculture sector** - can benefit from the tool by investigating future weather conditions and its corresponding effect on crop productivity and suitability, and changes in seasonality. The results can be used to inform planting seasons or management plans which may include further exploration into the use of more climate resilient crops in the future.
- **The Water sector -** Warming trends can lead to water scarcity, or the lack of potable water supplies, which can have significant implications for human health. Additionally, changes in watershed recharge rate and flow can affect subsistence and commercial farmers as well as smaller communities who, due to tradition or lack of adequate water infrastructure, rely on watersheds for irrigation and domestic water supply. In contrast, increases in rainfall can intensify flooding events which can lead to loss in tourist arrivals and infrastructural damage to name a few. As a result of its effect on multiple sectors, flooding events and land slippages are regarded as two of the greatest threats to CARICOM countries. Investigating future water and temperature levels can be helpful to this sector so that measures which can contribute to resiliency can be developed. For example, the implementation of solar powered desalination plants in the most vulnerable countries.
- **Forestry**- Climate drives important processes such as photosynthesis and evaporation, which influence forest structure and health. Forests provide important ecosystem services such as clean water, recreation and carbon storage. Additionally, the sector also contributes to the national economy through economically viable forest products including medicinal plants and commercial wood. These products and services are threatened by increased transpiration and evaporation rates in the future along with flora migration. Climate change may also weaken forest productivity by limiting the availability of water through increased evaporation and through the modification of

nutrient levels. Equally important, a changing climate may threaten forests through pest outbreaks and fires. Warming trends also influences the geographic distribution of vegetation which may put specific plant species at risk of extinction since future climate conditions may not be favourable for their growth. Furthermore, changes in vegetation can have negative implications for faunal species distribution, thus threatening their survival. It is therefore important to monitor climate conditions including precipitation and temperature, to inform decision making and future forestry and wildlife management plans. Therefore, being able to apply these tools will provide site specific information and thresholds' analysis that can be used to improve management plans and inform robust policies.

- **Tourism -** Since tourism is the main economic driver and foreign exchange earner in CARICOM countries, it is important for tourism related stakeholders to consider the outputs in future planning processes. It is likely that future weather conditions may not be favourable for tourism arrivals in the tropical countries including Belize. A warming climate may influence visitors from the northern hemisphere, who usually travel to warmer countries to avoid freezing temperatures, to vacation at home. Furthermore, flooding events and impacts of higher temperatures on terrestrial and marine ecosystems will not appeal to visitors. As such, the tourism sector can play an active role in improving resiliency to the sector by participating in climate friendly initiatives such as the implementation of renewable energy in the hotel sector, exploring and diversifying markets, and adapting safer building codes.
- **Infrastructure development and Urban development** – The tools can be used to inform policies for urban planning, future building codes and guidelines, and acceptable types of construction materials for improved resiliency.

5 Policy Implications for the Use of the Tool in Decision-Making

- There is a need to develop policies and create sensitisation and capacity building among stakeholders to facilitate the use of the tool in the development of national plans and programs in the health sector and others.
- Ministries of Health in CARICOM countries should proactively seek the inclusion of science based evidence to inform the development of policies, plans and strategies. The region can also rely on support from other regional agencies such as the Caribbean Public Health Agency (CARPHA) and the Pan American Health Organisation (PAHO) to mobilise technical cooperation and partnerships to undertake evidence based initiatives.
- Incorporating the application of the tool in future plans requires multi-sectoral support for detailed discussions regarding the results of the outputs and the corresponding implications on the other sectors.
- The utility of the tools are wide-ranging as it relates to the health sector. Future temperature and precipitation parameters can be used to inform the selection and development of appropriate adaptation measures and corresponding policy response to reduce the emergence of other climate related illnesses in the future such as waterborne and respiratory diseases, heat stress and dehydration, food-borne diseases and other vector borne diseases.

- Stakeholders should also consider the need for capacity building to effectively operate and understand the scientific background of the tools. Although start up would require investments, the implementation of the tool across sectors would deliver several benefits including the start of a proactive approach to planning which can improve future conditions for Caribbean residents. For instance, projections can show likely scenarios that can prompt decision makers to develop policies to aid in the transition to more sustainable and cost effective future programs such as the implementation of an Integrated Vector Management program.
- Since outputs for the tools require the use of observed data, the government should consider the implementation of rigorous strategies to allow for the collection of more reliable and high quality data to support the further development and enhanced functionality of these tools.
- In addition, given the availability and accessibility of the tools, government departments can benefit from conducting future risk assessments to assess impact on risk reduction and diseases' occurrences in order to prioritise future projects and focus on initiatives geared towards promoting resiliency.

6 Gaps and Further Work to be Undertaken in the Refinement of the Tool and its Application

Although the portal developers have improved the interface of the program tremendously, users would benefit greatly from having the detailed model and scenarios (WG_file_names_etccdi doc.) file available on the portal to guide usage. In terms of the TD tool, users are currently required to visit the WG interface to access the climate data files. It would be helpful if the climate data files needed to run the program can also be accessed on the TD interface. This can be achieved by ensuring that the files are automatically included in the TD package downloaded from the website. Alternatively, users can be given the option to select and download the variable of interest in a "step one" process on the interface. After users successfully download the data and run the program, a "how to" tutorial either written (with corresponding images) or video can be made available on the interface. The aim of these resources is to show users how to properly graph, analyse and interpret the data. A dedicated section on the portal can be used to share web links containing useful tips such as the conversion of Comma Separated Values files (CSV) to excel files, so as to guide users with proper data handling. Incorporating these actions would simplify the handling of the tool while simultaneously facilitating greater user interest.

With respect to limitations emerging from the study, unfortunately it took considerable time to obtain all necessary permissions to access the data. As a result, data analysis and the development of the case study report was delayed. To overcome issues regarding data gaps in the meteorological dataset, an average of the last known reading and the start date immediately after the missing data was applied to fill data gaps. This method was applied only to temperature gaps after consultation with key professionals in the meteorology field. Fortunately, the gaps for the Belize District data set were on average less than 5 days and relatively infrequent.

There were also several issues related to the dengue fever dataset. First, there were changes to the dengue fever classification on average every 2 years. The incompatibility increased uncertainty and challenged a positive conclusion that DF occurrence in the Belize District was in fact climate related. Additionally, the data set was separated according to two time periods since there were significant differences in DF occurrence in years prior to 2007 compared to years starting from 2007 onwards (i.e., there was significantly lower DF occurrence from 2001-2006 compared to significantly higher DF occurrence starting in 2007). As a result, the DF occurrence from the period 2002-2006 was excluded from the analysis to improve the confidence level of the study. Additionally, approximately seven reported DF cases in the year 2007 were unfortunately excluded from the study because the corresponding date of medical examination was missing.

There are several opportunities for further expansion of the dengue fever case study. Apart from rainfall and temperature, studies have shown an association between vapour pressure, wind speed and other variables on dengue fever occurrence. As a result, these variables could also be added to the analysis. Additionally, outputs from the CARIDRO tool can be included in the study to inform decision makers of likely drought scenarios, since drought conditions tend to increase DF occurrence. As it relates to the threshold detector, the study could be improved by investigating whether the impact of Tmax and Tmin temperature thresholds on dengue fever occurrence in Mexico is the same in Belize. Since weather conditions tend to differ across countries, it would be helpful to replicate the case study in the other districts such as the Cayo District, where, after the Belize District, DF outbreaks tend to be largest.

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8 References

BNMS, Belize National Meteorogical Service 2014. *Climate Summary* 2014 [cited October 22 2014]. Available from **http://www.hydromet.gov.bz/climate-summary**.

Clarke, C., C. Gomes, D. Alleyne, and W. Phillips. 2013. An assessment of the economic and social impacts of climate change on the health sector in the Caribbean. edited by Economic Commmission for Latin America and the Caribbean (ECLAC). Santiago, Chile: United Nations.

Colón-González, Felipe J, Carlo Fezzi, Iain R Lake, and Paul R Hunter. 2013. "The effects of weather and climate change on dengue." *PLoS neglected tropical diseases* no. 7 (11):e2503.

Shepard, D., L. Coudeville, Y. Halasa, B. Zambrano, and G. Dayan. 2011. "Economic Impact of Dengue Illness in the Americas." *Am J Trop med Hyg* no. 84 (2):200-207.

Taylor, M. A., A.A. Chen, and W. Bailey. 2009. Review of Health Effects of Climate Variability and Climate Change in the Caribbean. In The Mainstreaming Adaptation to Climate Change Project of the Caribbean Community Climate Change Centre (CCCCC).

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