ASSESSMENT OF CLIMATE RISKS ON HEALTH FOR NATIONAL ADAPTATION PLAN (NAP) FORMULATION PROCESS IN BHUTAN

Table of Contents

List of Figures

List of Tables

List of Acronyms

AR5	Assessment Report 5
BHMIS	Bhutan Health Information System
BHU	Basic health units
BLSS	Bhutan Living Standard Survey
BMHC	Bhutan Medical and Health Council
CCRA	Climate Change Risk Assessment
CSO	Civil Society Organisation
DDM	Department of Disaster Management
DHIS	Dzongkhag Health Information System
DoPH	Department of Public Health
EMSD	Emergency Medical Service Division
GDP	Gross Domestic Product
GLOF	Glacial Lake Outburst Flood
GNH	Gross National Happiness
GNHC	Gross National Happiness Commission
HMIS	Health Management and Information System
IPCC	Intergovernmental Panel on Climate Change
KGUMSB	Khesar Gyalpo University of Medical Sciences of Bhutan
KII	Key Informant Interviews
LLIN	Long Lasting Insecticide Net
MDG	Millennium Development Goals
MoAF	Ministry of Agriculture and Forests
MoHCA	Ministry of Home and Cultural Affairs
NAP	National Adaptation Plan
NCD	Noncommunicable diseases
NCHM	National Center for Hydrology and Meteorology
NDC	Nationally Determined Contribution
NECS	National Environment Commission Secretariat
NEWARS	National Early Warning, Alert and Response Surveillance
NGO	Non-governmental organization
NKRA	National Key Result Areas
ODF	Open Defecation Free
ORC	Outreach Clinics
PHCB	Population and Housing Census of Bhutan
PHED	Public Health Engineering Division
RCDC	Royal Center of Disease Control
RCP	Representative Concentration Pathway
RGoB	Royal Government of Bhutan
RSAHP	Rural Sanitation and Hygiene Programme
SDG	Sustainable Development Goals
SEA	Southeast Asia
SNC	Second National Communication
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children’s Emergency Fund
VBD	Vector-borne diseases

VDCP	Vector-borne Disease Control Program
WASH	Water, Sanitation and Hygiene (WASH)
WBD	Water-borne diseases
WHO	World Health Organization

1. About the report

Chapter 1 provides a brief overview of climate change impacts in Bhutan, the objectives, and the scope of work.

Chapter 2 outlines the approach and methodology used to assess the current impact of climate change on vector-borne and water-borne diseases and future projections of the diseases. The four-step process involving literature review, data collection, data analysis, and stakeholder consultation carried out as part of this study has been explained in detail in this chapter.

Chapter 3 presents the findings from the study under five sections. The chapter includes building impact chains, identifying indicators for climate risk assessment, baseline situation in Bhutan, current climate impacts on health and future projections. The first section explains how climate change can lead to an increased risk of vector-borne and water-borne diseases in the form of an impact chain. The next section provides a list of indicators based on literature review and maps these indicators against IPCC components. Section 3.3 presents the baseline situation in Bhutan in terms of climatic conditions derived from Dzongkhag level climate data for the period 1996-2020, the prevalence of various VBDs and WBDs at the Dzongkhag level, the existing health system and the processes and systems in place for health and disaster risk management. The next section explains the climate impacts on VBD/WDBs under Hazard, Exposure and Vulnerability as per IPCC AR5 framework along with Dzongkhag-level risk maps and ranking of VBD/WBDs in Bhutan. Section 3.5 provides assessment and mapping of future exposure to vector and water borne diseases based on climate change projection for the short, medium and long-term under RCP 4.5 and RCP 8.5 scenario.

Based on the findings obtained in Chapter 3, Chapter 4 provides a list of adaptation measures that the country can take to adapt and be resilient to the projected impacts of climate change on diseases in the future.

1.1. Introduction

Bhutan is highly vulnerable to climate variability and extreme events due to its mountainous terrain, landlocked nature, and high dependence on climate-sensitive sectors such as agriculture, hydropower and forestry.[1] The Intergovernmental Panel on Climate Change (IPCC) mentions that by 2100, South Asian countries, including Bhutan, will experience an increase in average temperatures, with increases in daily minimum and maximum temperatures, mostly taking place at higher altitudes.[2] Current evidence shows that Bhutan will experience more extreme weather events (severe and with increased frequency). Still, impacts are likely to be incremental in the near future and will only become more evident in the coming decades[3]. Data analysis from 1996-2017 over Bhutan from 15 weather stations reveals an increasing temperature trend over Bhutan (NCHM 2019). The Climate change risk assessment on water also substantiates these findings and points out to increase in average temperature in Bhutan. Climatic events, such as heavy rainfall, will become more common and lead to floods, erosion and landslides. Apart from this, the mountainous region is becoming increasingly susceptible to glacial lake outburst floods (GLOFs), as a result of glacial melting due to climate change.[4]

Increased temperatures and changes in precipitation are increasing the incidence of various vector-borne and water-borne diseases[5]. Globally, Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually. They can be caused by either parasites, bacteria or viruses. Water borne diseases are illnesses caused by pathogens in untreated or contaminated water. Contaminated drinking water is estimated to cause 485,000 diarrhoeal deaths each year. The impacts of climate change can be seen or observed through the changes in average temperature, precipitation, and extreme weather conditions. These

---

[1] Lhendup, P., Wikramanayake, E., Freeman, S., Sindorf, N., Gyeltshen, K., & Forrest, J. (2011). Climate change vulnerability assessment of Wangchuck Centennial Park, Bhutan. A report by the World Wildlife Fund and Wangchuck Centennial Park.

[2] Hijioka, Y., E. Lin, J.J. Pereira, R.T. Corlett, X. Cui, G.E. Insarov, R.D. Lasco, E. Lindgren, and A. Surjan, 2014: Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[3] Asian Development Bank (2018), Climate Change Country Risk Assessment, Bhutan.

[4] Gurung, D. R., Khanal, N. R., Bajracharya, S. R., Tsering, K., Joshi, S., Tshering, P., ... & Penjor, T. (2017). Lemthang Tsho glacial Lake outburst flood (GLOF) in Bhutan: cause and impact. Geoenvironmental Disasters, 4(1), 17.

[5] Githeko, A. K., Lindsay, S. W., Confalonieri, U. E., & Patz, J. A. (2000). Climate change and vector-borne diseases: a regional analysis. Bulletin of the World Health Organization, 78, 1136-1147.

changes directly impact human health or indirectly on disease-transmitting agents, thereby affecting human health.

There is increasing evidence about the impacts of climate change on vector-borne and water-borne diseases especially in tropical highlands and temperate regions[6]. Changes in climate will give rise to a wide range of health risks. In the context of Bhutan, some of these increased risks are[7]:

- probability of glacial lake outburst floods (12 of the 24 dangerous glacial lakes in Bhutan are considered potentially dangerous)
- the risk of flash floods and landslides during the monsoon period of June to August
- the geographical range and incidence of vector-borne diseases, particularly malaria and dengue. Dengue is an emerging infectious disease in Bhutan; it was first documented in the country in 2004 and is now endemic during the monsoon period
- the incidence of waterborne diseases due to drying up of water sources or contamination from flooding (diarrhoeal diseases already contribute to about 10–15% of the burden of morbidity)

Studies suggest that climate change is impacting almost every socio-economic sector including health sector in the country. According to the IPCC, the health of human populations is sensitive to shifts in weather patterns and other aspects of climate change such as changes in temperature and precipitation and occurrence of heat waves, floods, droughts, and forest fires. Further, ecological disruptions brought on by climate change (crop failures, shifting patterns of disease vectors), or social responses to climate change (such as displacement of populations following prolonged drought) indirectly contributes to negative impacts on health[8]. Physical injuries from climate induced hazards such as floods, flash floods, landsides, thunderstorms are also likely to increase with change in weather patterns.

Given this context, in addition to the direct impacts of climate change, this study also puts a strong focus on the role of non-climatic parameters that have the potential to increase or decrease the overall vulnerability of the system.

1.2. Objective of the study

The objective of this assignment is to prepare a risk mapping of vector- and water borne diseases associated with climate change. Building on the priority identified in the Health NAP in particular "Prepare Vulnerability and Risk mapping of health outcomes associated with climate change", this assignment builds upon and complements initial projections of vector-borne and water-borne diseases with analyses of exposure and vulnerability to identify risk prone Dzongkhags. This assignment will help improve understanding of the complex relationship between risks posed by climate change and by other socio-economic factors that influence population health. The outcome of the assignment will inform health official, regional and local planners and managers' decisions about adaptation measures to reduce these risks and help shape the health ministry's preparedness and response to emerging climate risks.

The scope of work of the assignment covers the following key tasks and activities:

[6] Dhimal, M., Ahrens, B., & Kuch, U. (2015). Climate change and spatiotemporal distributions of vector-borne diseases in Nepal–a systematic synthesis of literature. PloS one, 10(6), e0129869.

[7] https://www.who.int/globalchange/projects/adaptation/PHE-adaptation-final-Bhutan.pdf?ua=1

[8] Smith, K.R., A.Woodward, D. Campbell-Lendrum, D.D. Chadee, Y. Honda, Q. Liu, J.M. Olwoch, B. Revich, and R. Sauerborn, 2014: Human health: impacts, adaptation, and co-benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

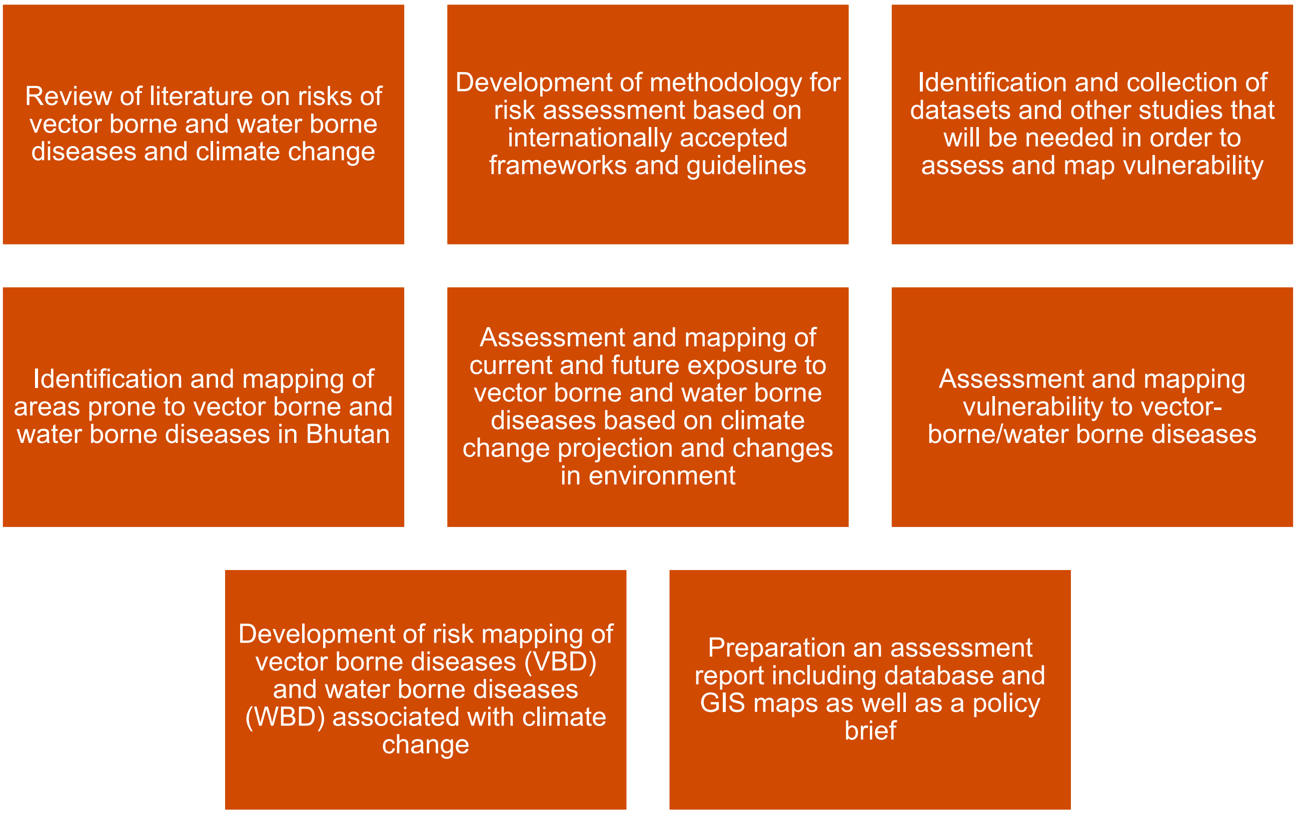


Figure 1: Scope of work

2. Approach and methodology

As a first step, consultations with key stakeholders such as United Nations Development Programme, National Environment Commission Secretariat (NECS) and Ministry of Health (MoH) were carried out to gain an understanding of the project, previous work done on the subject, and align on expected outputs from the assignment. This was followed by extensive literature review of policy documents, reports/strategies/plans, academic research etc. to gain an understanding of climate change impacts in Bhutan, impact of climate change on diseases and interlinkages with socio-economic factors. Based on this understanding, a methodology for assessing risk of vector and water -borne diseases to climate change was developed. Using the methodology current and future risks were assessed. Further, for the identified risks and its contributing factors, adaptation strategies were proposed.

An illustration of the approach that formed basis for preparing a risk mapping of vector borne diseases associated with climate change is provided below:

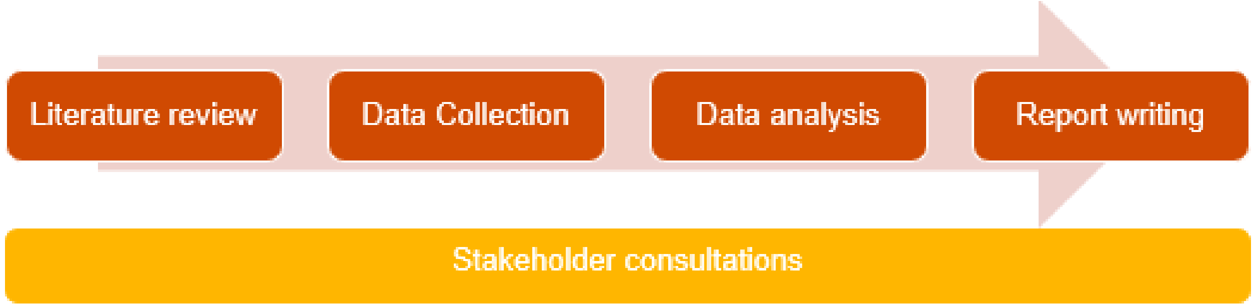


Figure 2: Overall approach

Detailed description on the methodological steps is discussed in the subsequent sections.

2.1. Literature review

Several documents including policies/strategies/plans of Bhutan related to climate change and health sector of Bhutan were reviewed to understand the baseline situation and future. Further, existing academic and grey literature on these subjects were reviewed to understand the linkages between climate change and health. List of documents reviewed is provided in the Annexure.

A review of literature on methodologies for climate risk assessment especially for assessing current and future risk of diseases to climate change were also undertaken. As part of this, the Risk-Impact framework proposed by the Fifth Assessment Report of IPCC (IPCC AR 5) was identified as suitable methodology to study climate risk to health in Bhutan.

IPCC AR5 risk assessment

The Risk-Impact framework proposed by IPCC AR5 (depicted in Figure 2) presents Risk[9] (or impact) (R) as a function of hazard[10] (H), exposure[11] (E) and vulnerability[12] (V).

$$\boldsymbol{R = f\ (H, E, V)}$$

As per this framework, risk includes an external dimension, which is climate-related stress (e.g., weather extremes) represented by the "hazard", as well as an internal dimension, which comprises "exposure" and

---

[9] The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (IPCC AR4 (2007), AR5 (2014))

[10] The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC AR4 (2007), AR5 (2014))

[11] The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC AR4 (2007), AR5 (2014))

[12] The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC AR4 (2007), AR5 (2014))

"vulnerability (sensitivity[13] and adaptive capacity[14])". The internal dimension describes the moderating attributes (socio-economic, physical or environmental) of the system.

$$R = f\ (H, E, S, AC)$$

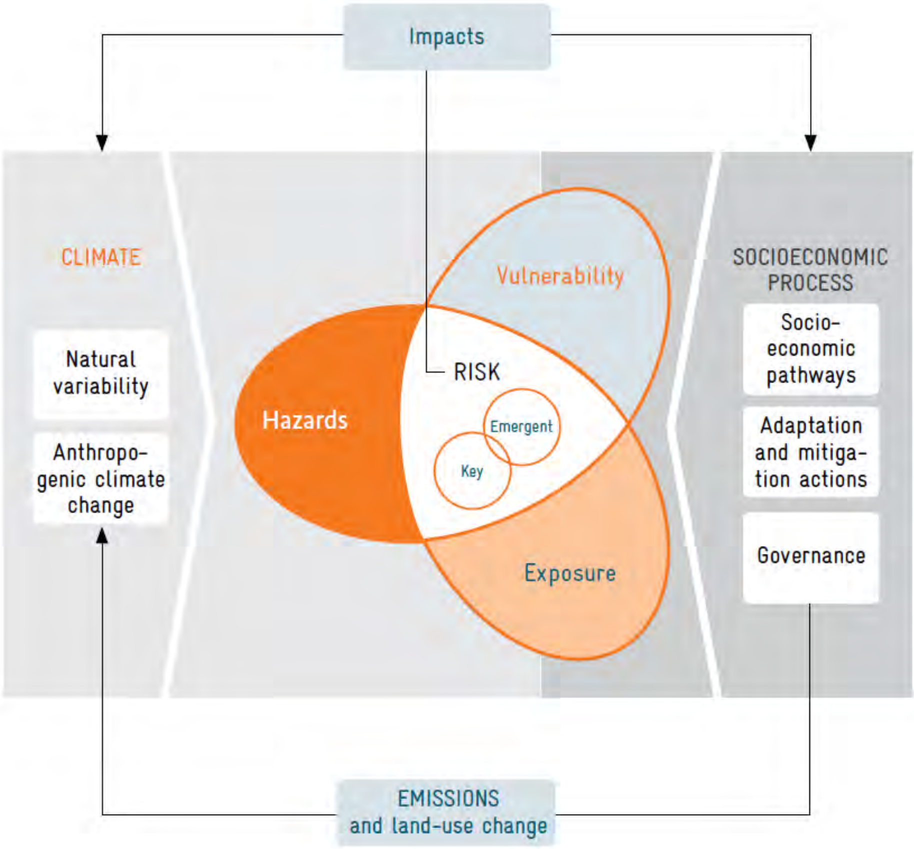


Figure 3: The contributing factors of Risk (adapted from IPCC AR5, 2014, P.1046)

Given that this is the most widely accepted framework for climate change risk assessment, this is most appropriate to study the impact and risk of climate change on health sector in Bhutan. A Climate Change Risk Assessment (CCRA) methodology based on this framework summarized in Figure 3 was used for risk mapping as part of this study:

$$\textit{Risk} = \textit{Hazard x Exposure x} \frac{\textit{Sensitivity}}{\textit{Adaptive capacity}}$$

Figure 4: CCRA methodology used in the study

Future risk assessment

To project future incidences of diseases identified under different climate scenarios, a *Poisson regression model* was developed using maximum temperature, minimum temperature, mean temperature, and rainfall as key climate factors to predict dengue, malaria, and diarrhoeal cases. This model is relevant when the response

[13] Predisposition of society and ecosystems to suffer harm as a consequence of intrinsic and context conditions making it plausible that such systems once impacted will collapse or experience major harm and damage due to the influence of a hazard event (IPCC AR4 (2007), AR5 (2014))

[14] The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences of climate change (IPCC AR4 (2007), AR5 (2014))

variable is comprised of non-negative integers and is not normally distributed[15]. It is a regression approach suitable for modelling variables that involve discrete data of the occurrences of some events over a specified interval. This is a well-established theory suitable in epidemiological research[16].

The following steps were followed for future projections:

- *Autocorrelation analysis* was performed to inspect the monthly dengue, malaria and diarrhoeal cases in Bhutan affected by previous cases using autocorrelation coefficient (ACF) and partial autocorrelation coefficient (PCF) values.
- *Cross-correlation analysis* was employed to observe the correlation between monthly positive cases and climate factors with different time lags to reveal the optimal lagged effect.
- *Pearson correlation* was performed between the different climate variables to check their collinearity.
- *Lagged analysis* with lags of 0– 3 months was performed to investigate the relationship between the diseases (2015–2020) and each of the climate factors.
- *Zero-inflated Poisson regression model (ZIP)* was preformed to estimate dengue and malaria cases in different emission pathways. It is essential when the number of zero count observation is reasonably high.

2.2. Data collection

After the first round of consultations, literature review and finalization of methodology, data requirements and sources were identified. To accurately identify data, impact chains were prepared. An impact chain lays the foundation of the entire risk assessment. It describes a cause-effect-relationship among elements that contribute to a consequence. For example, a climate signal such as a heavy rain event, may lead to a direct physical impact such as a flood or flash flood in a mountainous area, causing a sequence of intermediate impacts such as destruction of farmlands, forests, loss of lives and livelihoods, which finally lead to the risk. Impact chain also helps in understanding better the factors that drive vulnerability in the system under review and their cause-and-effect relationship. The methodological steps followed for development of impact chains are as follows:

- Identification of hazards – The climate hazards (change in temperature, change in precipitation, impact on land and hospital facilities due to flash floods and GLOFs) and disease prevalence were identified for Bhutan.
- Identification of potential impacts – Based on the understanding on hazards, direct and indirect impacts of hazards were identified for Bhutan.
- Determining exposure, sensitivity, and adaptive capacity – For the finalized impacts, the following were defined:
    - What climatic events have already led to impacts on the health sector/ vector-borne diseases?
    - What characteristics make the health system more susceptible to changing climate conditions?
    - Which adaptive capacities (knowledge, technology, institutions, and economy) allow the system to handle adverse climate change impacts)?

During this phase, climatic and non-climatic (socio-economic) factors that affect the overall risk of transmission of identified diseases were identified based on the literature reviewed and integrated into the impact chains. These factors were categorized under the IPCC AR5 components namely hazard, exposure, sensitivity, and adaptive capacity. Subsequently, indicators for each element of the impact chain covering these components were identified based on the availability of secondary and primary data sources. PHCB 2017, Statistical Yearbook 2019, Bhutan Living Standard Survey Report, 2017, Annual Health Bulletins are some of the secondary sources used for socio-economic data. Detailed information on sources is provided in the Annexure. At each stage of data collection and preliminary findings, consultations were carried out with different departments and local teams to validate data and findings.

[15] Frome and Checkoway, 1985
[16] Fairos et al. 2010; Fernandes et al. 2009; Wang et al. 2014

2.3. Data analysis

The data/information collected was analysed as per the CCRA framework discussed earlier to gain insights on disease trends, climate trends, risk assessment and mapping and future projections of the diseases. Several methodological steps were followed as summarized below:

Normalization of data: The values (N) were normalized by removing the units and converting all the values into dimensionless units that are expressed as values between 0 and 1.

$$N_{ij}^{p} = \frac{Xij - Min\ i\ (Xij)}{Max\ i\ (Xij)\ -\ Min\ i\ (Xij)}$$

Where, *Xij* is the actual value, *Max i (Xij)* and *Min i (Xij)* are maximum and minimum values, respectively.

Analysis of sub-components: After normalization, the indicators was averaged using the formula of *simple arithmetic mean* to get the value of average index (AI) for each major component:

$$AI\ = \sum N_{ij}\ / \ n$$

Where, AI is the value of average index for major components, Nij represents the normalized value of indicators /sub-components and n is the number of indicators in each major component. Equal weights were assumed for all the major components and sub-components.

Analysis of major components: The major components was multiplied with the weight allocated to get the index value of IPCC defined contributing factors – Hazard, Exposure, Sensitivity, and Adaptive Capacity.

$$\boldsymbol{Hazard}\ = \sum (W_i\ x\ A_i\ )/\sum W_i$$

$$\boldsymbol{Expoure}\ = \sum (W_i\ x\ A_i\ )/\sum W_i$$

$$\boldsymbol{Sensitivity}\ \ = \sum (W_i\ x\ A_i\ )/\sum W_i$$

$$\boldsymbol{Adaptive\ Capacity}\ \ = \sum (W_i\ x\ A_i\ )/\sum W_i$$

Where, AI_i is the major component and Wi is the weight of each major component.

Vulnerability Index: The values of sensitivity and adaptive capacity were aggregated to obtain the vulnerability index value. The approach used for calculation of vulnerability is presented below:

$$\boldsymbol{Vulnerability}\ = \frac{Sensitivity}{Adaptive\ capacity}$$

Risk Index: The values of IPCC defined contributing factors – Hazard, Exposure, and Vulnerability was aggregated to obtain the overall *Risk Index* value.

$$\boldsymbol{Risk}\ = Hazard\ x\ Exposure\ x\ \ Vulnerability$$

The value for risk index ranges from 0 to 1, with higher values reflecting higher degree of risk. Finally, the entire range was equally divided into five categories and each is assigned a qualitative indicator of risk - Very High, High, Medium, Low, and Very Low.

The outcomes of analysis included a map depicting area prone to vector borne diseases in Bhutan, risk and vulnerability index for different Dzongkhags, and risk matrix showing temporal change of vulnerability. Based on this, a number of adaptation strategies were identified.

2.4. Stakeholder consultation

Key stakeholders in Bhutan were identified with the support of local consultants, UNDP and NECS. Consultation with the Royal Centre for Disease Control, Health management and information system (HMIS) team and VDCP were held to understand the availability of data for different diseases. Monthly update calls were held with the UNDP and NECS to discuss project related challenges and progress. Some of the key stakeholders are as below:

- Department of Public Health, Ministry of Health, Bhutan
- Environmental Health Program and Rural Sanitation and Hygiene Program under Department of Public Health
- Vector-borne Disease Control Programme (VDCP), DoPH, Ministry of Health, Gelephu
- Royal Centre for Disease Control (RCDC), DoPH, Ministry of Health, Thimphu
- Climate Change Division, NECS

- Water and Sanitation Division, Department of Engineering Services, Ministry of Works and Human Settlement
- Khesar Gyalpo University of Medical Sciences of Bhutan (KGUMSB)

Key informant interviews were carried out to gain an in-depth understanding of the current adaptive capacity and measures taken by the different departments.

Findings of the study were validated with key stakeholders that included NECS, UNDP, UNICEF, DoPH, VDCP and KGUMSB.

3. Findings from the study

3.1. Impact chains for climate change and VBD/WBD

The IPCC AR5 report states with high confidence that as new conditions emerge under climate change, range of existing diseases may extend into areas that are presently unaffected. It can be said that local changes in temperature and rainfall can alter the distribution of some vector-borne and water-borne diseases[17].

Vector-borne diseases: Vector-borne diseases are among the most well studied diseases associated with climate change, owing to their large disease burden, widespread occurrence, and high sensitivity to climatic factors. In contrast to some other climate-sensitive health risks, such as heat-stress, or exposure to storms and floods, the influence of meteorological factors is less direct, and more diverse, both within and between individual diseases[18]. Climate is an important influence on vector-borne disease transmission, and there is evidence that ongoing climate change is affecting and will continue to affect the distributions and burdens of these infections. There is evidence that climate variability such as increase in temperature, precipitation, and humidity increases the geographic range of mosquito distribution, the proliferation, reproduction of both pathogen (*Plasmodium* parasite in case of malaria) and mosquitoes and subsequently increases the chances of human-vector contact[19]. Literature review shows that VBDs such as dengue, malaria, chikungunya, kala-azar, and scrub typhus and WBDs such as diarrhoea, dysentery, and cholera[20] are sensitive to climatic parameters.

Water-borne diseases: IPCC states that there is "very high confidence" that increased risks of food- and water-borne diseases can be expected if climate change continues as projected across the representative concentration pathway (RCP) scenarios until mid-century. Anthropogenic climate change has caused increase in the number of warm days and nights, and the frequency and intensity of both droughts and heavy rainfall events. This has implications for waterborne diseases; high temperatures can alter pathogen survival, replication and virulence, heavy rainfall events can mobilize pathogens and compromise water and sanitation infrastructure, and droughts can concentrate pathogens in limited water supplies[21]. The potential for climate change to affect diarrhoeal diseases was recognized starting with early efforts to estimate the impacts of anthropogenic climate change on human health. Diarrhoeal disease outbreaks have been associated with both heavy rainfall and dry periods, demonstrating that dry periods can concentrate disease causing agents and precipitation can mobilize them. In both cases, enabling contamination of drinking water sources and increasing chances of human-pathogen contact. For instance, extremely low rainfall can force people in developing countries to resort to use of polluted waters, while too much rain can contaminate unpolluted waters.

Impact Chains: Based on the desk research and consultations, a qualitative impact chain for climate change and the pathway to increased risk of vector borne and water borne diseases was developed. The impact chain in Figure 5: Impact chains for vector-borne diseases and Error! Reference source not found. show how changes in temperature and precipitation in conjunction with socio-economic factors can translate into an increased risk of vector and water borne disease transmission.

[17] IPCC (2014). Human health; impacts adaptation and co-benefits. In Part A: global and sectoral aspects contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change
[18] Smith KR, et al. 2014.
[19] Rocklöv, J., & Dubrow, R. (2020). Climate change: an enduring challenge for vector-borne disease prevention and control. Nature immunology, 21(5), 479-483.
[20] There is no data on Cholera either with HMIS or RCDC, according to the Deputy Chief Laboratory Officer of RCDC, Cholera cases are absent in-country for the past 5 years.
[21] Levy, K., Smith, S. M., & Carlton, E. J. (2018). Climate change impacts on waterborne diseases: moving toward designing interventions. Current environmental health reports, 5(2), 272-282.

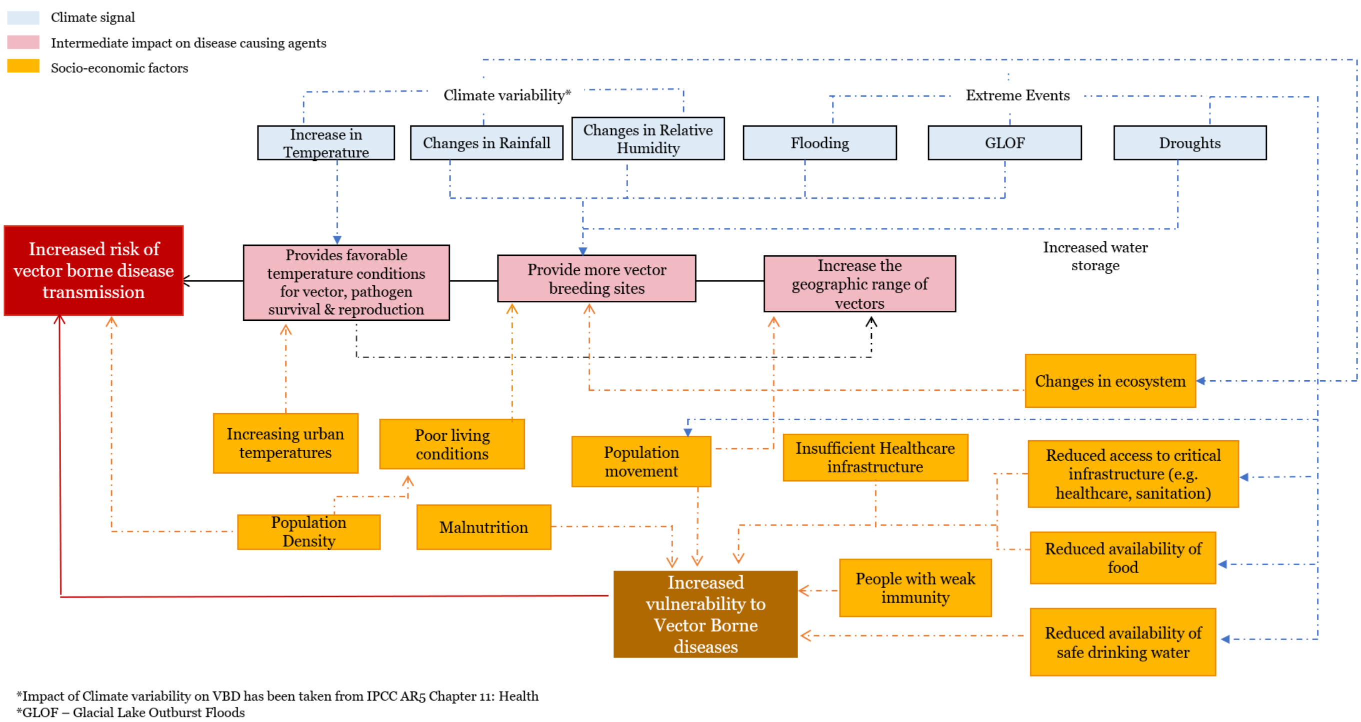


Figure 5: Impact chains for vector-borne diseases (Source: PwC analysis)

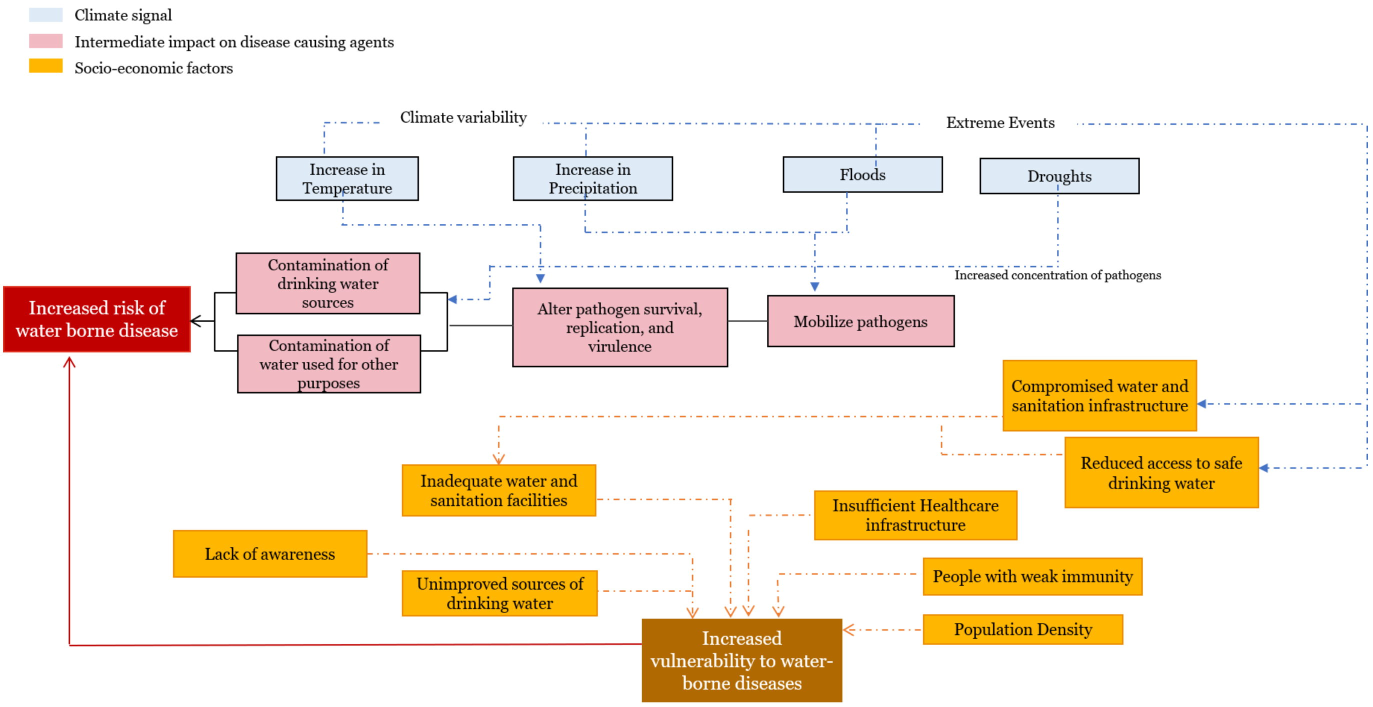


Figure 6: Impact chain for water-borne diseases (Source: PwC analysis)

Increase in temperature provides favourable condition for vector, pathogen survival and reproduction (Lin, 2009; Li et al., 2011). Ideal temperature range for survival through all life phases of dengue and chikungunya vector (*Aedes aegypti*) is between 20 and 30 °C (Ebi, 2016). The malaria mosquito is sensitive to increase in temperature and malaria transmission has been observed to peak at 25⁰ C (Mordecai, Erin A et al., 2015). In China, a 1°C increase in mean temperature was associated with a 3.8% increase in the odds of scrub typhus cases during the same week[22]. Similarly, for Kala-Azar, small fluctuations in temperature can have a profound effect on the developmental cycle of Leishmania promastigotes in sandflies[23]. With respect to water-borne diseases, temperature is a key determinant for seasonal patterns of dysentery-associated pathogens (D'Souza et al., 2004) and the current impact of climate change owing to temperature increase is estimated to lead to over 80,000 additional deaths per year in developing countries (IPCC AR5).

Heavy precipitation favors the spread of vector borne and water borne diseases. Dengue transmission occurs mostly during the wettest months of the year (Gubler and Kuno, 1997; Chadee et al., 2007), but drought can also be a cause if households store water in containers that provide suitable mosquito breeding sites (Beebe et al., 2009; Padmanabha et al., 2010). Changes in rainfall patterns create favorable conditions for mosquito breeding in many areas (Onyango, 2016) and heavy rainfall may increase vector breeding grounds increasing the risk of malaria transmission (VDCP, RGoB). Heavy rainfalls can increase the abundance of *Aedes. albopictus*, thereby increasing the risk of Chikungunya transmission (Waldock J et al., 2013). During an epidemic in central Thailand, it was seen that chikungunya infection followed periods of heavy rainfall by approximately six weeks (Braden Meason and Ryan Paterson, 2014). Humidity and rainfall can also influence water borne diseases such as diarrhoea and dysentery (Yang et al 2008, Alexander et al 2013). A study in Vietnam found a correlation between rainfall and likelihood of detecting pathogenic enteric viruses in water sources wherein a 100mm increase in precipitation corresponded to a 4% increase in the incidence of bacillary dysentery (bacteria-caused dysentery) in Kon Tum Province, Vietnam (Lee et al., 2017).

Change in relative humidity: Humidity change affects the virus of vector-borne diseases as humidity and water are crucial for vector breeding. WHO estimates that rising global temperatures, as well as altered precipitation and humidity linked to climate change, could significantly alter VBDs and their effect on human populations—making epidemics more difficult to predict and control[24]. Humidity was found to affect malarial parasite development in Anopheline mosquito (Patz et al., 2003) and temperature and humidity during rainy season favored dengue virus propagation in mosquitos, contributing to the outbreaks of dengue hemorrhagic fever in Yangon and Singapore (Thu. et al. (1998)). Relative humidity and rainfall are also significant factors that can affect the incidence of scrub typhus (Yuehong Wei et. al. (2017)).

Changes in the frequency of extreme events, such as fewer frosts and more floods can have large effects on disease vectors. The increasing temperatures will also intensify the hydrological (rainfall and evaporation) cycle, leading to an increased frequency and intensity of extreme weather events such as storms, floods, and droughts. Extreme low rainfall and droughts can lead to inadequate water supply and need for water storage. It can also force people to make more use of polluted water (Hunter, 2003; Ashbolt, 2004). These can act as suitable mosquito breeding ground for the vector and increase human exposure to pathogens, as contaminants are spread by floodwaters[25]. Heavy rain or flooding can also lead to increased breeding of mosquitoes, and outbreaks of the disease provided that other conditions are suitable (RW Sutherst, 2004). Extreme events such as floods, landslides etc. can also lead to damaged infrastructure, blocked roads, unavailability of food, reduced access to basic facilities and critical infrastructure negatively affecting the adaptive capacity of the system.

Non-climatic drivers, such as population displacement, changes in ecosystem, public health infrastructure, safe water and sanitation facilities can have large effects on disease transmission. *To holistically understand the impact of climate change on increased risk of disease transmission, it is important to study the role of non-climatic parameters that can increase or decrease the vulnerability of the system.*

Changes in ecosystem can influence vector abundance which could degrade or enhance vector habitats and species competition, or it could increase or reduce the abundance of vector predators or vector pathogens. In addition to human interventions, changes in ecosystem can also be caused due to climate change (Joacim Rocklöv & Robert Dubrow, 2020). Forest clearance for urbanization, agriculture or other land use alters ecosystem dynamics and leads to new breeding habitats for disease vectors such as mosquitoes, fleas, and ticks by reshaping existing ecosystem boundaries. Such boundaries are often sites of contact between humans and

[22] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5358896/
[23] https://www.who.int/news-room/fact-sheets/detail/leishmaniasis
[24] https://climatenexus.org/climate-issues/health/climate-change-and-vector-borne-diseases/
[25] https://www.safewater.org/fact-sheets-1/2017/1/23/effectofclimatechange

forest pathogens. There is a well-documented positive association between the increased deforestation of an area and the emergence of zoonotic, vector-borne diseases (Gottwalt 2013).

Movements of people, materials, or vehicles have been responsible for short- and long-distance transfer of several disease vectors. Travelers have carried pathogens into other countries including malaria and dengue viruses (Sutherst 2004). Urbanization, globalization and lack of effective mosquito control have been cited as three principal drivers that have contributed to the emergence of dengue. Large urban centers with crowded human populations live in intimate association with large mosquito populations. Such settings provide ideal home for maintenance of the viruses and the periodic generation of epidemic strains. These are also cities that have modern airports through which millions of passengers pass each year providing the ideal mechanism for transportation of viruses to new cities, regions, and continents where there is little or no effective mosquito control (Gubler 2011).

Water and sanitation facilities - Drinking water containing pathogenic microorganisms is the main driver of WBDs. WBDs are linked to the ingestion of pathogens via contaminated water or food. Increasing occurrence of floods can threaten water quality and public health especially in areas with poor sanitation facilities and unprotected sources of drinking water.

Densely populated areas are a result of unplanned urbanization with poor living conditions, inadequate water supply, unsafe drinking water and insufficient sanitation facilities. Developing countries with densely populated areas are particularly susceptible to disease transmission, as water carries wastes, shallow water provides breeding conditions for mosquitoes, and drainage and sewage systems can become blocked. The overall risk on health gets compounded when these areas have poorly developed health systems, minimal water, and wastewater treatment.

Gendered impacts - The distinct roles and relations of men and women in each culture, dictated by that culture's gender norms and values, give rise to gender differences and inequalities. Literature suggests men and women suffer different negative health consequences following extreme events such as floods, windstorms, droughts, and heatwaves[26]. Almost 90% of the burden of diarrhoeal disease is attributable to lack of access to safe water and sanitation. In times of water scarcity, women are compelled to draw water from unsafe sources including streams which may lead to water-borne diseases which is a leading cause of death especially among children[27]. Women are more likely to come in close proximity to domestic standing-water and mosquito-breeding sites as they spend more time around the house performing domestic tasks. Men are also found to be at higher risk of vector borne disease due to various occupational factors, such as forest work, firewood collection, guarding fields at night, or cross-border travel[28]. Frequent occurrence of extreme events such as floods may also increase the prevalence of VBD/WBDs. An increase in prevalence of diseases will likely aggravate women's caregiving of family and community members who are ill[29].

Pre-existing health conditions, food insufficiency, inadequate nutrition within certain sub-population groups such as children, elderly, women, and pregnant women[30] are disproportionately affected by VBD/WBDs. Dengue infections in patients with underlying diseases or co-morbid conditions can be severe and may lead to more complications or even death if not managed properly.

Public health system without adequate resources and infrastructure to treat infected patients may exacerbate vulnerabilities causing higher case fatality rates

3.2. Indicators for climate risk assessment as per IPCC AR5 framework

To perform an assessment of climate change risk and impact on health, it is important to first identify the hazard, a natural or human-induced physical event or trend or physical impact[31]. In the context of this study, in line with the findings from the literature review and context of Bhutan, hazard consists of three major components: climate variability, extreme events and cases of vector borne, and water borne diseases at the

[26] https://www.who.int/globalchange/GenderClimateChangeHealthfinal.pdf
[27] https://www.who.int/globalchange/GenderClimateChangeHealthfinal.pdf
[28] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3278342/
[29] https://www.un.org/womenwatch/feature/climate_change/downloads/Women_and_Climate_Change_Factsheet.pdf
[30] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6038986/
[31] Oppenheimer, M., Campos, M., Warren, R., Birkmann, J., Luber, G., O'Neill, B., Takahashi, K., Brklacich, M., Semenov, S., Licker, R. and Hsiang, S., 2015. Emergent risks and key vulnerabilities. In Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects (pp. 1039-1100). Cambridge University Press.

Dzongkhag level. Degree of exposure is expressed in the terms of Dzongkhag-wise population density. Socio-demographic profile, health, livelihood, knowledge, infrastructure, access to services and adaptation strategies are important areas in this study for determining the vulnerability of population to diseases in different Dzongkhag. Knowledge, institutions, and access to services have been identified as the major components to evaluate adaptive capacity of the Dzongkhag. Detailed mapping of indicators against IPCC components is presented in the Table below:

Table 1: Indicators for risk assessment mapped against IPCC components

IPCC component	Major Component	Sub-component
Hazard	Climate Variability	• Max Temperature • Min Temperature • Mean Temperature • Standard Deviation Temperature • Standard Deviation Relative Humidity
		• Mean Precipitation • Standard Deviation Precipitation
	Extreme events	• Area of land affected due to Floods, GLOFs • Number of Health facilities damaged due to Floods, GLOFs
	Vector borne disease	• Dengue Cases • Malaria Cases • Chikungunya cases • Kala-Azar cases • Scrub Typhus cases
	Water borne diseases	• Diarrhoea cases • Dysentery cases
Exposure	Population	• Population density
Sensitivity	Demographic Profile	• % of Elderly • % of Children • % of Female population • Female Headed Households
	Economic Situation	• Consumption Poverty Rate • Unemployment Rate • Dependency Ratio • Food insufficiency
	Urbanization and Population displacement	• % change in urban population (2005-2017) • No. of tourist arrivals • % of rural-urban migration
	Changes in ecosystem	• % change in cultivated agriculture land (2010 - 2016) • % change in forest cover (2010 – 2016)
	Health issues	• Food insufficiency • Infant Mortality rate • Disability Prevalence Rate
Adaptive Capacity	Knowledge	• Literacy rate

	Access to services	Households with access to • Safe drinking water • Improved sanitation facilities • Drainage facilities • Nearest road head in less than 30 minutes
	Health	• Availed health services during the past year (%) • Employed in Health services (%) • Health facilities per 1000 pop

3.3. Baseline situation in the country

Baseline assessment establishes the as-is situation in Bhutan and provides key information on the current climatic, socio-economic and health conditions at the Dzongkhag level in the country. This information is important to map progress and assess the impacts of the adaptation interventions recommended as part of the study.

3.3.1. Climatic conditions in Bhutan

Climatic conditions in terms of temperature, rainfall, and extreme weather events and how that has changed in the recent past years in the country are discussed in this section. This is based on the historical temperature and rainfall data for each Dzongkhag of Bhutan obtained from NCHM and analyzed for the period 1996-2020.

Temperature (Tmax): Monthly trend of average maximum temperature shows that the temperature tends to peak during the summer months (June, July, August, and September) reaching an average maximum temperature of around and greater than 25°C.

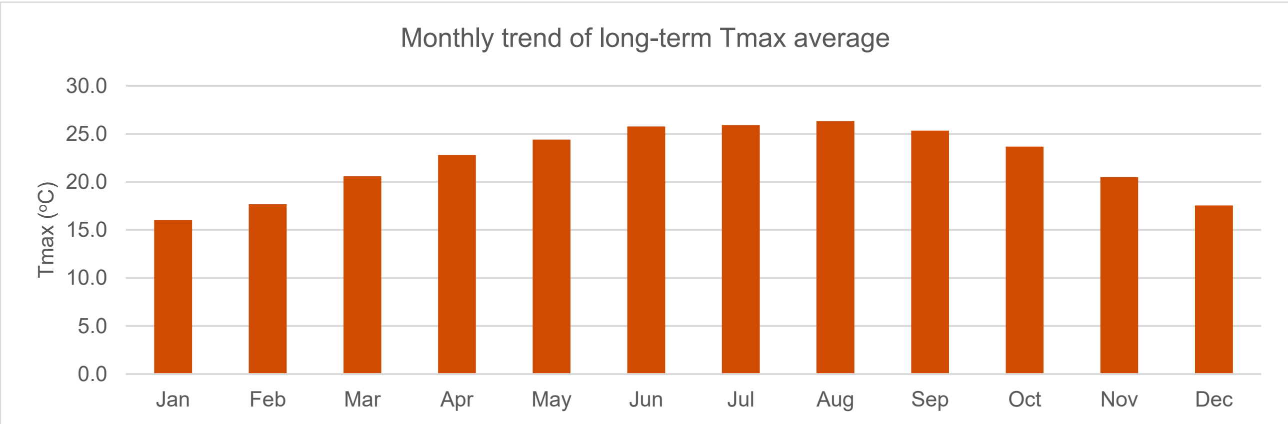


Figure 7: Monthly trend of Tmax/Seasonal variation of maximum temperature (Source: PwC analysis)

At Dzongkhag level, the long-term average of average monthly maximum temperature shows Chhukha has the highest average Tmax at 30°C followed by Sarpang, Samtse, Punakha and Wangdue. Higher temperatures are more favorable for vector and pathogen survival. Furthermore, Chhukha, Sarpang, Samtse, Samdrup Jongkhar are Dzongkhags that lie on the southern border of Bhutan have a higher risk of importing the disease from neighboring states in India.

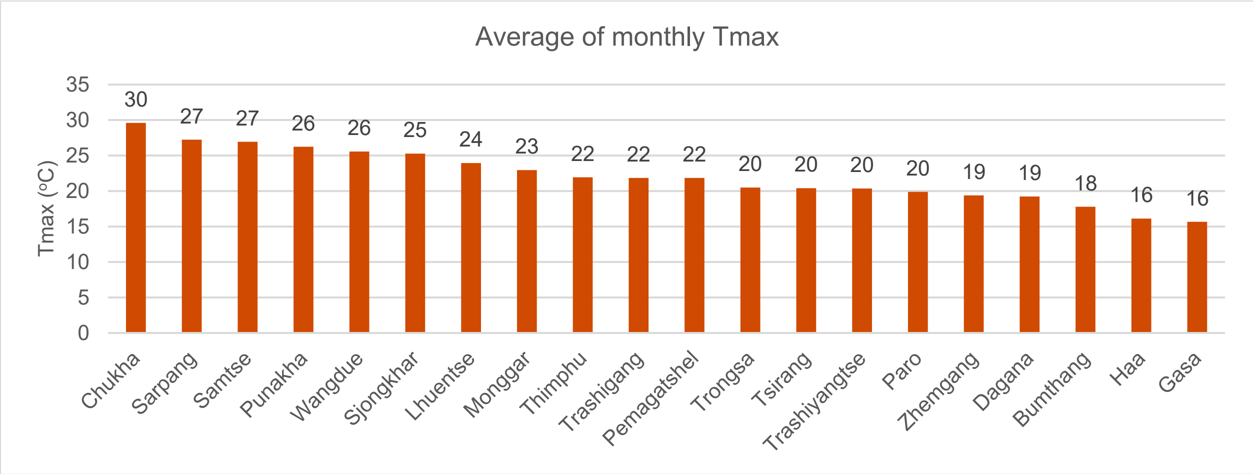


Figure 8: Dzongkhag-wise long-term average of maximum temperature (Tmax) (Source: PwC analysis)

Rainfall: The monthly trend of annual rainfall in Bhutan shows higher rainfall during the months of June, July, August and September and during the south west or summer monsoon months in Bhutan. These months contribute to around 72% of the total annual rainfall in Bhutan.

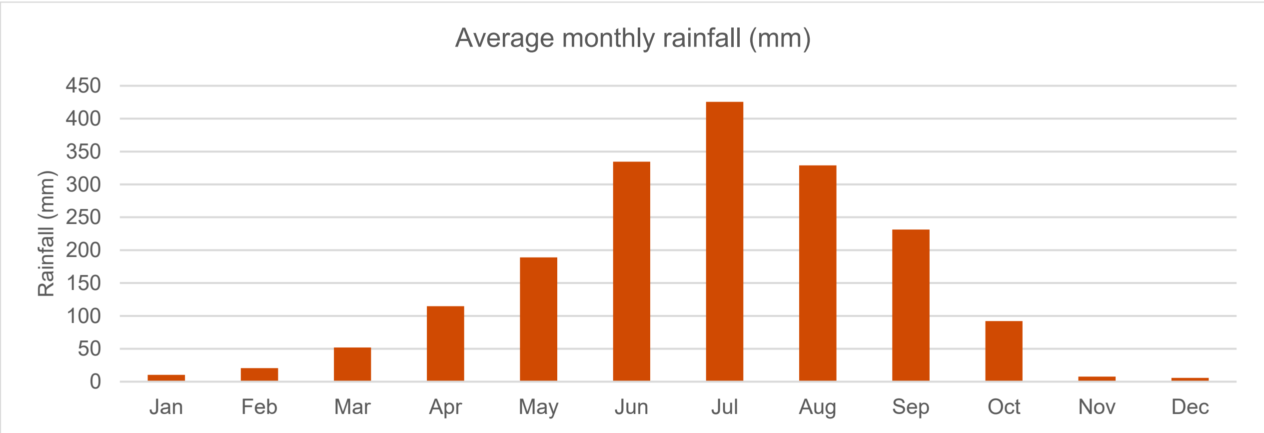


Figure 9: Average monthly rainfall in Bhutan (mm) (Source: PwC analysis)

At a Dzongkhag level, it is observed that average yearly rainfall is the highest in Samtse Dzongkhag (5443mm) followed by Sarpang, Chhukha, Samdrup Jongkhar. This is much higher than the average rainfall in Bhutan that is around 1800mm in a year. Higher rainfall may lead to water accumulation and provide favorable breeding condition to vectors. Run-offs resulting from excessive rainfall, may lead to water contamination leading to higher risk of water borne diseases. In addition, as noted in the previous section, these Dzongkhags lie on the southern border of Bhutan and are at a higher risk of importing the disease.

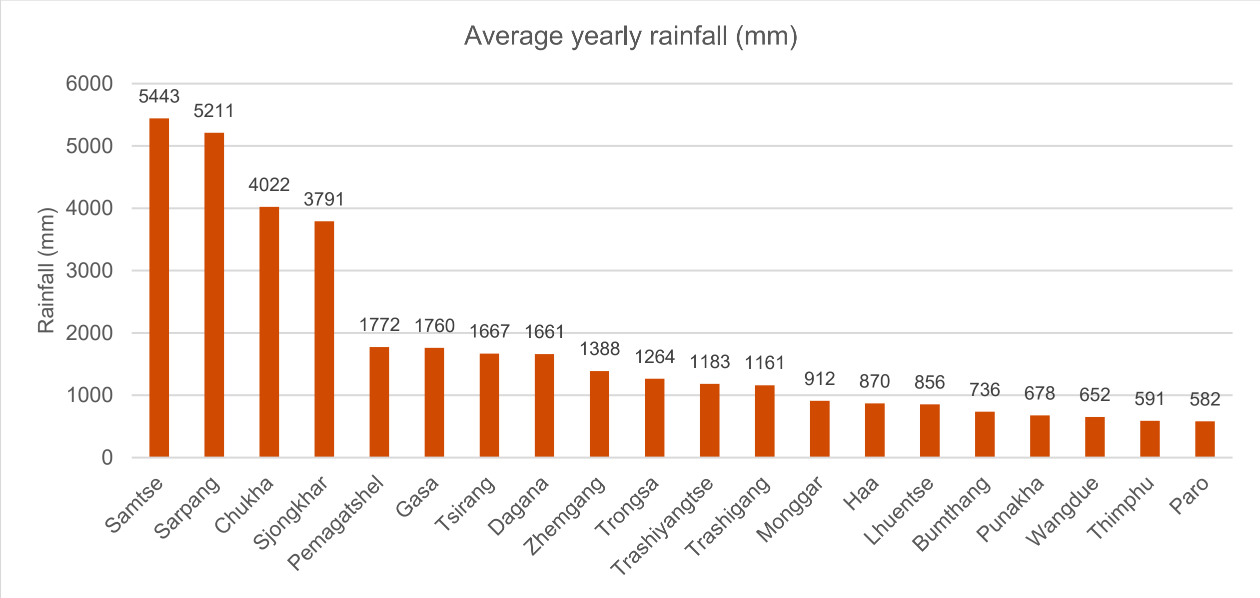


Figure 10: Dzongkhag-wise average yearly rainfall (Source: PwC analysis)

Extreme events: Extreme weather is important in the context of this study as water accumulation and contamination caused due to intense rainfall, or water storage during droughts can lead to an increased risk of VBD/WBDs. In addition to the increased risk of the spread of disease, intense rainfall can cause flash floods, landslides and other hazards that can have significant socio-economic consequences and adversely affect people's ability to access basic services, livelihood, and well-being, particularly of marginal and poorer communities.

Precarious geographical location and effects of climate variability and change have highly exposed Bhutan to a diversity of hazards, including cyclone induced storms, intense rainfall, flash-floods, landslides, earthquakes, glacial lake outburst floods (GLOF) and dry spells. Heavy seasonal monsoon rains and glacial melt are the most common cause of flooding and landslides in Bhutan. The country is experiencing prolonged dry spells in some parts of the country and unseasonal and intense rainfall and hailstorms. Heavy rainfall triggering floods and flash floods are a recurring phenomenon in Bhutan, especially during the summer monsoon[32].

Bhutan reported heavy rainfall and flash floods during 2016-2019 (National Center for Hydrology & Meteorology 2020). In 2016, Bhutan experienced heavy rain over most parts of the country during the month of July. Southern parts of the country received heavy to very heavy rainfall during these periods. Due to consistent heavy rain, there were several flash floods and landslides reported from different parts of the country. Dzongkhags that were impacted the most included Samtse, Chhukha and Sarpang. In April 2019, heavy rainfall was reported in the month of April in the eastern parts of Bhutan and small flash floods were reported in Lhuentse Dzongkhag. In August 2019, continuous rainfall led to a flash flood in Wangdue Dzongkhag in Bhutan. The flash flood damaged infrastructure, irrigation water channel, drinking water supply and paddy fields[33].

3.3.2. Health System in Bhutan

Bhutan recognizes health as a prerequisite for economic and spiritual development, poverty reduction and the road to Gross National Happiness. Health has held a prominent place in Bhutan's economic development where the government spends around 7.4 to 11.4% of total government expenditure on health (Policy and Planning Division, 2009). Until the 1960s, traditional healing methods were predominantly used in Bhutan. With the establishment of modern health-care system, both the traditional and modern medicines are integrated and delivered at various levels of health centres in the country (WHO 2017). All health care services are provided by the Government and are free of cost. There is no regulatory framework for operation of the private medical sector in Bhutan and their engagement in health care is limited to private diagnostic centers (catering mostly for screening of foreign workers) and private retail pharmacies in major Dzongkhag towns[34].

[32] National Center for Hydrology and Meteorology 2019
[33] https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/Extreme%20Weather%20Records.pdf
[34] Sharma et al (2017) Measuring universal health coverage: a three-dimensional composite approach from Bhutan

The 12th five-year plan of Bhutan recognizes health as one of the nine domains that form the basis for achieving GNH. Four of the 17 National Key Result Areas (NKRAs)[35] fall under the Health domain. These include Water, Food and Nutrition Security Ensured; Poverty Eradicated & Inequality Reduce; Healthy and Caring Society Enhanced, Liveability, Safety and Sustainability of Human Settlements Improved. Under each NKRA, key performance indicators have been mapped along with lead agency, collaborating agencies, baseline, targets and sources etc.

Key performance indicators

Bhutan has made remarkable progress in improving the health and quality of life of its population in recent decades, achieving almost all Millennium Development Goals (MDGs) and on a steady progress to achieve Sustainable Development Goals (SDGs). Life expectancy at birth estimated at 34.5 years in 1960 increased to 71.7 years in 2019[36]. The increase in life expectancy may be attributed to improved socio-economic development, government's investment in health and education, improved water and sanitation and advancement in medical technology and services in the past years. Bhutan was among few countries in the world to achieve the Millennium Development Goal 5 (improve maternal health) in 2015. Such a positive outcome may be due to increasing trends of antenatal care coverage and institutional deliveries coupled with enhanced competency of healthcare professionals among other reasons.

Briefly, the table below captures the impressive achievements made by Bhutan and a comparison with other countries in South Asia

Table 2: Comparison of key health indicators of Bhutan with other South Asian countries in the region (Source: PwC analysis)

Parameters	Source	Bhutan	Nepal	Sri Lanka	Bangladesh	India
Maternal Mortality Ratio (per 100,000 live births)	WHO 2017	183	186	36	173	145
Under 5 Mortality Rate (per 1000 live births)	WHO 2019	28	31	7	31	34
Life expectancy at birth (years)	WHO 2019	73.1	70.9	76.9	74.3	70.8
Fertility Rate, total, Birth per woman	World Bank 2018	2.0	1.9	2.2	2.0	2.2
Immunization Coverage (%) (DPT)	World Bank 2017	98%	90%	99%	98%	89%

Bhutan is among the top global performers in gains in life expectancy in the past 40 years. The targets of MDGs 4 and 5 have been achieved and since 2010, immunization levels have been maintained over 95%. Despite remarkable success, the country faces a triple burden of health challenges. While communicable diseases such as respiratory and skin infections and diarrhoeal diseases remain a substantial burden to the people, non-communicable diseases (NCDs) are increasing rapidly. Moreover, Bhutan is also prone to natural disasters and hazards such as landslides, floods and outbursts of supraglacial lakes (WHO 2017).

Policy environment

Preservation and conservation of the environment is one of the pillars of Gross National Happiness and it is very well translated into the *Constitution of the Kingdom of Bhutan* which recognizes the need for the Royal Government of Bhutan to ensure an environment which is safe and healthy. *Bhutan State of Environment Report 2016* highlights the implication of climate change, water, air and environment on human health.

[35] A National Key Result Area (NKRA) is a national level development outcome to contribute towards achieving the plan objective

[36] https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=BT

The National Health Policy mandates the health system to institute a comprehensive regulatory system for all health-care facilities and services in the country to regulate the quality, safety, equity and efficiency of health services[37]. The policy aspires to be congruent with the philosophy of Gross National Happiness and reflects various inputs ranging from social, spiritual, cultural and environmental aspects. The policy is currently being revised and the first ever National Health Bill is being drafted to chart out a comprehensive roadmap for the future ((Ministry of Health 2020). The section 14.7 of the *National Health Policy* states "Prediction, Preparedness and Mitigation measures to address adverse effects of climate change on health shall be put in place through comprehensive multisectoral plan /emergency preparedness and public education on behavioural adaptations.

Health policy objectives are executed through health sector strategic (5- year) and operational (annual) plans. The national five-year plan, provided by the Gross National Happiness Commission (GNHC), guides the drafting of health sector strategic plans, and emphasizes an intersectoral planning approach through multi-stakeholder participation (WHO 2017).

Institutional framework

National Environment Commission (NEC) is overall coordinating agency responsible for monitoring of environment and climate change, impacts of economic development activities, management of climate change information, education, awareness, and outreach activities and conducts studies on emerging climate change issues.

The MoH is the central authority responsible for the development of health policy and for all other stewardship functions, as well as for organizing and provision of quality and comprehensive health-care services, including health promotion, disease prevention, curative, and rehabilitative services. The MoH also focuses on providing technical support to the Dzongkhags in planning, administration, and provision of services to the people, as well as on developing standards in relation to human resources for health (HRH), medical supplies and infrastructure development. In line with the decentralization policy of the Royal Government of Bhutan (RGoB), health administration and management has been devolved to Dzongkhags over the past few decades. Dzongkhag health offices undertake the deployment of HRH in their respective Dzongkhags. Public health services are well established, with a Department of Public Health (DoPH) in the Ministry of Health (MoH) overseeing the various programmes being implemented through the health facilities. Programmes are in place to address the country's public health concerns in communicable Diseases (CDs) as well as noncommunicable diseases (NCDs), and other areas such as WASH (Water, Sanitation and Hygiene) and environmental health. The programmes on rural water supply and sanitation have been recently transferred to Ministry of Works and Human Settlement (MoWHS) and hygiene component retained with MoH.

Since 2010, MoH in partnership with UNICEF and SNV has implemented community level demand driven Rural Sanitation and Hygiene Programme (RSHAP) in 16 Dzongkhags to facilitate in improving the Open Defecation Free (ODF) Gewog/Dzongkhag status and access to improve sanitation services as one of the key among many WASH intervention. To emphasize much desired importance to sanitation and hygiene, the Royal Government endorsed a "National Sanitation and Hygiene Policy 2020" which will form the backbone in providing the much-anticipated directives and way forward in promoting the living standards of its people through improved sanitation and hygiene in the country. With the support from the UNICEF, the MoWHS is also in the process of publishing a "National Public Toilet Guideline" after successfully sensitizing its engineers from Local Government in April 2021. The guideline which is due within third quarter of 2021 is expected to address the shortcomings in the design of public toilet especially persons with disabilities and third genders.

Environmental Health Program was created in *Ministry of Health* under DoPH in 2008 to manage programs on environmental health and climate change. The program started with advocacy and awareness on health impact of climate change and implemented a pilot project on health adaptation to climate change with support from WHO and UNDP and funding from Global Environment Facility. This program has established surveillance and early warning systems for climate sensitive diseases in high-risk Dzongkhags of Bhutan and monitors air quality and pollution parameters as one of the key program interventions.

The Department of Medical Services (DoMS) manages delivery of clinical services across health facilities and Department of Medical Supplies and Health Infrastructure (DoMSHI) manages the procurement and

[37] Ministry of Health, Royal Government of Bhutan, 2011

distribution of all medicines and medical supplies for the MoH. Rational prescribing is observed which may be due to the regular updating and implementation of the National Essential Medicines List, availability, and application of Standard Treatment Guidelines, having formularies and the absence of a private sector. Stock-outs and expiry of medicines have also been prevented through an effective supply chain management system.

In line with the national health policy, the engagement of the private sector in health-care delivery is limited to pharmaceutical retail shops and selective diagnostic centres (catering mostly for screening of foreign workers) and private retail pharmacies in major Dzongkhag towns[38].

Health Service Delivery Infrastructure: The coverage of health facilities has increased, with a quarter of rural households living within 30 minutes of the nearest health facility. The beds per 10,000 population is 22 which is significantly lower if compared to global estimates[39].

Bhutan has 49 hospitals including the National Traditional Medicine Hospital (NTMH), 186 Primary Health Centers, 53 Sub-posts, 542 Outreach Clinics (ORCs) three *Thromde* Health Centers, and five Health Information and Service Centers[40]. The table below shows the distribution of health facilities across the *Dzongkhags* of Bhutan. To address the emerging challenges in epidemiological shifts, epidemics and emergencies owing to effects of climate change, Bhutan must continue to invest in infrastructural development including consolidation and up-gradation of health facilities.

Health Human Resource Availability: Overall, the health workforce increased by about 12% between 2018 and 2019. The figure below shows the trend of available doctors and nurses in Bhutan over the last five years. In 2020, the number of doctors and nurses per 10,000 population were 4.62 and 20.9 respectively, which is lower than most countries in Southeast Asia. The Ministry of Health has set high priority on human resource development to overcome the shortage both in terms of quantity and specialties[41].

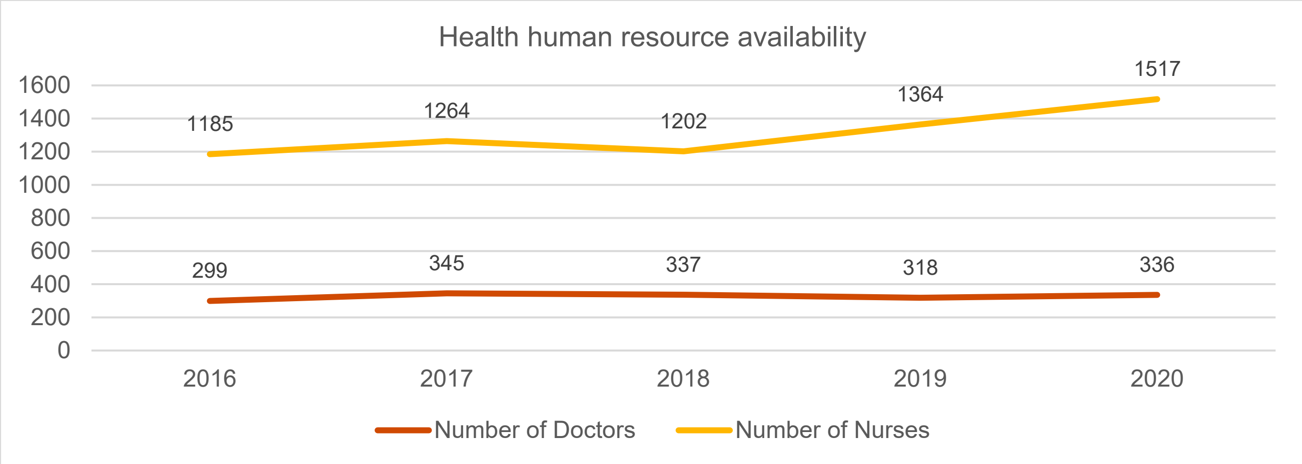


Figure 11: No. of doctors and nurses (Source: PwC analysis)

The MoH also focuses on providing technical support to the Dzongkhags in planning, administration, and provision of services to the people, as well as on developing standards in relation to human resources for health (HRH), medical supplies and infrastructure development. In line with the decentralization policy of the Royal Government of Bhutan (RGoB), health administration and management has been devolved to Dzongkhags over the past few decades. Dzongkhag health offices undertake the deployment of HRH in their respective Dzongkhags.

Practice of medical and health professionals and standards of medical education and training programmes in the country are regulated by the Bhutan Medical and Health Council (BMHC) as empowered by the Medical and Health Council Act 2002 of Bhutan. The Disciplinary Proceedings for Medical Malpractice and Negligence Regulations 2009 lays down the procedures to be followed for complaints and investigation mechanism and disciplinary proceedings against all registered medical and health professionals in Bhutan.

[38] Sharma et al (2017) Measuring universal health coverage: a three-dimensional composite approach from Bhutan
[39] Annual Health Bulletin 2020
[40] Annual Health Bulletin 2020
[41] Annual Health Bulletin 2020

Bhutan has signed up to the International Health Regulations (IHR) which is a binding legal agreement to prevent and respond to acute public health risks that have the potential to cross borders and affect people world-wide and a key intervention is to strengthen the monitoring and surveillance of both patients and diseases. Key surveillance and information systems are in place in Bhutan and include: Dzongkhag Health Information System 2 (DHIS2), National Early Warning, Alert and Response Surveillance (NEWARS), electronic Patient Information System (ePIS), Bhutan Health Information System (BHMIS) and Laboratory Information System.

Health Financing: In 2016, the Royal Government of Bhutan spent approximately 9% of the general government expenditure on health which represents approximately 3.5% of gross domestic product (GDP) and is similar to the other South Asian countries[42]. The total health expenditure as a share of GDP has remained flat lined approximately 3.5-4% over the years[43]. Seventy-five percent of the total expenditure on health is financed by the Government.

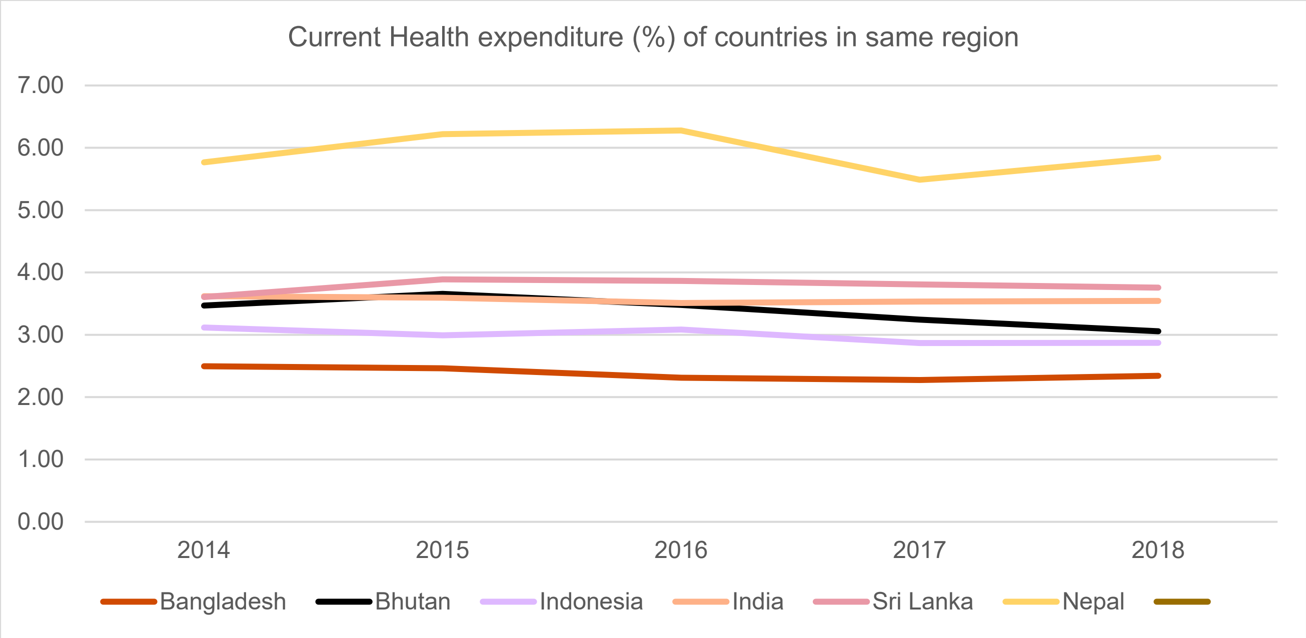


Figure 12: Comparison of current health expenditure[44] as a percentage of GDP among a few comparable South Asian countries (Source: World Bank)

The per capita spending in healthcare has increased over the period of time from Nu. 1400 in 2000-2001 to Nu. 7,512.00 in the fiscal year 2015-2016. The Out-of-Pocket (OOP) expenditure for health, has seen a steady increase from 11% in 2010, to 12% in 2014, and to 20% in 2016. The share of external support has been decreasing over the past few years, with the recent status reported at around 9.5%. However, the Bhutan Health Trust Fund (BHTF) is gaining prominence in Bhutan's healthcare financing and its role is expected to increase in the coming years with the gradual phasing out of the traditional donors[45].

3.3.3. Vector and Water borne diseases in Bhutan

Vector borne diseases prevalent in Bhutan are primarily malaria, dengue and a few isolated cases of chikungunya, Japanese encephalitis (JE), kala-azar and scrub typhus. Bhutan is at the verge of eradicating Malaria; however, the country is observing increased incidence of Dengue especially along the southern border. Waterborne diseases prevalent in urban Bhutan are diarrhoea, dysentery, typhoid, cholera, and skin infections. Poor sanitation is one of the leading causes of diarrhoeal diseases. With improvement in health care system, water and sanitary facilities, diarrhoeal mortality especially in under-five children has reduced drastically in the past few years in Bhutan[46].

[42] Ministry of Health. National Health Accounts, Bhutan Fiscal Years 2014-15 & 2015-16.
[43] Annual Health Bulletin 2020
[44] Level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year. This indicator does not include capital health expenditures such as buildings, machinery, IT and stocks of vaccines for emergency or outbreaks.
[45] HMIS and Research Section, Policy and Planning Division (PPD), (2020), Annual Health Bulletin, Ministry of Health
[46] http://indiaenvironmentportal.org.in/files/Urbanization%20and%20water%20sanitation%20and%20hygiene%20in%20Bhutan.pdf

In the context of the present study, the impact of climate change on climate sensitive vector borne and water borne diseases is being explored. The section below describes the trends observed in key vector borne and water borne diseases reported in Bhutan over the last 5 years.

Malaria: In Bhutan, *Plasmodium* species that cause malaria are *P. falciparum* and *P. vivax. P. falciparum* causes a more severe form of malaria, with higher mortality, while *P. vivax* remains in the body longer, causing a more gradual health deterioration. Epidemics of *falciparum* malaria occur among vulnerable populations where host immunity to malaria is non-existent or poorly developed. Bhutan planned to achieve malaria elimination by 2020, however, the target has been revised due to a sudden surge of locally transmitted malaria cases between June to August 2020[47].

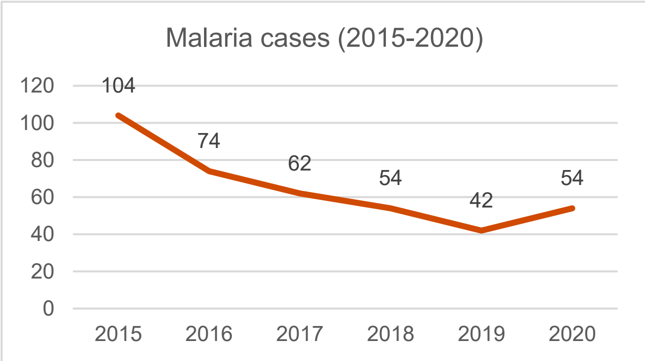


Figure 13: No. of malaria cases in Bhutan (2015-20). Source: MoH

Based on the number of cases reported, there are five endemic Dzongkhags (Chhukha, Samtse, Samdrup Jongkhar, Sarpang and Zhemgang) and seasonal transmission in the Dzongkhags of Dagana, Lhuentse, Monggar, Pema Gatshel, Punakha, Tsirang, Trongsa, Trashigang, Trashiyangtse and Wangdue Phodrang. The national malaria control program is focused on seasonal spraying, passive case finding and treatment and provision of treated mosquito nets free of cost to the households with 100% coverage among risk populations. With the malaria Annual Parasite Incidence (API) below one per 1,000 risk population since 2010, the ministry was prompted to move for malaria elimination by 2018. However, the target could not be achieved due to 54 malaria cases reported in the same year including six indigenous cases. In 2019, there were 42 reported malaria cases with two indigenous, 30 imported, and 10 introduced cases. Sarpang is the Dzongkhag from where maximum number of malaria cases havebeen reported. At present, from the reported cases it is evident that malaria transmission peaks during the months of April and August-September. These peaks were more evident before LLIN (long lasting insecticide net) was introduced as a measure for malaria control by VDCP. As malaria endemic areas are mostly situated along the international border, curbing the cross-border malaria transmission is required to achieve malaria elimination in Bhutan.

Dengue was first diagnosed and reported in July 2004, in Bhutan, when an alarming number of people reported to Phuentsholing hospital with fever and rashes. Although the mosquito vectors *Aedes aegypti* and *Aedes albopictus* were identified and known to exist in the southern regions this was the first time that the disease was suspected and investigated. A total of 2,616 and 2,547 (68 are confirmed cases) suspected dengue cases were reported in 2004 and 2006 respectively. Since then, dengue fever has remained endemic in the town of Phuentsholing during the monsoon period probably due to variation in temperature and precipitation[48],[49].

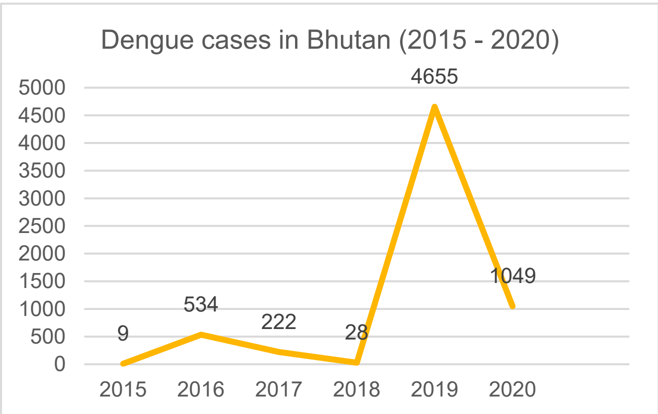


Figure 14: Number of dengue cases in Bhutan

Transmission of dengue is observed mainly along the border with India, particularly along the southern foothills, where the climate is subtropical. The climate near the border with China does not support the survival of mosquitoes and hence does not experience dengue transmission (Tsheten T et al 2021).

The country witnessed a major outbreak in 2019, with total of 4,655 cases. Most of these cases were reported from Phuentsholing Hospital under Chhukha Dzongkhag. A study on the Dengue cases in 2019 revealed that

[47] Penjor, K., Tobgyal, Zangpo, T. et al. Has COVID19 derailed Bhutan's national malaria elimination goal? A commentary. Malar J 20, 20 (2021). https://doi.org/10.1186/s12936-020-03562-5

[48] Sangay Zangmo et.al. Molecular epidemiology of dengue fever outbreaks in Bhutan, 2016-2017. PLOS neglected tropical diseases (2017). https://doi.org/10.1371/journal.pntd.0008165

[49] Dago Tshering, Gyambo Sithey (2008), Climate change and health in Bhutan. The Royal Society for Protection of Nature (RSPN)

that dengue is more common in adults (20-40 years of age) with a mean age of 29.5 years[50]. As quarter of the reported cases were below 20 years of age in the outbreak areas, WHO reported that Phuentsholing could be gradually advancing to a hyper-endemic state where multiple serotypes co-circulate exposing the community to dengue virus at an early age.

Chikungunya: Chikungunya was first was reported in Bhutan in 2012. Chikungunya virus (CHIKV) is spread by the mosquito vectors *Aedes. aegypti* and *Aedes. Albopictus*. *A. aegypti* thrives in urban areas, while *A. albopictus* lives in both urban and rural settings (Meason, 2014). Chikungunya cases were in the range of 0-18 in the last 4 years. These cases were mostly reported from Dzongkhags in the southern border - Samtse (11), Chhukha (5), Samdrup Jongkhar (4), Tsirang (4), Dagana (1).

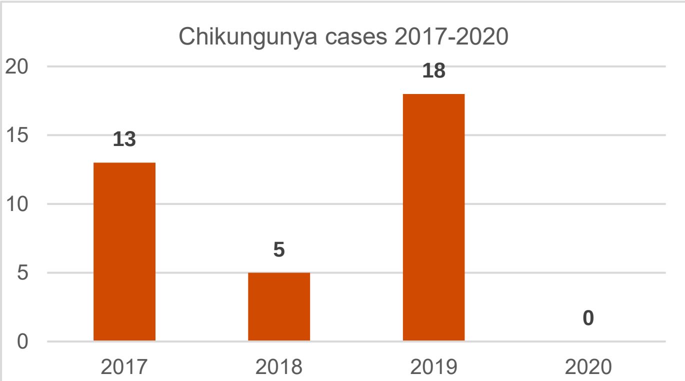


Figure 15: Chikungunya cases in Bhutan (2017-20). Source: RCDC

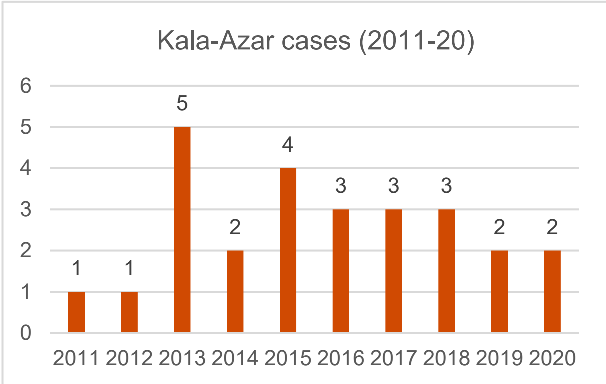


Figure 16: Kala-Azar cases in Bhutan (2011-20) (Source: PwC analysis)

Kala-Azar: Visceral leishmaniasis or kala-azar is caused by *Leishmania donovani* parasites and transmitted by the sand fly, *Phlebotomus argentipes*. A total of 26 cases were reported during the period 2011-2020 as reported by the health center JDWNRH in Thimphu Dzongkhag[51]. The sand flies are not encountered in the southern belt of malaria endemic districts, it often affects the poorest households who often reside in mud-plastered houses, with presence of heaps of cow dung or rat burrows where the vector thrives, and in bushes and vegetation around houses where spraying for malaria may not be done (Environmental Health Program, DoPH 2012).

The low incidence of other vector borne diseases, except for dengue, such as Japanese Encephalitis, Leishmaniasis etc. especially in the malaria endemic areas could be attributed to the vector control and other strategies targeted for malaria. In case there is a limitation of such interventions post malaria elimination and coupled with climate change, there is a likely risk of emergence or heightened transmission intensity of many vector borne diseases. Hence continued surveillance together with a sustainable approach towards integrated vector control should be the norm of the day. However, there is no assurance on the continuity of those control and preventive interventions post malaria elimination. This calls for a continued surveillance together with a sustainable approach towards vector control through community engagement and ownership.

Scrub-Typhus: Scrub typhus, also known as bush typhus, is a disease caused by a bacteria called Orientia tsutsugamushi. Scrub typhus is spread to people through bites of infected chiggers (larval mites). Most cases of scrub typhus occur in rural areas of Southeast Asia, Indonesia, China, Japan, India, and northern Australia[52]. Bhutan experienced outbreaks of scrub typhus in 2009 and 2014. The first occurred during July 2009 in Gedu, a locality in the south-western part of the country. The second outbreak occurred at a remote boarding primary school in 2014, at Athang, Wangduephodrang district in central Bhutan. The data on scrub typhus is collected from the fever surveillance started by RCDC in 2017 in selected sites (Punakha, Tsirang, Wangduephodrang, Trongsa, Samtse, Trashigang, Gedu and Samdrup Jongkhar) in Bhutan[53]. Figure 17 shows the spread of Scrub Typhus across Dzongkhags for the period 2016-20. It can be seen that the highest number of cases were reported

[50] Annual Health Bulletin 2020
[51] VDCP, MoH
52 https://www.cdc.gov/typhus/scrub/index.html
53 RCDC, MoH

in Samtse during the period 2016-2020 followed by Tsirang, Chhukha, Samdrup Jongkhar and Wangdue. A few isolated cases were also reported in Punakha, Trongsa, Trashiyangtse and Trashigang.

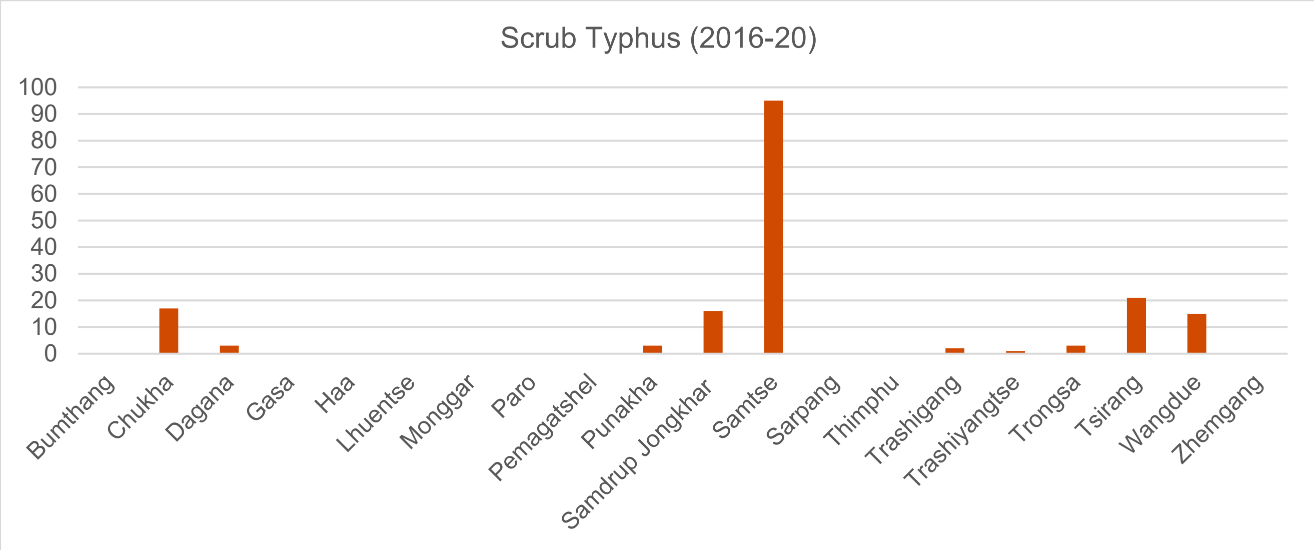


Figure 17: Dzongkhag-wise Scrub Typhus cases in Bhutan. Source: DoPH, MoH

Water-borne diseases: In Bhutan, diarrhoeal disease continue to be a major problem affecting the survival of the children. Diarrhoeal disease had remained one of the top three causes of morbidity in Bhutan for the last one decade and contributed to about 10-15 % of the morbidity cases. Urban centres and particularly those in the warmer sub-tropical zone reported highest diarrhoeal cases because, besides the larger population size, they have large urban congregated settlement. Safe drinking water, hygiene and sanitation are significant concerns in such settings. There is a gradual increase in the diarrhoeal episodes from the month of April to June and then the number of episodes gradually subsides. This increase coincides to the monsoon months characterized by wet and humid weather pattern.

Dzongkhag wise distribution of average diarrhoeal cases during 2016-20 is shown in the figure below. Paro has the highest cases per 10,000 population and Thimphu has the lowest.

However, notable changes were observed in terms of diarrhoea and dysentery cases as they have seen gradual decline over the years and were no longer among the top-ten causes of morbidity by 2019. In the last ten years, the diarrhoeal case has reduced from 65,495 cases in 2009 to 42,472 in 2019 and 25,262 in 2020[54]. Such an achievement can be largely attributed to increased number of ODF Gewogs, access to improved sanitation facilities and access to improved drinking water. The proportion of the population with access to safe drinking water increased from 78% in the 2000 to over 98.6% in 2020[55].

54 Health Management and Information System (HMIS), Ministry of Health. (2020)
55 Annual Health Bulletin, 2020

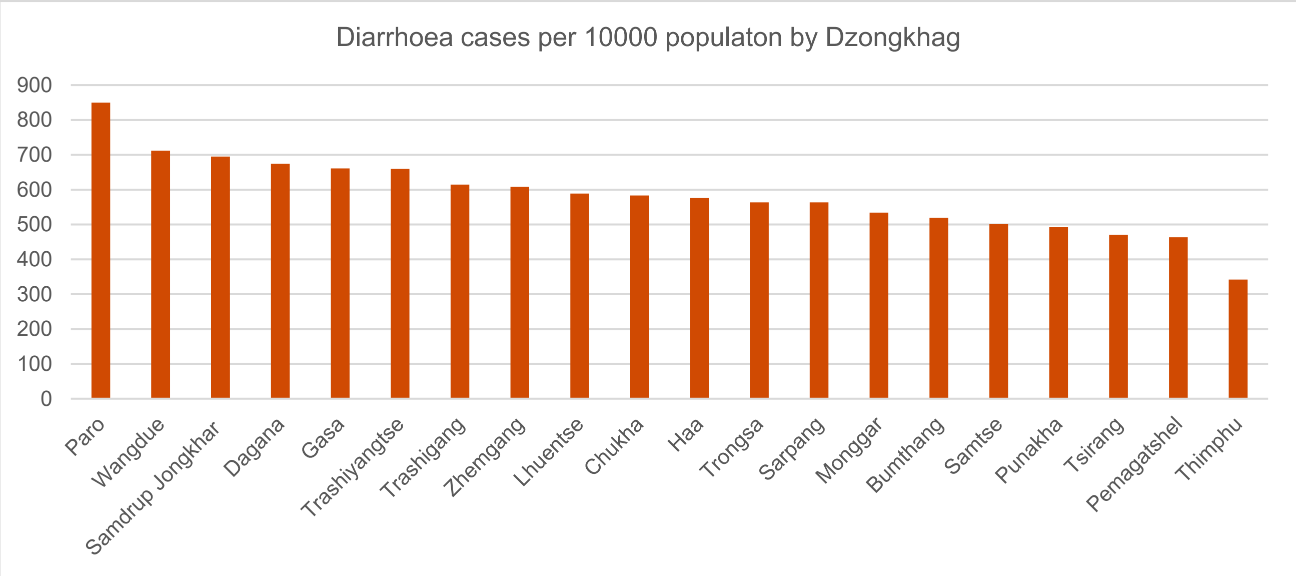


Figure 19: Dzongkhag-wise Diarrhoea cases per 10,000 population in Bhutan in 2019 (Source: PwC analysis)

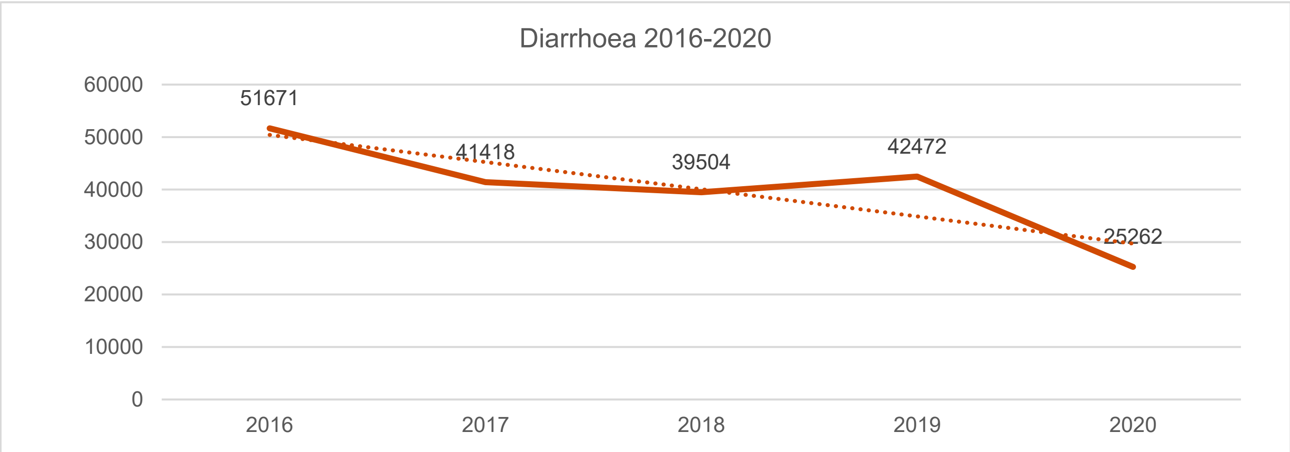


Figure 18: Cases of Diarrhoea (2016-20) (Source: PwC analysis)

Health sector programs and initiatives

VBDs: The Communicable Disease Division under DoPH manages the Vector borne Disease Control Program (VDCP) which was established as National Malaria Eradication Program in 1964 and later renamed as Malaria Control Program. In 2003, the program got named as VDCP as the program extended management over other emerging and re-emerging vector-borne diseases besides malaria. The VDCP is a central program based in Gelephu and mandated to cover the whole country in all twenty Dzongkhags. However, the focus is in the Dzongkhags where the vector borne diseases are more prevalent. The program has moved into an integrated community health approach with all activities well integrated with other diseases at Basic health units (BHUs) at Gewog level and Dzongkhag hospitals at Dzongkhag level. There are trained entomology technicians stationed in southern Dzongkhags of Bhutan, which are endemic to vector borne diseases, to strengthen vector surveillance ad reporting.

A key part of the elimination strategy of Malaria is the 1-3-7 surveillance and response model followed for notification-investigation-prevention. This requires malaria case to be reported within one day, full outbreak investigation to be conducted within three days, and response actions to be completed within seven days. All positive cases are treated and followed up as per the national treatment guideline. All these activities are delivered through primary health care system and reaches the last mile of service delivery in rural pockets. Since one of the concerns is around imported cases from southern Dzongkhags sharing borders with India, cross border collaboration and data exchange is being focussed on, however, optimal results are yet to be achieved.

Dengue case surge jostled the program and highlighted the gaps in capacity to manage such outbreaks in 2019. However, the program has developed clinical case management protocols and built capacity through intensive trainings across the cadres of health workers to manage future outbreaks of Dengue. Since Dengue is more of an urban phenomenon, coordination with Gelephu administration on city planning, waste management, drainage and sanitation work are important and stressed upon by VDCP stakeholders. Similar strategic approach and actions are being taken for Chikungunya and kala azar management as well.

However, the program has staff shortages at field level. The key strategies of VDCP demand intensified surveillance, prevention activities and shortages of human resource is likely to pose grave threat even to sustain the achievements so far made in future. To address the HRH shortages, the program has proposed a diploma course in medical entomology at KGUMSB and was endorsed by the RCSC. The first batch will be commenced in the 2022 academic year. There is also a need to further strengthen the local entomological capacity so that evidence can be generated on vector bionomics.

WBDs: To manage water borne diseases and to promote healthy hygiene practices, Rural Water Supply and Sanitation Programme in Bhutan was officially started in 1974 by Royal Government of Bhutan with technical and financial support from UNICEF. Universal access to improved sanitation and water supply is fundamental to enabling health and wellbeing of the people. Recognizing the importance, Royal Government of Bhutan endorsed the UN General Assembly resolution on the human right to access safe drinking water and sanitation, on 28 July 2010. As per the updated accelerated strategy of 2020, Bhutan is focussing on 'Safe Sanitation' compared to 'Improved Sanitation' and focussing on community led sustainable changes in sanitation challenges.

DoPH manages Rural Sanitation and Hygiene Programme (RSAHP) and has reached 16 out of 20 Dzongkhags through Public Health Engineering Division (PHED). Remaining four Dzongkhags will be covered in 2021. DoPH played a central role in managing water, sanitation and hygiene (WASH) programs until 2020 after which rural water and sanitation was shifted to Ministry of Works and Human Settlement (MoWHS). At present, the Royal Center of Disease Control (RCDC) coordinates quality monitoring of drinking water through health workers, in both urban and rural zones. However, there is scope of strengthening and scaling up water quality monitoring throughout the country.

Though the country has enormous water resources and water supply coverage is increasing but localized water shortage and drying of water sources in many places especially in eastern and southern part of the country is a concern. In addition to issues of quantity, water quality is also becoming increasingly prominent problem with urbanization. This leads to water storage leading to breeding sites for vectors. In view of the issues stated above and also to focus on the Royal Government's strategy on achieving food self-sufficiency, the Royal Government has initiated Water Flagship Program on a war footing to enhance the drinking water supply and irrigation. Of the five Flagship Programs initiated currently, the Royal Government has allocated the largest chunk of budget (Nu. 3000 million[56]) to Water Flagship Program recognizing its importance. Several drinking water schemes have been completed and many are under construction.

3.3.4. Health and disaster risk management in Bhutan

Emergencies triggered by climate variability and extreme events often strain the health system due to resulting morbidity and mortality. In Bhutan, the most significant impact of climate change is seen in the form of Glacial Lake Outburst Flood (GLOF), flash flood and landslides. The Emergency Medical Service Division (EMSD) under Department of Medical Services in MoH, acts as the nodal body for the preparedness and medical responses during disasters and health emergencies. Health Emergency and Disaster Contingency Plan 2016 serves as the guiding document for the preparedness and response of disasters and health emergencies. This document covers various emergency preparedness subjects such as institutional mechanism, roles and responsibilities, communication, and key actions crucial for emergency and disaster management including pre-positioning of supplies. EMSD coordinates with Department of Disaster Management (DDM) under Ministry of Home and Cultural Affairs, the apex body of disaster preparedness and management in the country, to mobilize resources (technical & financial support) from national and international partners during emergencies.

[56] http://flagship.gnhc.gov.bt/water-flagship/

The current surveillance mechanism is an integrated system of indicator-based surveillance (IBS) and event-based surveillance (EBS). There are 22 notifiable diseases and syndromes. Outbreak notification to the RCDC through mobile phone-based messaging has been introduced from Dzongkhag level upwards and feedback of surveillance results is shared back with the Dzongkhags via the web-based National Notifiable Diseases Surveillance (NNDS) system.

A separate information mechanism is instituted for disease outbreaks and health emergencies including disasters. Given that response to large scale emergencies involves multiple sectors and NGOs, the health system has in place a contingency plan where information flow is coordinated with the Department of Disaster Management (DDM). However, for disease outbreaks that require health system response, a team comprising clinicians, laboratory officials, Dzongkhag health officers and epidemiologist/public health expert are dispatched to the affected place for investigation and interventions. The teams share their findings with the MoH and relevant agencies to prevent similar events in the future. Dzongkhag teams consisting of a Dzongkhag health officer, a medical officer and a Health Assistant that manage small-scale outbreaks are the DHRRT (District health rapid response team). For outbreaks of greater magnitudes, posing serious threat to public health, the investigation is coordinated and carried out by the MoH, with the team comprising officials from the RCDC and officials from the DoPH and DoMS called the NHRRT (National health rapid response team).

3.4. Current Climate Impacts on Health

Several important aspects that lead to higher risk and vulnerability of the communities living in the 20 Dzongkhags emerged from the analysis of their climatic and socio-economic profiles. The key findings are presented in the following sub-sections, which correspond to the hazard, exposure, vulnerability (sensitivity and adaptive capacity), and risk-impact aspects of the IPCC's AR5 framework.

Each sub-section answers the following questions:

Subsection	Questions
Hazard	What are the hazards that can lead to higher risk of vector and water borne diseases in different Dzongkhags?
Exposure	Which Dzongkhags are most exposed to VBD/WBDs?
Sensitivity	What are the socio-economic factors that make Dzongkhags sensitive to the diseases?
Adaptive capacity	What are the factors that increase the adaptive capacity to the impacts of climate change?
Risk/Impact	Which Dzongkhags are at risk or impacted most by climate change?

3.4.1. Hazards

Major component 1: Climate variability

Increase in temperature, erratic rainfall patterns and changes in relative humidity can increase the risk of VBD/WBDs through increased geographical range of vectors, favourable conditions for vector and pathogen survival and reproduction. In Bhutan, Lhuentse, Punakha and Trongsa show high standard deviation of Tmax in comparison to other Dzongkhags while Paro and Trongsa show higher standard deviation of Tmin indicating more climate variability.

Chhukha, Dagana and Sarpang show higher climate variability in terms of rainfall and least in Bumthang, Thimphu and Wangdue. Haa, Chhukha, Dagana and Sarpang show a higher standard deviation in terms of relative humidity and Bumthang, Lhuentse show the least.

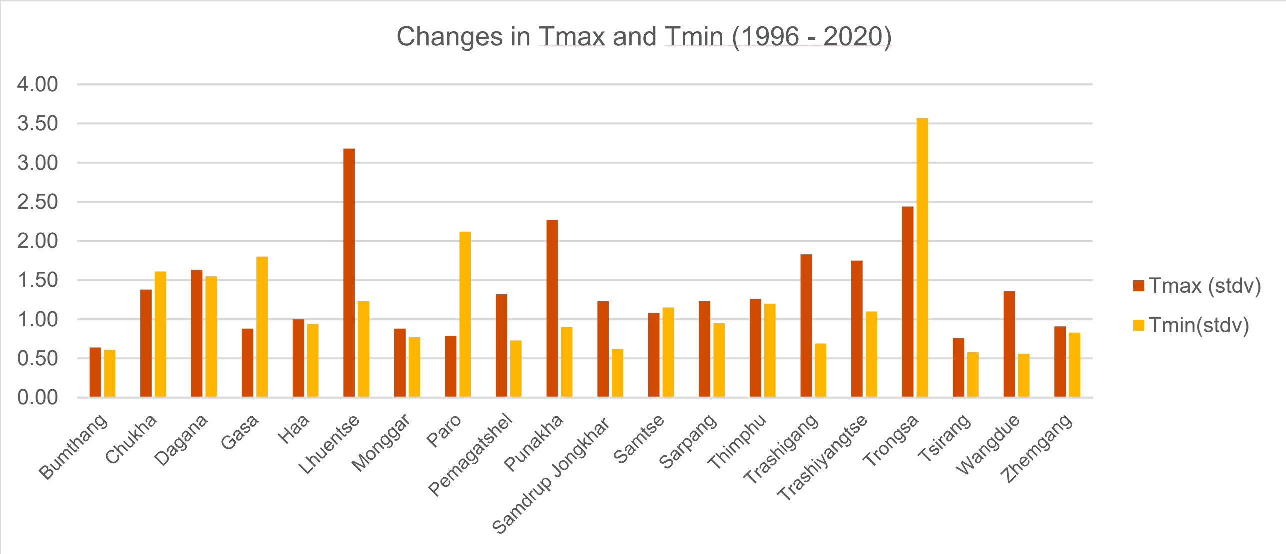


Figure 20: Dzongkhag-wise climate variability - Tmax and Tmin (Source: PwC analysis)

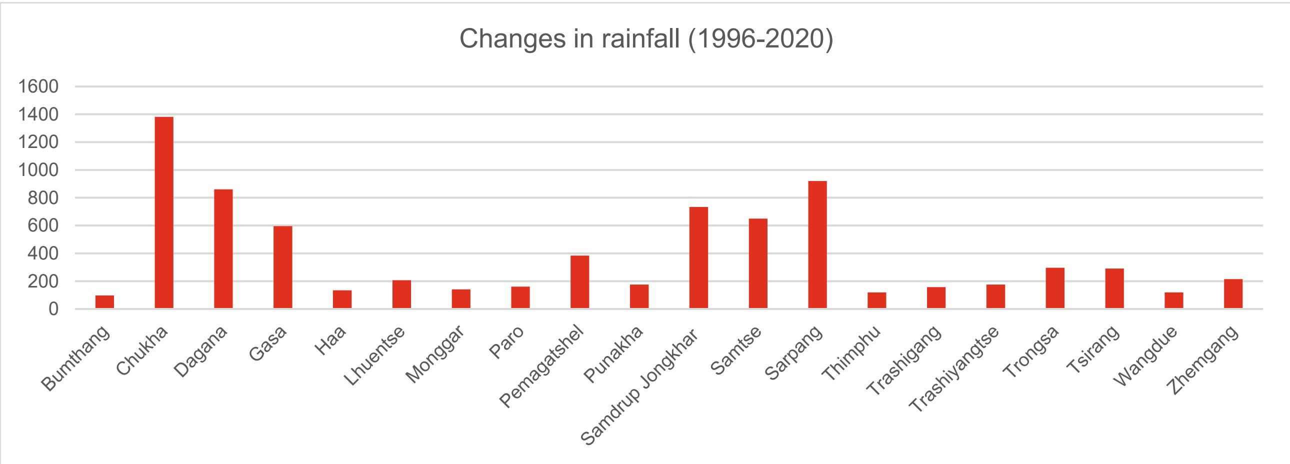


Figure 21: Dzongkhag-wise climate variability – rainfall (Source: PwC analysis)

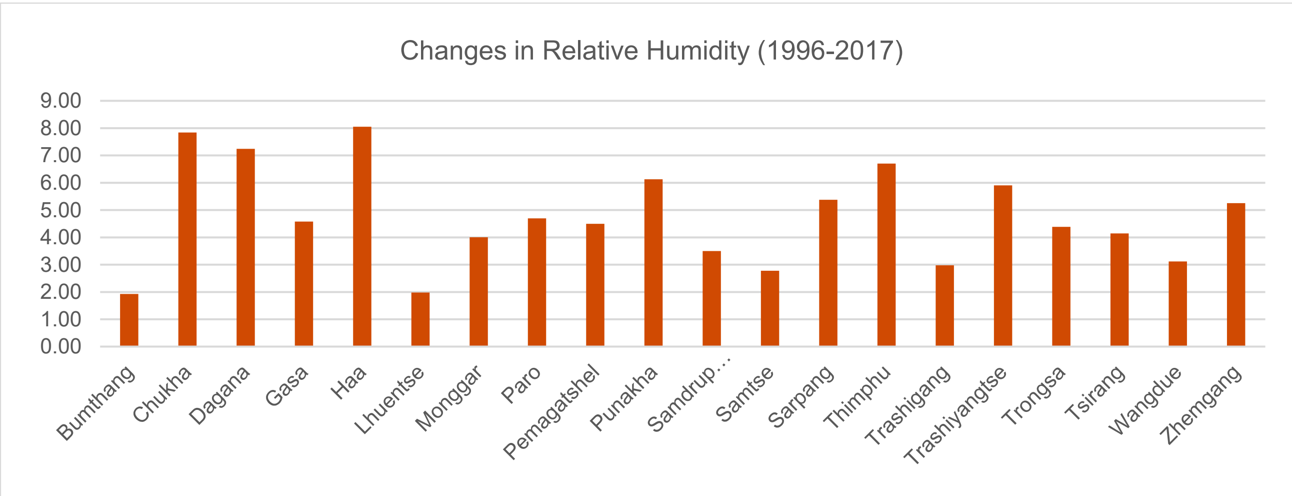


Figure 22: Dzongkhag-wise climate variability - relative humidity (Source: Climate data book of Bhutan, 2018)

Major component 2: Extreme events

Extreme events were assessed based on the impact of floods and GLOFs on land and health facilities between 2006-2019. Punatsang Chhu basin in Punakha has the highest number of glaciers (NCHM, 2018) and glacial lakes than any other major river basins (Bhutan Glacial Lake Inventory, NCHM, 2021). Consequently, it was observed that Punakha was the only Dzongkhag between 2006-19 that experienced a GLOF. The GLOF damaged the Dzongkhag's health facilities and land area. 11 out of 20 Dzongkhags were impacted by floods in the form of damage to land area. These include Samtse, Trashiyangtse, Monggar and Punakha. Some impact was also observed in Samdrup Jongkhar, Trashigang and Trongsa, Bumthang, Chhukha and Dagana. Further, past events also indicate that the rice fields are most affected during the GLOF and flooding which could affect the nutritional status of the people. With one in every five children (under five) affected by chronic under nutrition (21% stunting) under normal condition and 6% wasted (under 5)[57], extreme weather conditions are bound to aggravate this situation[58].

Damage to health services due to extreme events was reported in 11 out of 20 Dzongkhags with the highest impact observed in Punakha, Lhuentse and Chhukha[59].

Major component 3 (VBD/WBD): Vector borne diseases

Data for the period 2015-20 was analysed to understand Dzongkhag-wise cases of vector borne diseases. It was found that 10 out of 20 Dzongkhags in Bhutan experienced cases of Dengue in the past 6 years with Chhukha reporting the greatest number of cases due to an outbreak in 2019[60]. In 2019, Chhukha was the worst-affected Dzongkhag due to Dengue with a cumulative incidence of 607.55 cases per 10,000 population. Sarpang, Thimphu and Trashiyangtse followed next with 40–60 per 10,000 population (Tsheten T et al 2021). Cases of malaria were reported in 14 out of 20 Dzongkhags in the past five years with Sarpang reporting the highest number of cases followed by Chhukha. A total of 36 cases of Chikungunya were observed in Bhutan in the last three years, 11 of them were reported in Samtse Dzongkhag and cases in the range of 1 to 5 were reported in nine other Dzongkhags. A total of 26 cases of Kala-Azar were reported during the period 2011-2020 as reported by the health center JDWNRH in Thimphu Dzongkhag (VDCP). Cases of scrub typhus were reported in 10 out of 20 Dzongkhags and highest no of cases (95) were reported in Samtse during 2016-20.

Overall, on a scale of 0 to 1, normalised values show that Dzongkhags that have the highest incidence of vector-borne diseases are Samtse, Chhukha, Tsirang and Monggar, Bumthang, Gasa and Lhuentse have the lowest.

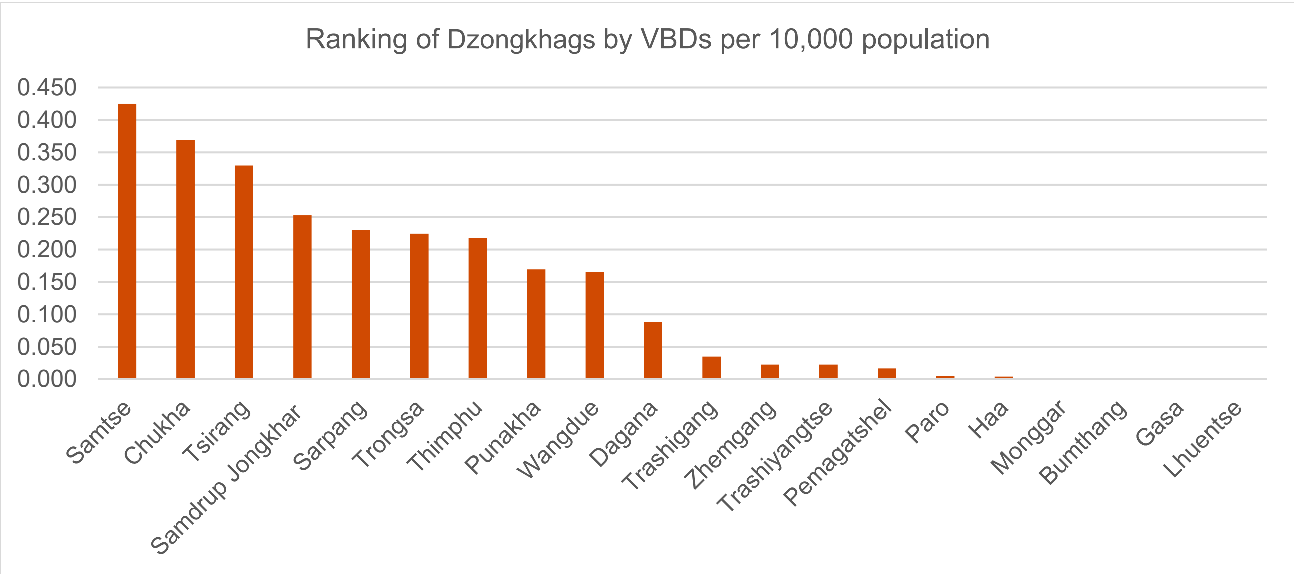


Figure 23: Ranking of Dzongkhags based on annual incidence of VBDs Dengue, Malaria, Chikungunya, Kala-azar and Scrub Typhus (Source: PwC analysis)

The case of Thimphu – Based on consultation with key stakeholders, it was noted that while cases of Dengue are reported in Thimphu, these are attributed to the national referral hospital, where severe dengue patients are

[57] Ajay Tandon et. al. (2020), Assessing public financing for nutrition "what is measure gets managed", World Bank Group
[58] Environmental Health Program, DoPH (2012), Assessment of Health Vulnerability and adaptation to climate change, MoH.
[59] Dzongkhag Disaster reports from 2006-2019, Department of Disaster Management
[60] Dzongkhag level data on Dengue cases, 2015-2020, MoH

referred from other Dzongkhags. VDCP also informed the team that Thimphu does not have suitable climatic conditions for VBD transmission.

As per studies, the dengue vector *Ae. Aegypti* has been reported in Dzongkhags Chhukha, Samtse, Samdrup Jongkhar, and Wandiphodrang while *Ae. albopictus* is reported to be present in 16 Dzongkhags excepting Thimphu, Gasa, Bumthang, and Paro[61]. Consistent with our findings, a recent study on the rising cases of Dengue in Bhutan which finds that low-lying areas and those located along the southern border are at higher risk of dengue, *but the vulnerability extended to higher elevation areas including some areas in the Capital city Thimphu, where the vulnerability score was >0.80 in three sub-districts, namely Kawang, Chang and Mewang during the summer season. The higher risk was mostly associated with relatively high population density, agricultural and built-up landscapes, and relatively good road connectivity*[62]. This shows that as changes in climatic conditions occur, vector-borne diseases spread to higher elevation areas such as Thimphu and parts of Trashiyangtse, leading to an increase in the overall disease risk.

Water borne diseases: Disease data for diarrhoea and dysentery for the period 2016-20 was analysed to understand the Dzongkhag-wise distribution of water borne diseases in Bhutan. Unlike vector-borne diseases that is concentrated in a few Dzongkhags, water-borne diseases are reported from across Bhutan. During 2016-2020, 584 cases per 10,000 population were reported on an average every year with Paro, Trashiyangtse and Trashigang reporting the highest number of cases of dysentery and diarrhoea.

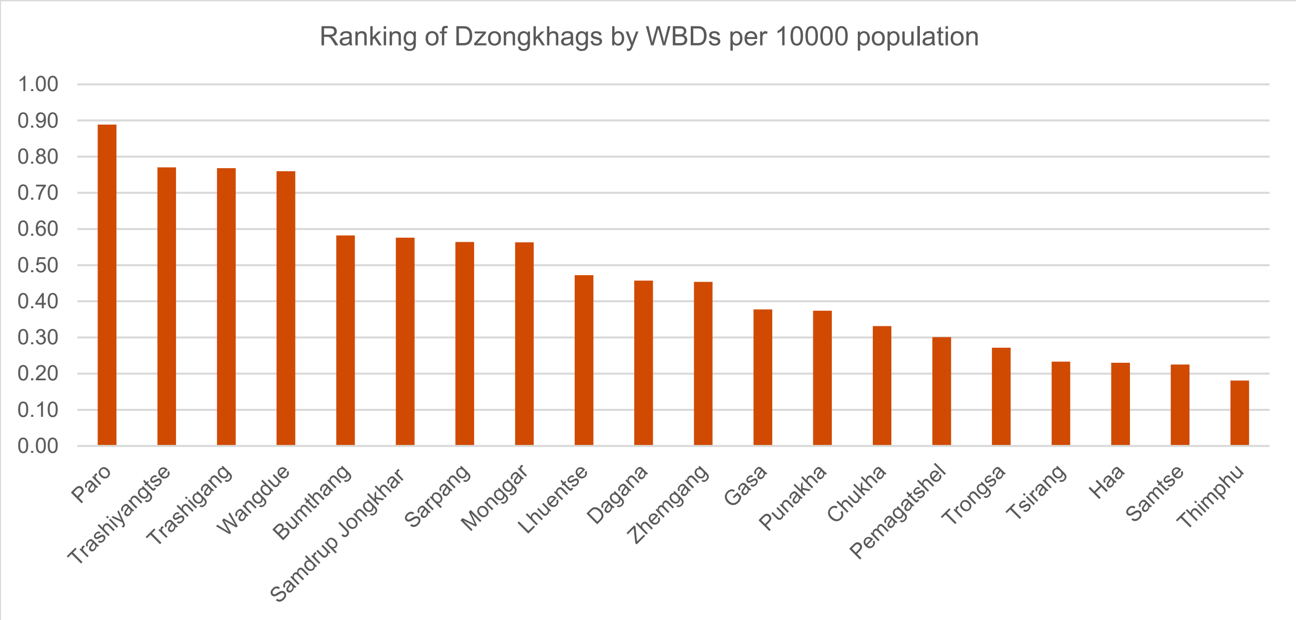


Figure 24: Dzongkhag-wise ranking by WBDs per 10000 population (Scale 0-1) (Source: PwC analysis)

Based on the indicators discussed above, Dzongkhag-wise mapping of hazards with a focus on vector-borne diseases shows that Chhukha, Punakha and Sarpang are most prone to hazards (climate variability, extreme events, VBDs). All three Dzongkhags have high climate variability, Punakha is more prone to GLOFs and Chhukha and Samtse have reported a higher number of VBDs.

[61] Tsheten Tsheten, Angus Mclure, Archie C. A. Clements, Darren J. Gray, Tenzin Wangdi, Sonam Wangchuk, Kinley Wangdi Int J Environ Res Public Health. 2021 Jan; 18(1): 354. Published online 2021 Jan 5. doi: 10.3390/ijerph18010354

[62] Tsheten Tsheten, Archie C. A. Clements, Darren J. Gray, Kinley Wangdi, PLOS Neglected Tropical Diseases. 2021 Feb. Dengue risk assessment using multicriteria decision analysis: A case study of Bhutan

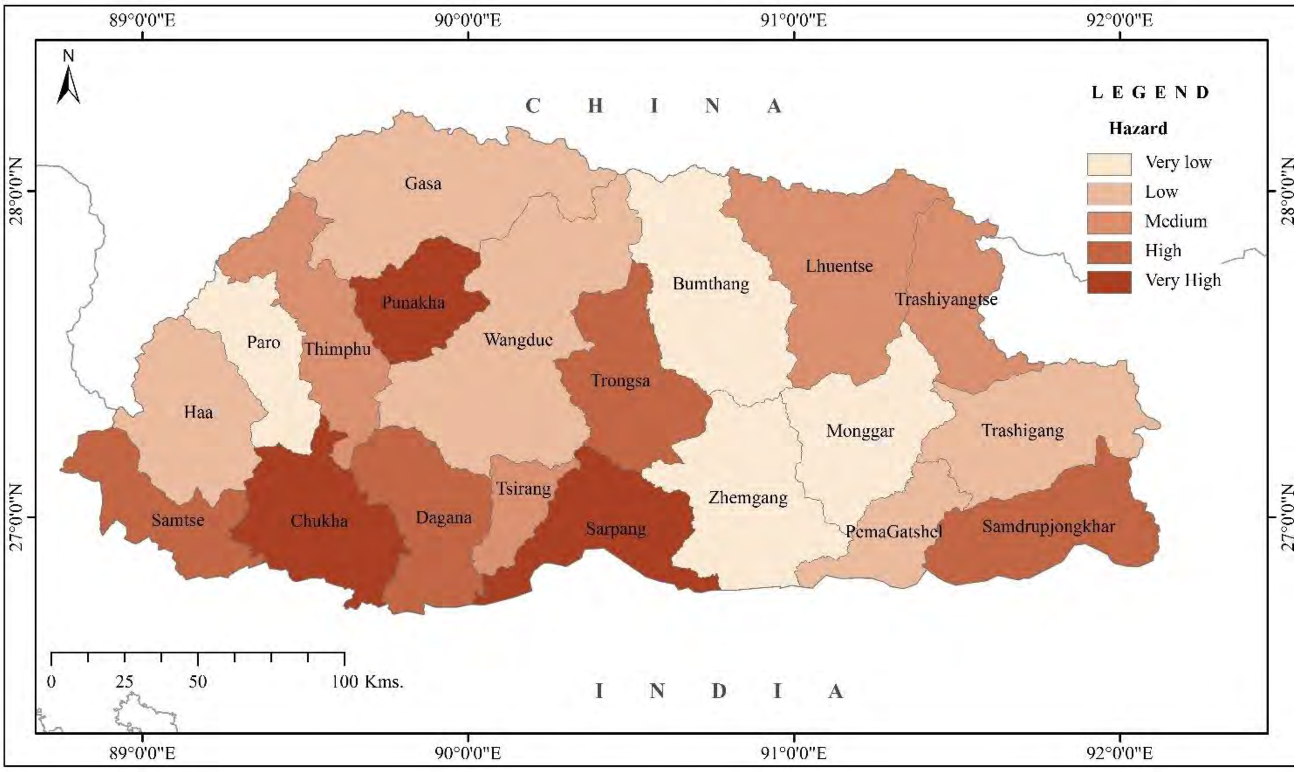


Figure 25: Dzongkhag level hazard map for Bhutan (Focus on VBDs)

Similarly, the hazard map with a focus on waterborne diseases shows that Punakha, Sarpang, Chhukha and Lhuentse are most prone to hazards (climate variability, extreme events and WBDs). This is due to higher climate variability, impact of extreme events and higher cases of WBDs.

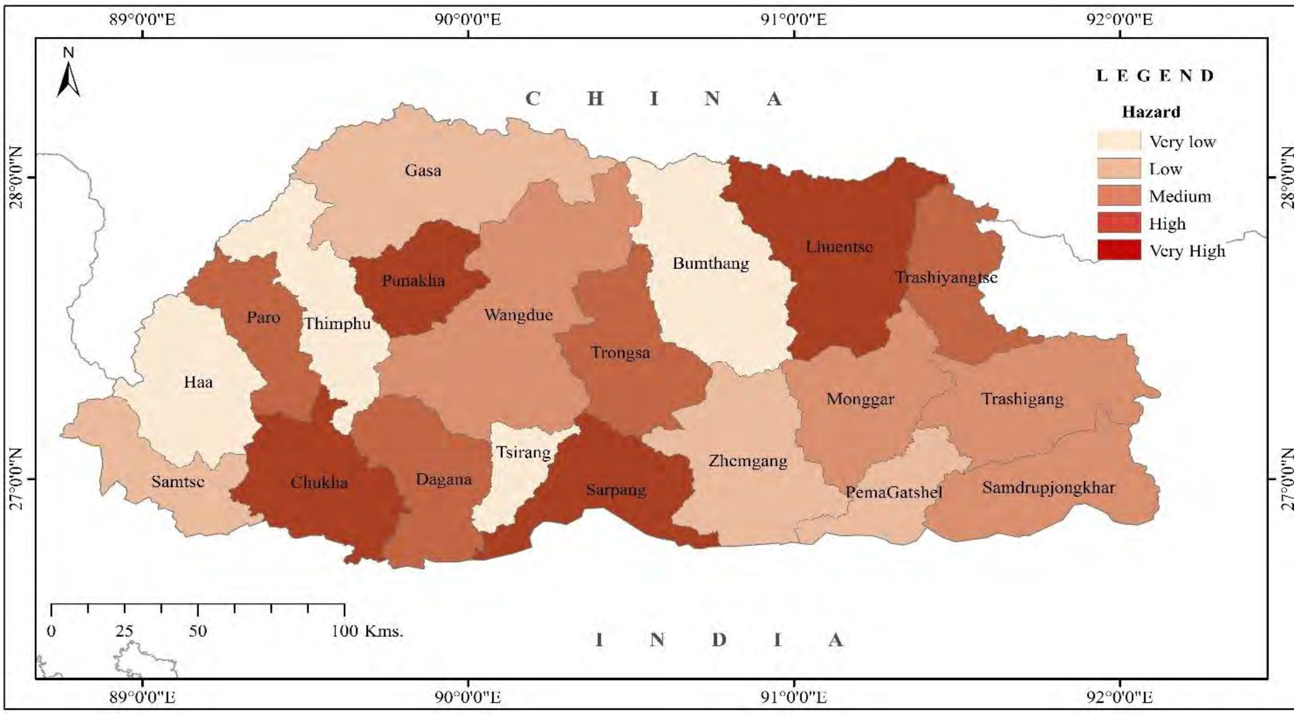


Figure 26: Dzongkhag level hazard map Bhutan (Focus on WBDs)

3.4.2. Exposure

Major component: Population

Sub-component/Indicator: Population density

Density of population (number of people per square kilometre) can influence the opportunities for pathogen-human interaction increasing or decreasing the risk of VBD/WBDs. Bhutan has around 20[63] persons/km^2. Thimphu has the highest population density (67 persons/km^2) followed by Samtse, Chhukha, Paro and Tsirang. Bumthang, Haa, Lhuentse and Gasa have the lowest population density with 4-5 persons/km^2.

The exposure map for vector borne and water borne diseases is as shown below.

Figure 27: Dzongkhag level exposure map to climate risks for VBDs

[63] National Statistics Bureau,2021

Figure 28: Dzongkhag level exposure map to climate risks for WBDs

3.4.3. Vulnerability - Sensitivity

Major component 1: Sub-population groups

Certain sub-population groups such as children[64], elderly[65], female-headed households are at increased risk of climate related illness due to multiple factors including due responsibilities, sector specific employment, lower wages, health issues and poor immunity.

For example, adverse effects of malaria, diarrhoea, and undernutrition are presently concentrated among children, for reasons of physiological susceptibility[66]. Similarly, pediatric age group are at a high risk for morbidity and mortality from Dengue. In Bhutan, Monggar (11,400 children) and Trashiyangtse (5,582 children) have a higher percentage of children and Pema Gatshel (6,512 elderly) and Zhemgang (1,571) have a relatively higher percentage of elderly population.

[64] Children: Age 0-14,
[65] Elderly: Age 65+
[66] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf

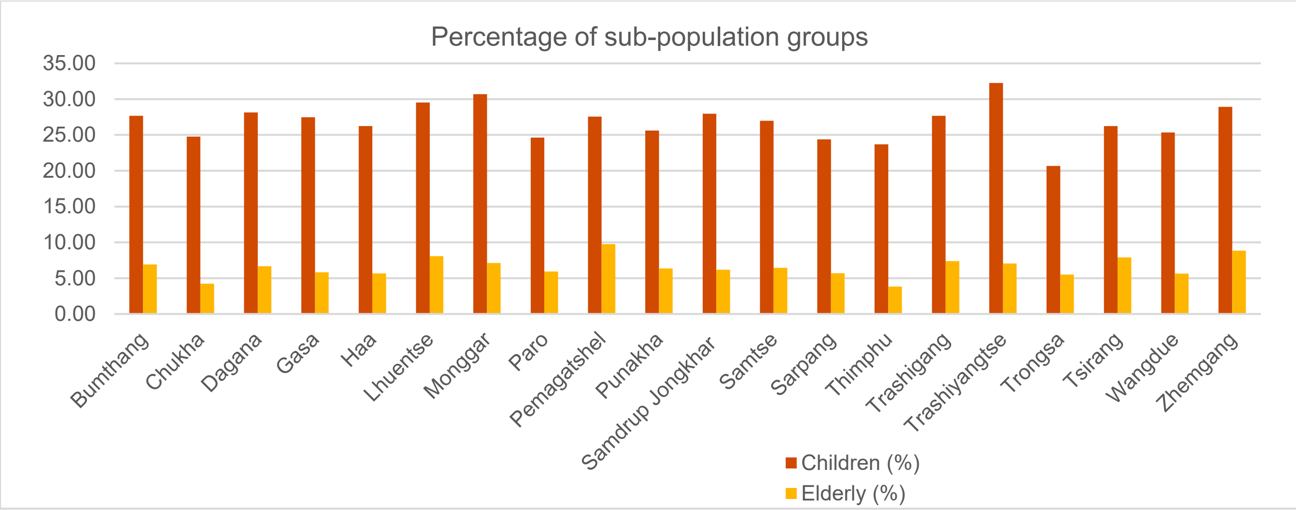


Figure 29: Percentage of children and elderly groups in Bhutan bu Dzongkhag (Source: PwC analysis)

Female-headed households was taken as an indicator to integrate differences in impact of climate change due to gender. In Bhutan, literacy rates disaggregated by gender show that females (59%) have a lower literacy rate than men (73%)[67]. 83% of families headed by male were seen to provide better water supply to the family as compared to female headed families (Public Health Engineering Division, DoPH 2020). Women and girls are also considered to be more vulnerable to extreme events due to lack of awareness, access to information, lower literacy rate etc. Therefore, female headed households may get impacted differently due to extreme events. From a health perspective, BLSS 2017 states that females are also more susceptible to sickness or injury than males, irrespective of area (urban or rural).

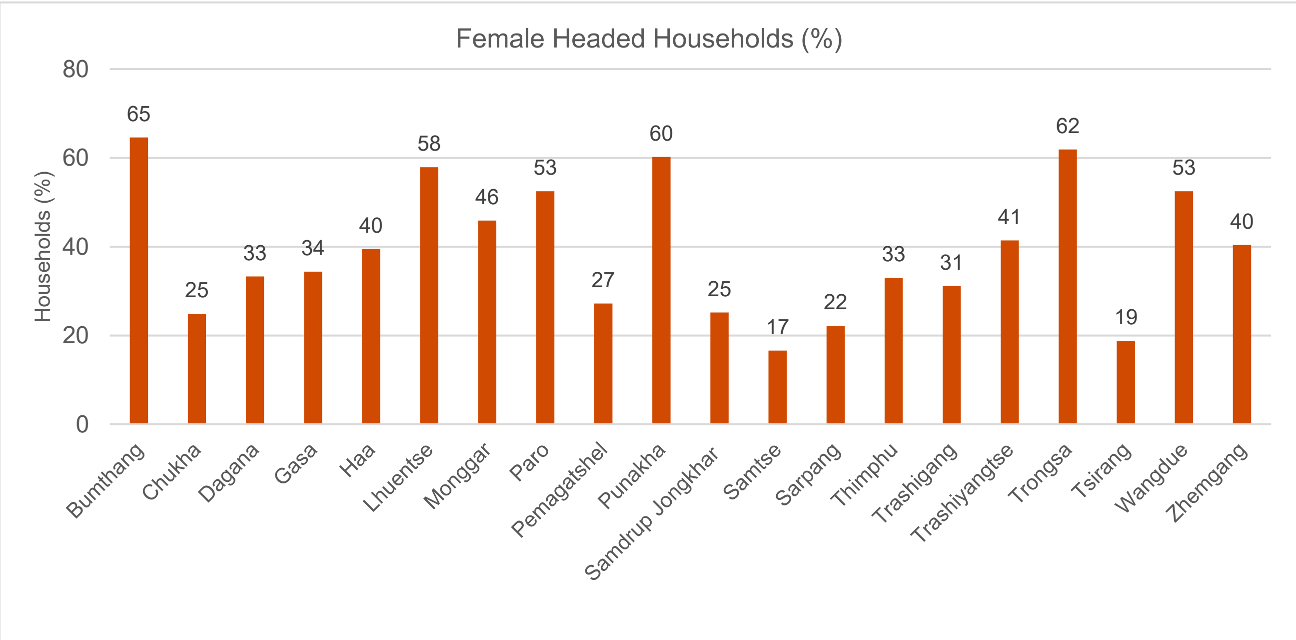


Figure 30: Percentage of female headed households by Dzongkhags (Source: PwC analysis)

Across the Dzongkhags, proportion of female-headed households ranges from 17% in Samtse to 65% in Bumthang. Bumthang, Punakha, Trongsa have the highest number of females headed households in comparison to other Dzongkhags making them more sensitive to the impacts of health and climate change.

Overall, in terms of sub-population groups (children, elderly and female headed households) Bumthang and Lhuentse are found to be more sensitive.

[67] Bhutan living standard survey report, 2017

Major component 2: Economic situation

Weaker sections of society, poorer households may not have adequate resources to protect themselves from the impact of climate change. The Dzongkhag-wise estimation of economic situation of households has been done based on indicators such as consumption poverty rate, dependency ratio and unemployment rate. Among Dzongkhags, Thimphu has the highest unemployment rate with 6%, followed by Paro (2.8%), and Chhukha (2.7%). Consumption poverty rate is highest in Dagana and Zhemgang and dependency ratio is higher in Transhiyangtse, Monggar and Zhemgang. Overall, the economic situation is most sensitive in Dagana and Zhemgang.

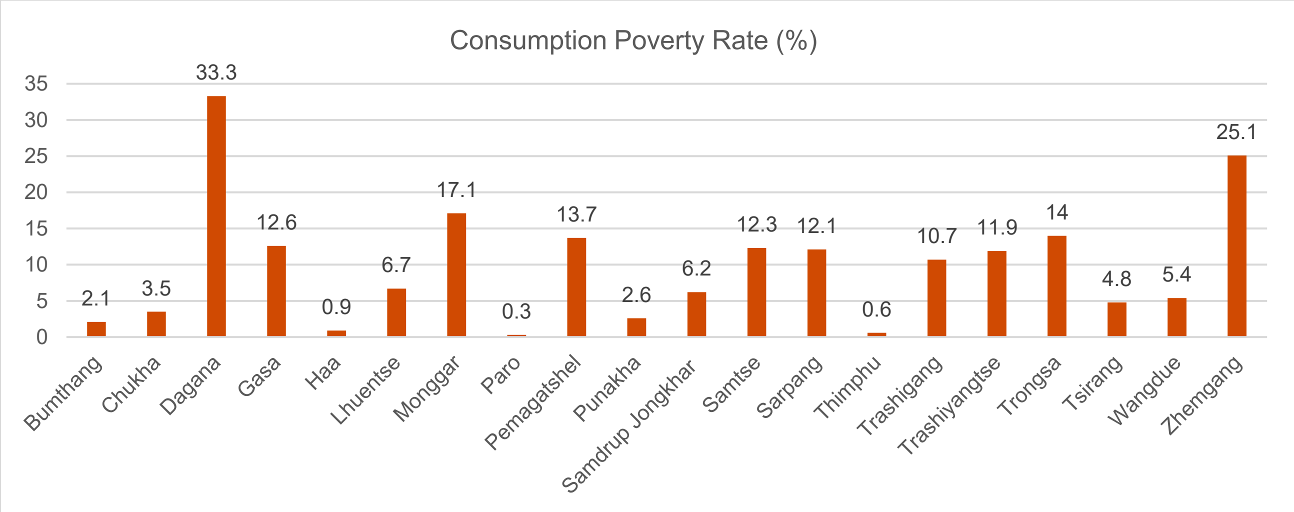


Figure 31: Consumption poverty rate by Dzongkhags (Source: PwC analysis)

Major component 2: Urbanisation and population displacement

Unplanned urbanisation can lead to areas with increased density of human hosts. Poor sanitation and water supply in developing countries have been associated with higher rate of disease transmission at same vector density and create more vector-breeding sites. Between urban and rural areas in Bhutan the BLSS 2017 report finds that the incidence rate of sickness or injury is higher in urban areas (13.3%).

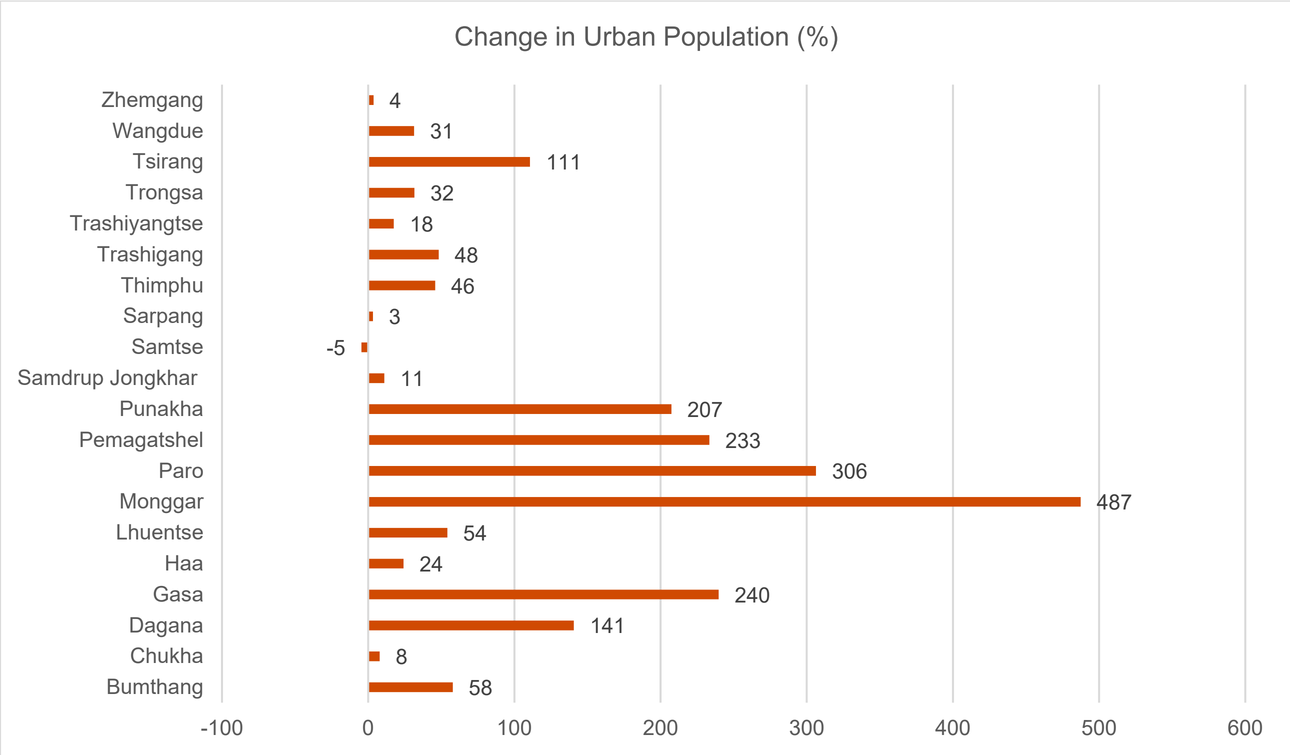


Figure 32: Dzongkhag-wise change in urban population in Bhutan (Source: PwC analysis)

In Bhutan, the percentage increase in urban population between 2005-17 was observed to be the most in Monggar and Paro. Percentage of rural-urban migrants are highest in Chhukha, Samdrup Jongkhar, Sarpang and Thimphu.

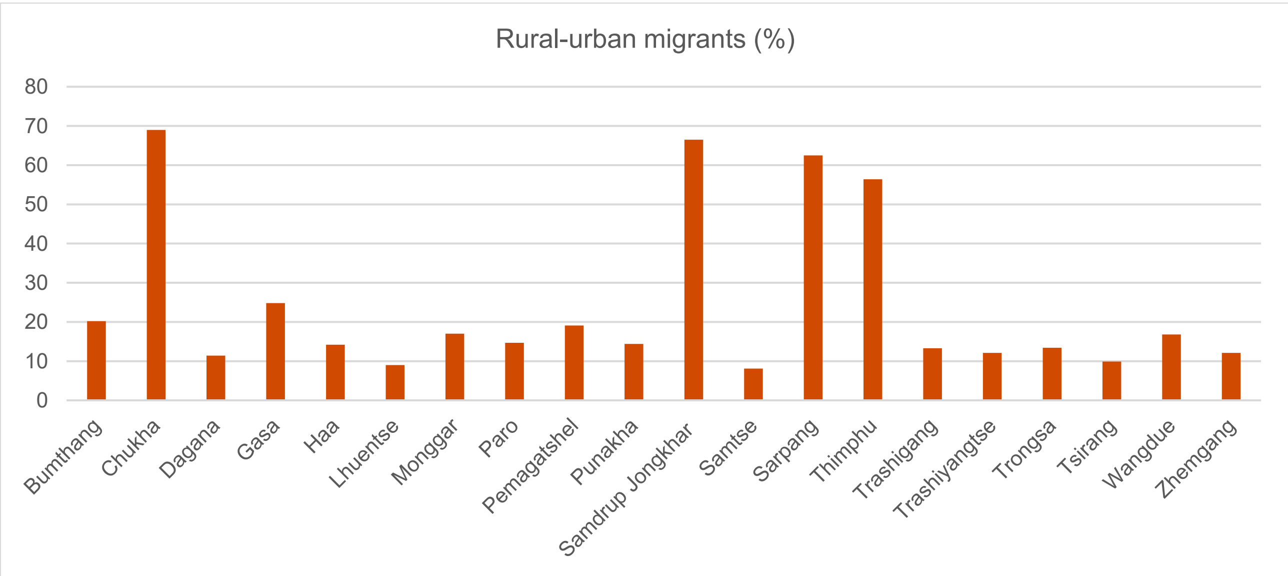


Figure 33: Percentage of rural-urban migrants by Dzongkhags in Bhutan (Source: PwC analysis)

Moreover, climate change may lead to more population displacement and migration in the future[68] and suitable climatic conditions may increase transfer of pathogens between regions of endemicity and disease-free

[68] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap12_FINAL.pdf

regions[69]. Tourism, trade and travel are also factors that add to the overall risk[70]. Percentage of tourist arrivals is highest in Paro followed by Thimphu and Punakha.

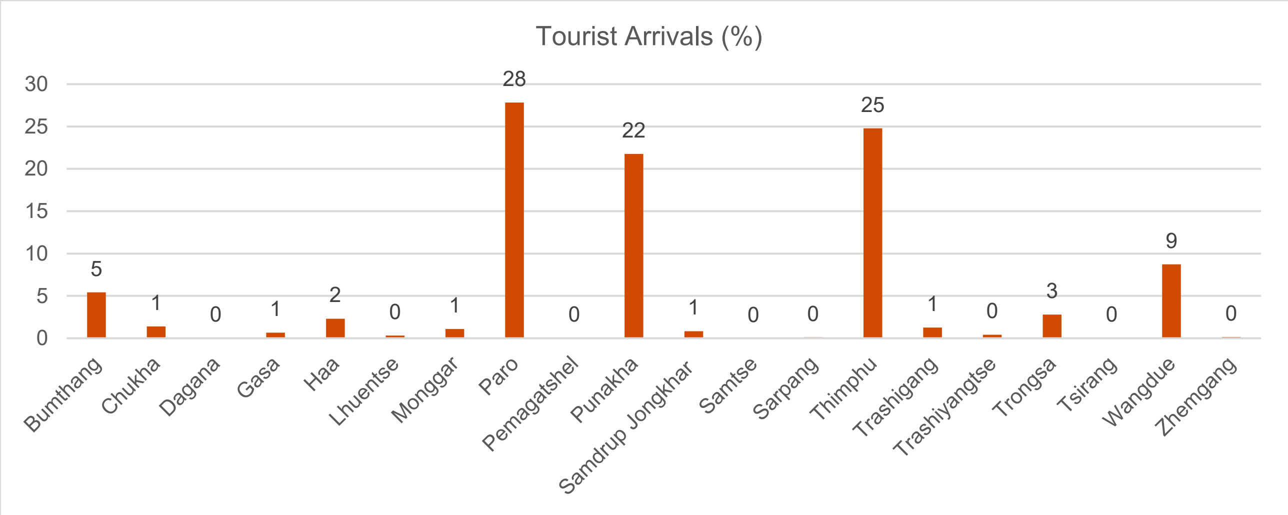


Figure 34: Percentage of tourist arrivals by Dzongkhags in Bhutan (Source: PwC analysis)

Major component 4: Health issues

Dzongkhags with higher levels of food insufficiency, pre-existing health issues and poor performance on health-related indicators are more sensitive to climate impacts. It is expected that health losses due to climate change-induced undernutrition will occur mainly in areas that are already food-insecure[71]. Food insufficiency (i.e., not enough food to feed all household members) is highest in Dagana (565 households), Samtse (1,447 households) and Wangdue (840 households) adding up to a total of 2,852 households. Within these Dzongkhags, Lhamoi Dzingkha Town and Kana geog in Dagana, Tading and Namgyalchhoeling geogs in Samtse, Wangdue Phodrag Town and Daga geog in Wangdue experience the highest food insufficiency[72].

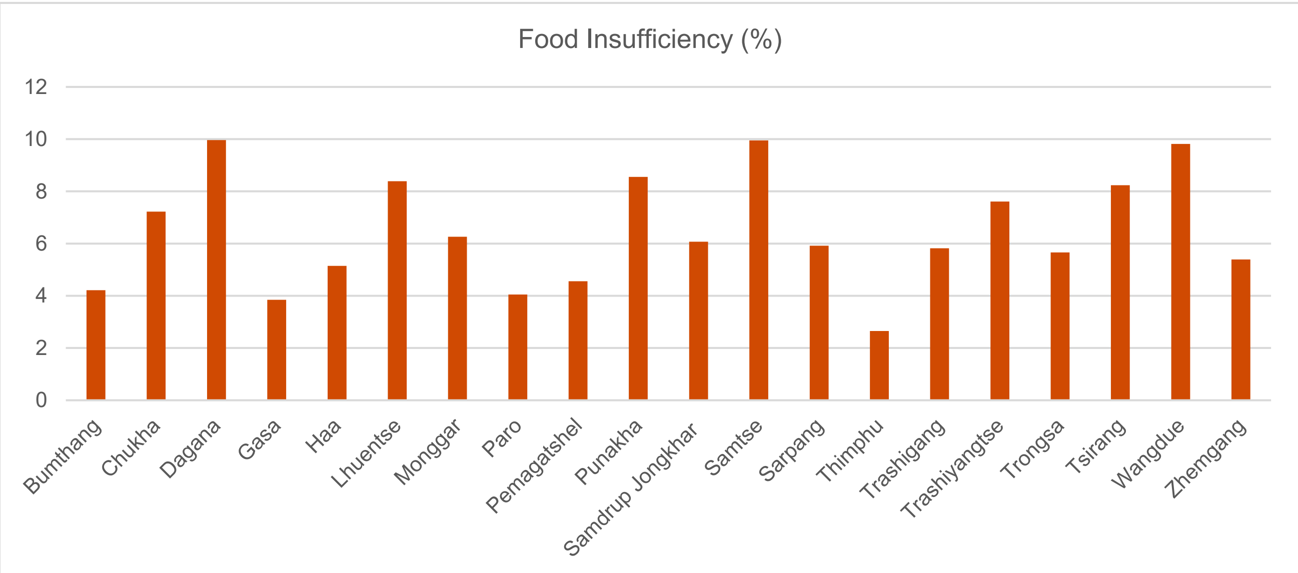


Figure 35: Percentage of food insufficiency by Dzongkhag in Bhutan (Source: PwC analysis)

[69] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC321469/
[70] https://www.nature.com/articles/s41590-020-0648-y
[71] https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf
[72] Population and housing census of Bhutan, National Statistics Bureau of Bhutan, 2017

Infant mortality and child mortality rates are important measures of the health status of a population. Infant mortality rate is highest in Gasa and Wangdue Dzongkhag and lowest in Thimphu and Paro.

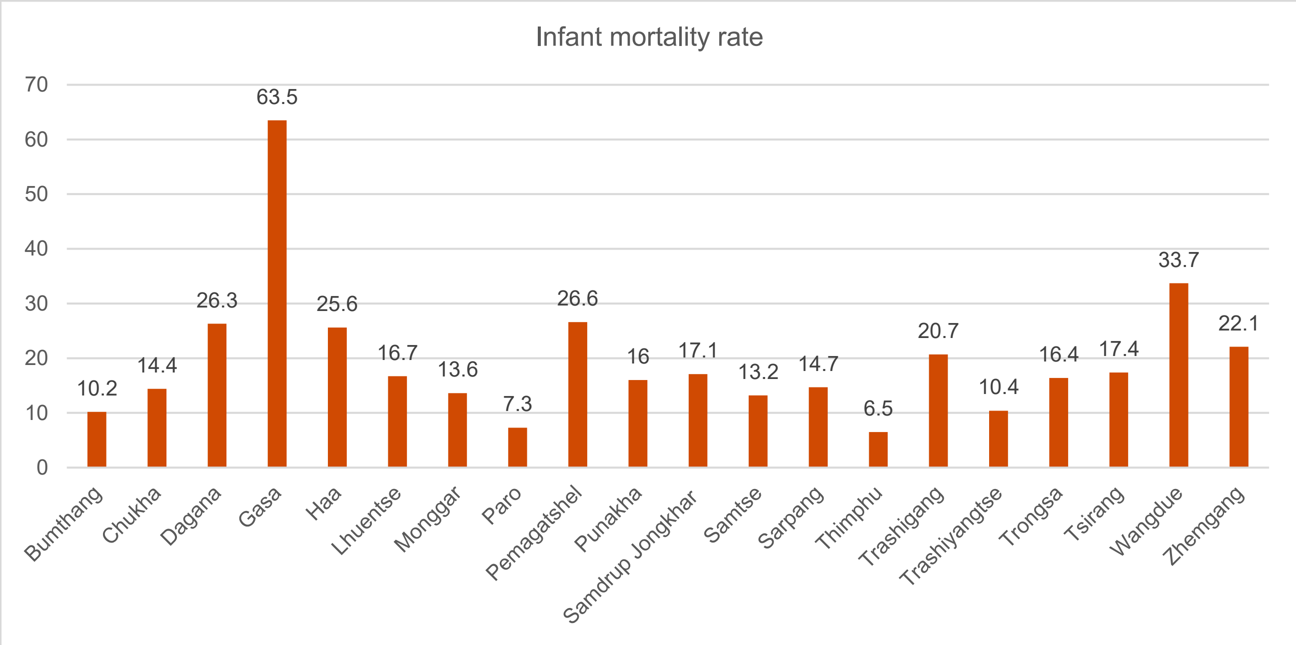


Figure 36: Infant mortality rate by Dzongkhags in Bhutan

Major component 5: Changes in ecosystem

With changes in land use comes fragmentation of habitats, loss of biodiversity and alteration of existing vector-host-parasite relationships. This can lead to changes in the physical environment for vectors and hence affect patterns of disease[73]. Insights from stakeholder consultation with VDCP further confirmed this relationship. Malaria was found more on the forest fringes and kala-azar was found in places with hydro-power projects (VDCP, MoH).

Across Dzongkhags, in terms of changes in forest cover, it was observed that Trongsa had the highest negative change in forest are while Pema Gatshel saw a positive growth.

[73] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC321469/

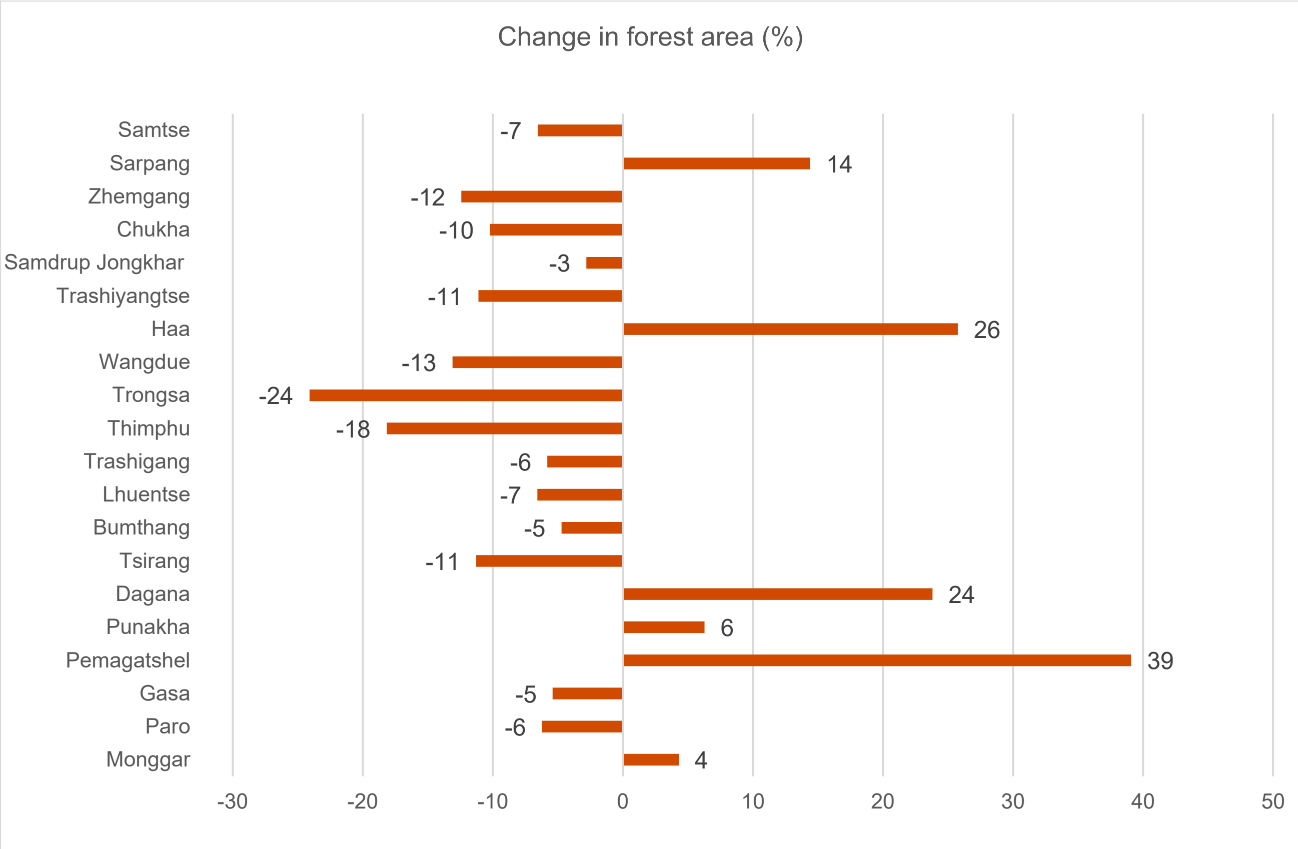


Figure 37: Percentage change in forest area by Dzongkhag in Bhutan (Source: PwC analysis)

The overall sensitivity Dzongkhag level map for vector-borne diseases shows Dagana, Punakha, Monggar and Zhemgang to be the most sensitive Dzongkhags while Trongsa is least sensitive.

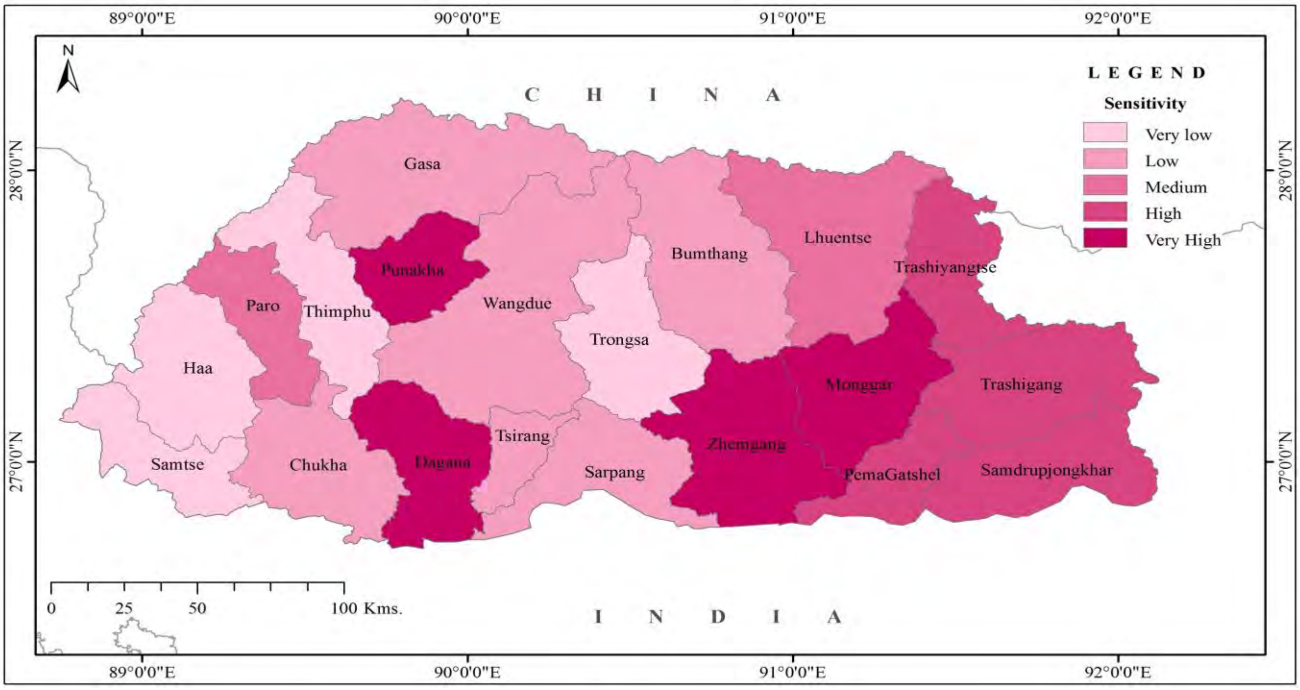


Figure 38: Dzongkhag-level sensitivity map for VBDs in Bhutan (Source: PwC analysis)

The overall sensitivity Dzongkhag level map for water-borne diseases shows higher sensitivity in the Eastern Dzongkhags of Bhutan and Dagana on the Southern border.

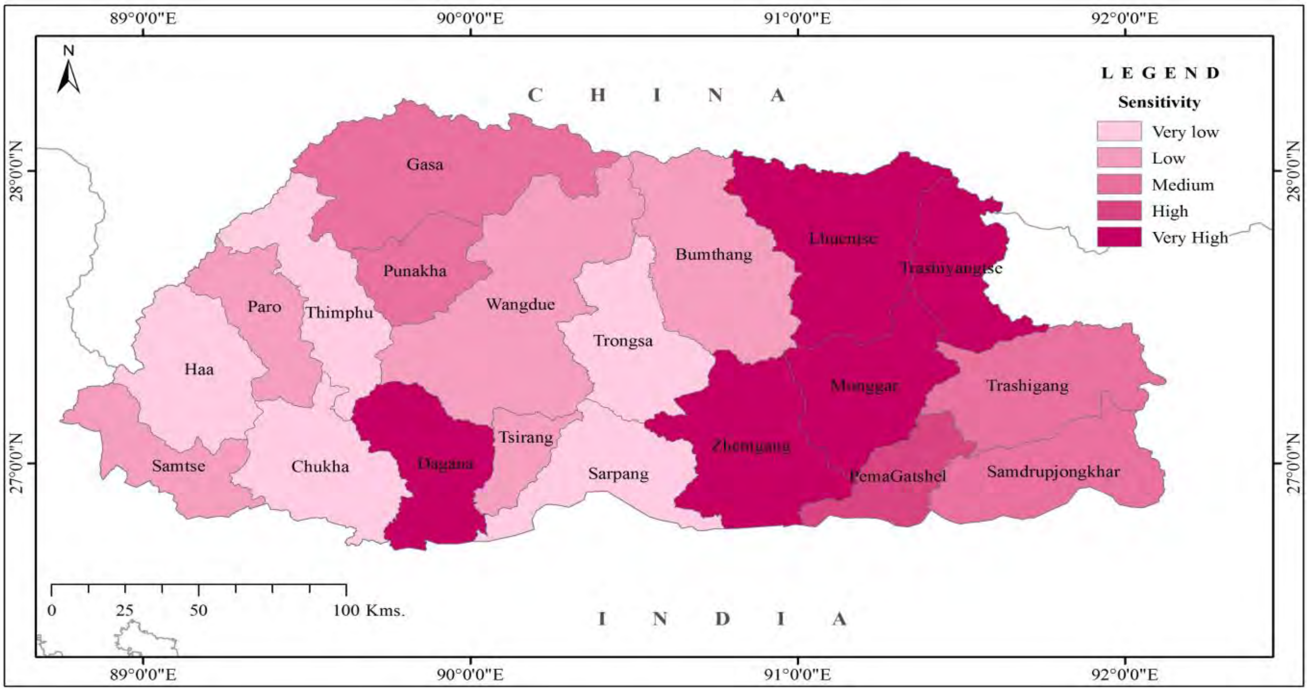


Figure 39: Dzongkhag-level sensitivity map for WBDs in Bhutan (Source: PwC analysis)

3.4.4. Vulnerability - Adaptive capacity

Major component 1: Knowledge

The average literacy rate in Bhutan is around 71.4% (National Statistics Bureau 2017). Literacy rate here is taken as a proxy for knowledge to understand whether the population has the expertise or knowledge which might aid adaptation. The highest literacy rate is observed in Thimphu Dzongkhag at 83.9%. There is marked difference in the literacy levels between the male and female populations in Bhutan, with 73% of the male population literate as compared to 59% of the female population (National Statistics Bureau 2017).

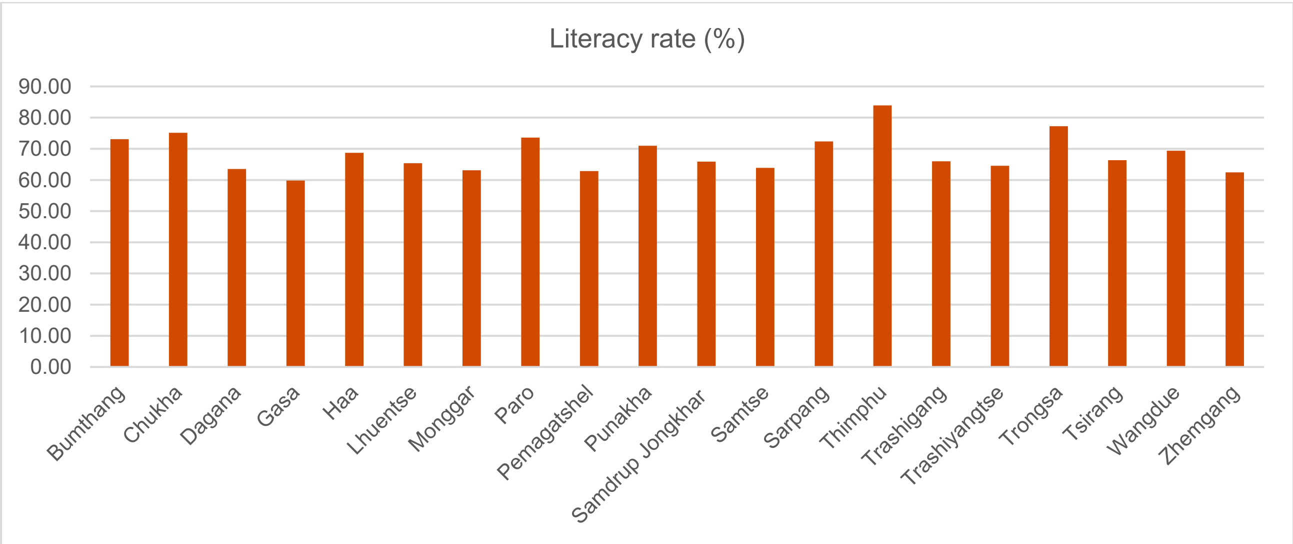


Figure 40: Literacy rate (Source: PwC analysis)

Major component 2: Access to services

The condition of the physical infrastructure (provision of water for drinking, sanitation) that supports human settlements play an important role in determining the risk of the disease. In Bhutan, the focus up until a few years back was on *improved* sanitation and hygiene which meant putting the structures in place which may or may not be *safe*. With SDG goals, the focus shifted to *safety* of water source and outlet and similarly for sanitation. This meant use of pour flush toilets and regular monitoring of water sources by RCDC. The DoPH considers this shift in focus to have improved the quality of water and sanitation services thereby contributing to the decline in water-borne diseases. An impact study carried out in four Dzongkhags (Pema Gatshel, Monggar, Samdrup Jongkhar, Lhuentse) by the rural sanitation and hygiene program shows that water contamination was the primary cause of Diarrhoea and Dysentry and the declining trend of diseases was seen in areas where the rural sanitation and hygiene program had reached. Consultations with the DoPH also revealed issues of localized drying up of water resources in the Eastern Dzongkhags where water supply is dependent on streams which is fed by monsoon rain. This was cited as a possible contributing factor for inadequate hygiene in rural communities. The rural sanitation and hygiene program under the DoPH has covered 16 Dzongkhags with a few last mile households that did not get covered due to inadequate income sources and female headed households. The four Dzongkhags that did not get covered include Thimphu, Paro, Gasa and Bumthang (DoPH, MoH).

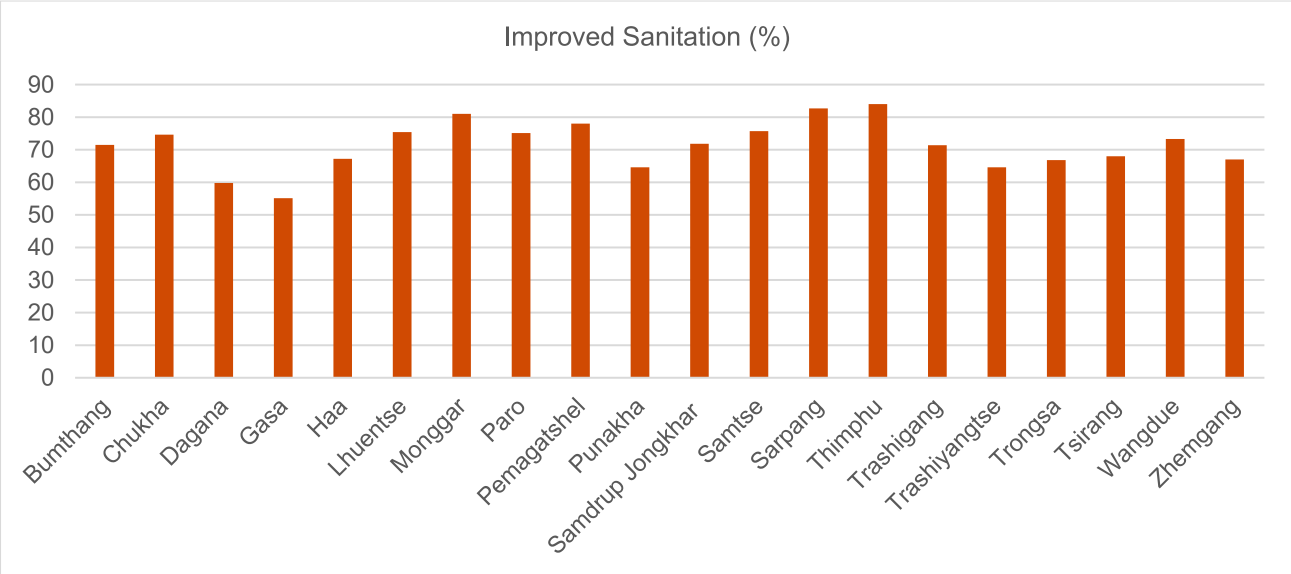


Figure 41: Improved Sanitation (%) by Dzongkhag

Access to sanitation facilities is at 71.8% in Bhutan. These deficits impact overall community hygiene while they also bear gender specific repercussions. Nearly one third of the schools were found to have no separate toilets for girls, around 47% women missed school because of lack of water and clean toilets. The poor sanitation facilities and consequent inadequate personal hygiene can lead to serious skin infections, worm infestations and diarrhoea[74].

[74] https://www.unicef.org/bhutan/wash-water-sanitation-and-hygiene/maternal-newborn-and-child-health/wash-water-sanitation-and-0-0-1

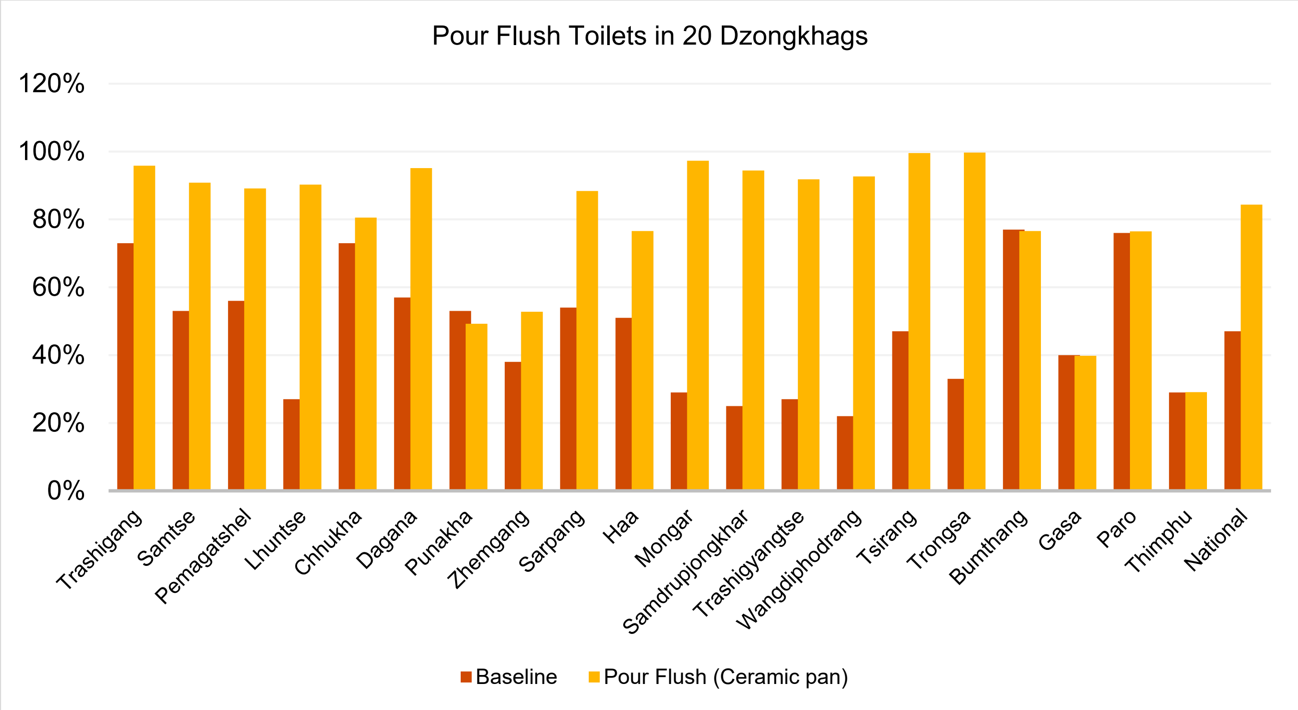


Figure 42: Pour flush toilets in 20 Dzongkhags. Source: PHED, DoPH programme reporting.

Important progress has also been made against vector-borne diseases, through a combination of poverty alleviation and socioeconomic development, increased access to health services, larger scale of coordinated control programmes, and the development and deployment of more effective interventions.

Ranking of Dzongkhags based on access to basic facilities shows Thimphu has better access while Gasa has the poorest. Percentage of households with improved sanitation facilites is only 55% in Gasa as opposed to Bhutan's average of 71.39%[75]. Zhemgang also ranked much lower due to poor coverage of drainage and sanitation.

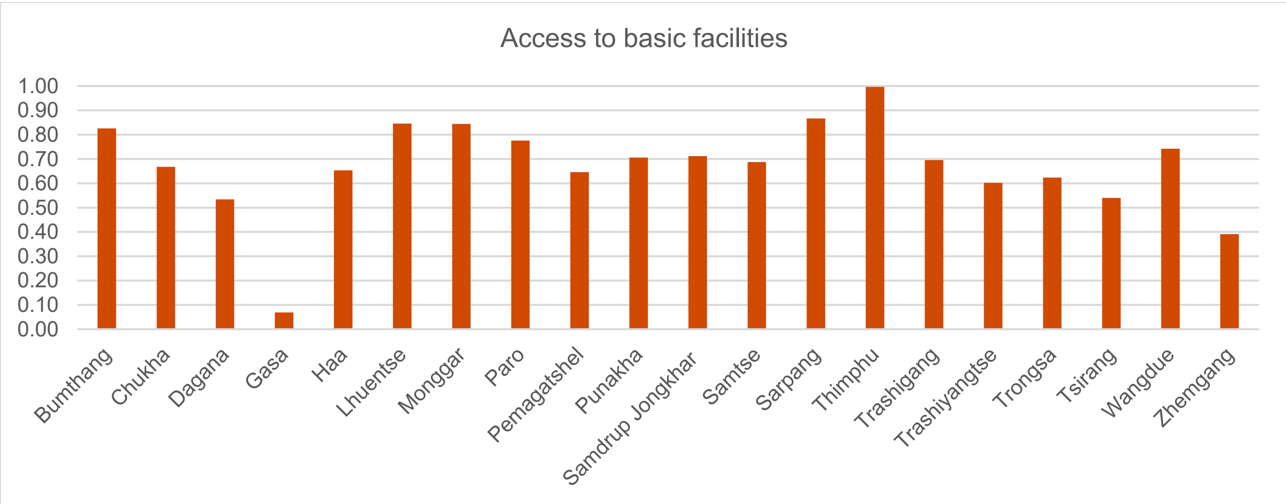


Figure 43: Ranking of Dzongkhags based on access to basic facilities by Dzongkhag in Bhutan. Scale (0-1) (Source: PwC analysis)

Major component 3: Health Services

Availing health services can indicate awareness and accessibility. As per the data, majority (90.1%) of the households have availed health services. Dzongkhag ranking of health services measured in terms of people employed in health services, health services availed and health facilities per 1,000 population shows Zhemgang

[75] PHCB 2017, NSB

has better health services while Gasa and Samtse rank much lower. Chhukha also ranks relatively lower considering that it has a high number of cases of vector borne and water borne disease.

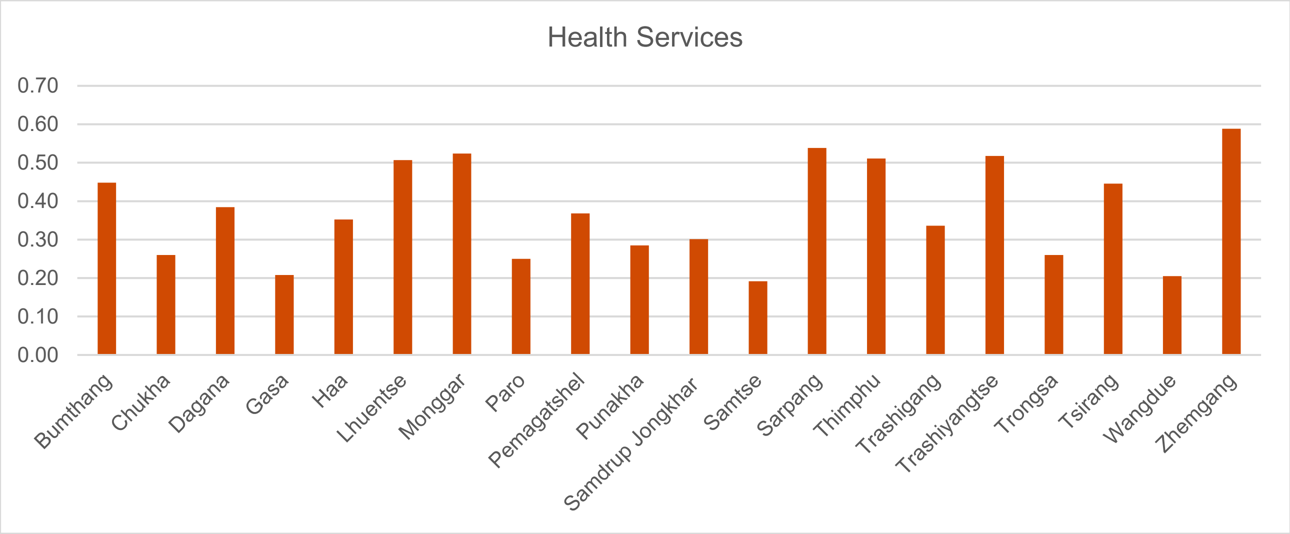


Figure 44: Ranking of Dzongkhag on Health services (Scale: 0-1) (Source: PwC analysis)

The overall adaptive capacity map for VBD/WBDs shows Thimphu, Sarpang and Bumthang have higher adaptive capacity than other Dzongkhags. Zhemgang, Gasa, Dagana, Tsirang have lower adaptive capacities.

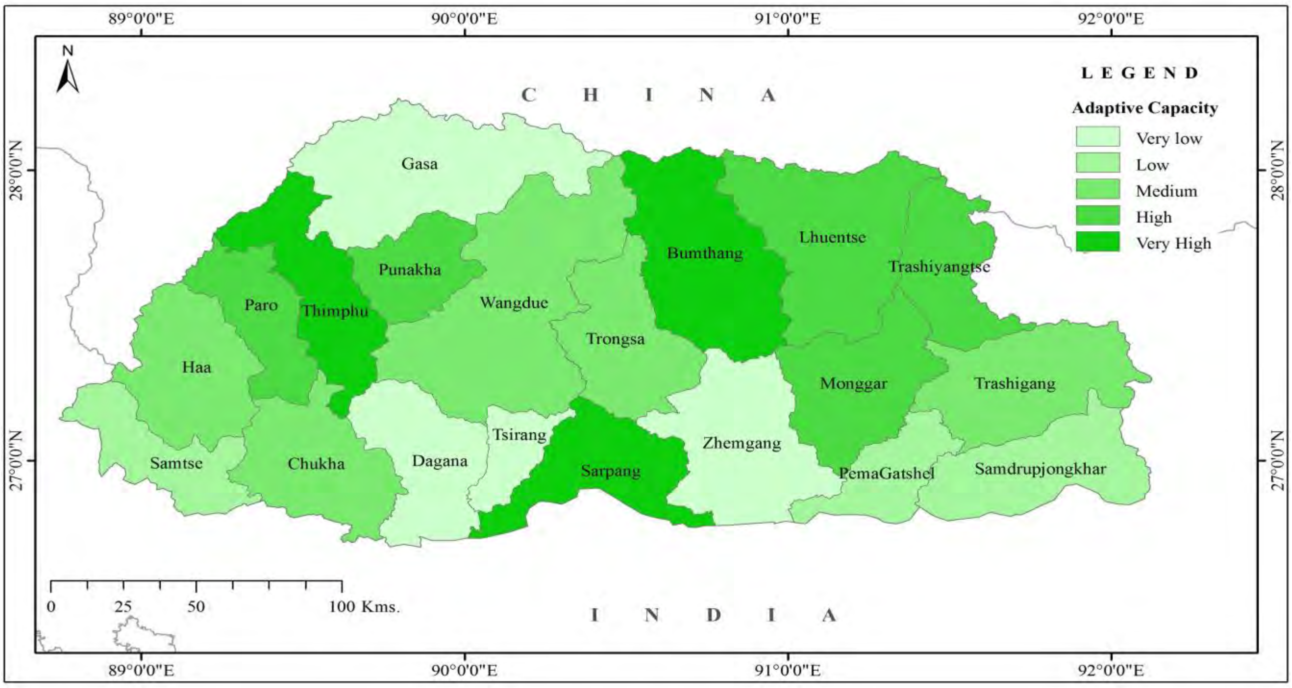


Figure 45: Dzongkhag-level adaptive capacity map – Focus on VBD in Bhutan (Source: PwC analysis)

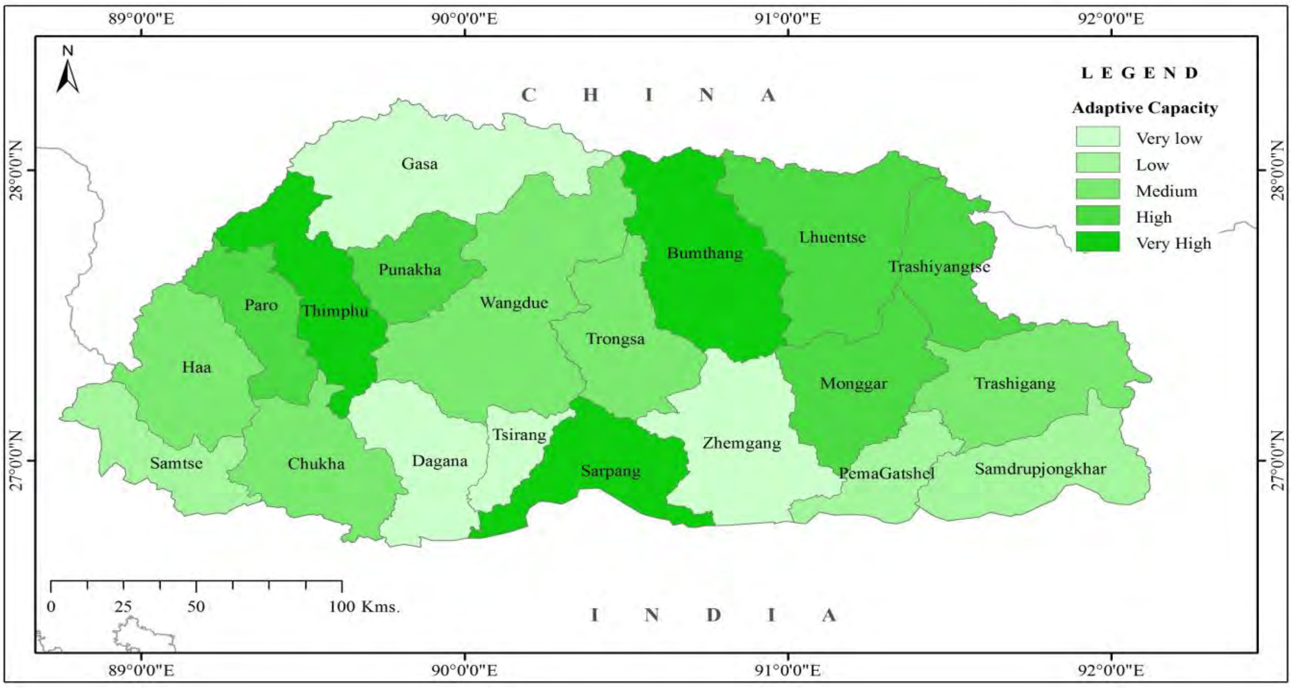


Figure 46: Dzongkhag-level adaptive capacity map – Focus on WBD in Bhutan (Source: PwC analysis)

3.4.5. Risks

Considering the hazard, exposure, sensitivity and adaptive capacity, risk profiling of Dzongkhags was carried out. Risk mapping was conducted separately for VBDs and WBDs.

Dzongkhag level risk mapping for VBDs: The overall risk assessment map for vector-borne diseases shows that Samtse, Chhukha and Punakha ad Tsirang have very high risk and Gasa, Bumthang, Lheuntse and Haa have the lowest.

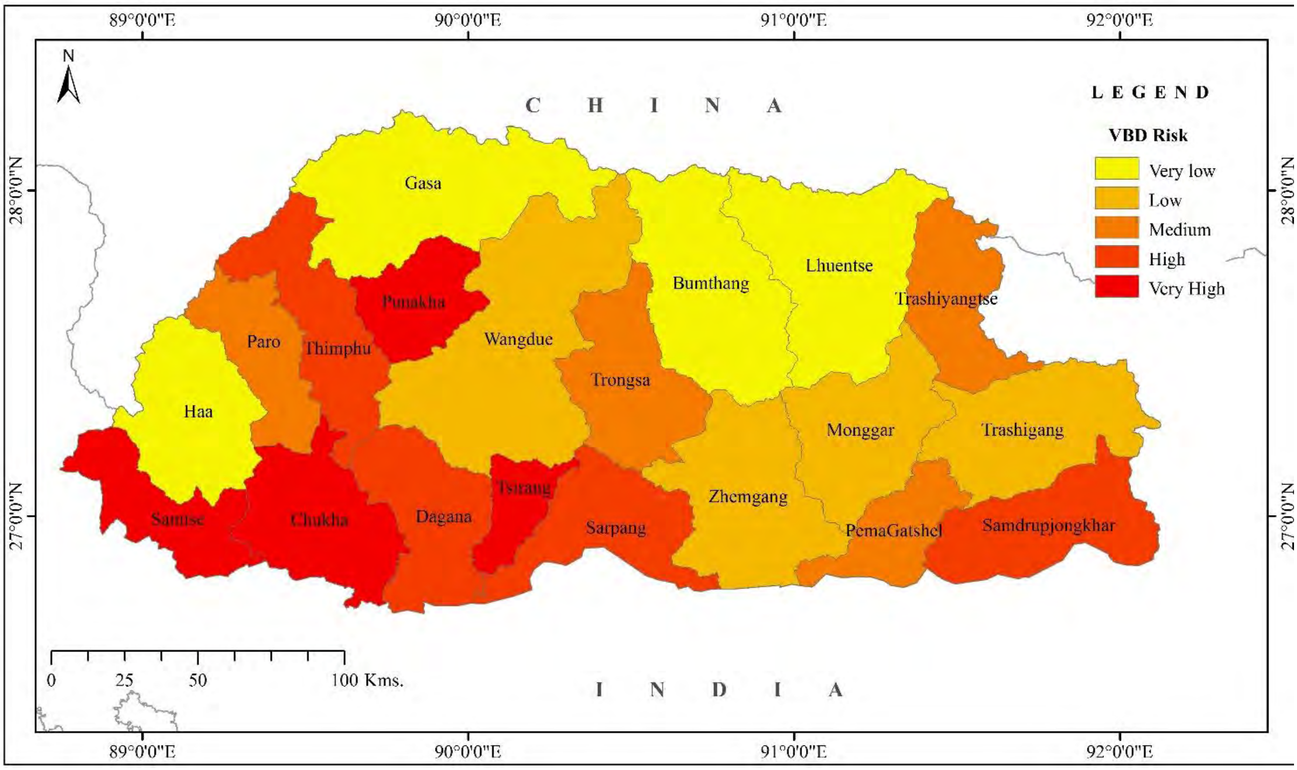


Figure 47: Dzongkhag level climate risk mapping – Focus on VBDs (Source: PwC analysis)

These Dzongkhags have high risk due to climate variability, extreme events and prevalence of vector borne diseases and changes ine ecosystem. Samtse, Chhukha and Tsirang have high exposure due to high population densities of 47.96 and 36.68 and 35.02 persons per square kilometer in comparsion to Bhutan's average of 19 persons per square kilometer. Punakha does not have as many cases of VBD however it is at high risk due to floods. Punakha was also one of the more sensitive Dzongkhags, primary drivers being higher share of tourist arrivals (22%) , food insufficiency (9%) and doubling of urban population (207% increase since 2005). In comparsion to these three Dzongkhags, Bumthang, Haa and Gasa have low risk primarily due to low exposure and fewer cases of VBDs. Other high risk Dzongkhags are Thimphu, Dagana, Sarpang and Samdrup Jongkhar. With respect to Sarpang, the highest number of malaria cases are reported in Sarpang. Consultations with VDCP revealed that Sarpang was considered the most endemic among these Dzongkhags for malaria. Possible reasons among other included that Sarpang borders the forest area and the exposure is high because people reside in villages in these forest areas. However more research is needed on this subject to validate this assumption. With respect to Dengue, the VDCP informed that rainfall, temperature and water shortages played an important role in its transmission.

Chhukha, Samtse, Tsirang are among the Dzongkhags that have the highest cases of VBDs. The results of the overall risk assessment continue to show these Dzongkhags are also at an overall high risk after considering other climatic and non-climatic factors. Adaptive capacity plays an important role in reducing the vulnerability. The capital city, Thimphu is observed to be at high risk due to high population density, climate variability, urbanisation and associated challenges. However, high adaptive capacity helps in reducing Thimphu's overall risk. A recent study on vulnerability to Dengue by location and season finds that the vulnerability of Dengue has extended to higher elevation areas. The higher risk was mostly associated with relatively high population density, agricultural and built-up landscapes and relatively good road connectivity[76]. Studies have shown that that even under current climatic conditions, continuous human movement will enable dengue vectors to spread and occupy suitable habitats, posing a risk to human health[77].

To summarize the above findings, key drivers that lead to VBD are mapped for top three Dzongkhags with highest risk and compared against three Dzongkhags with lowest risk.

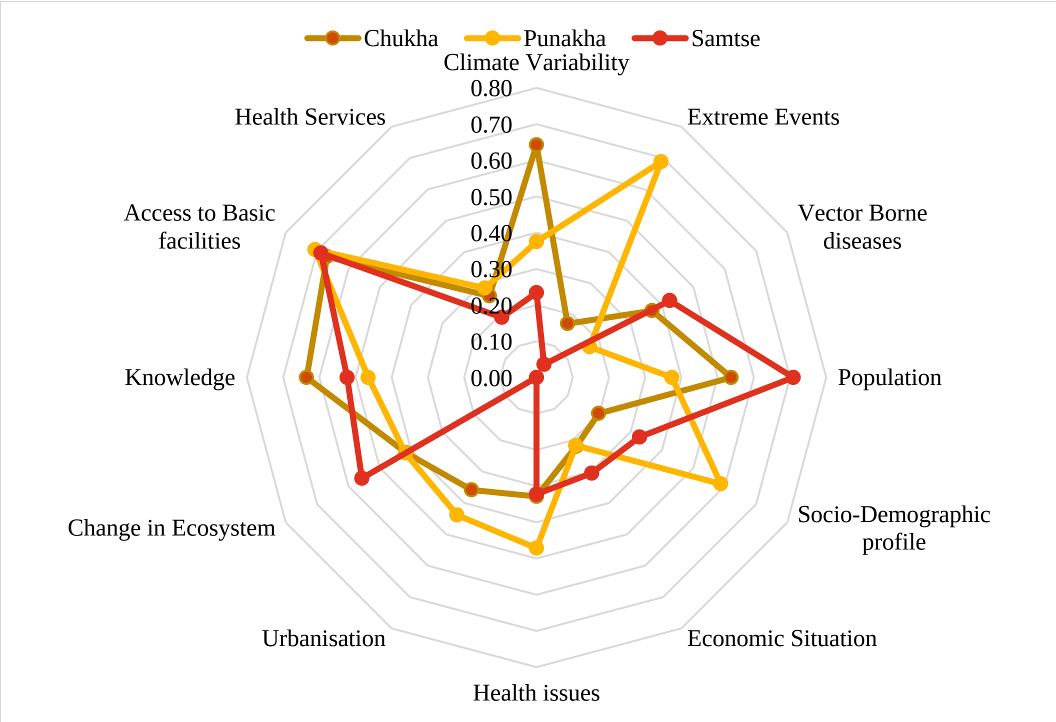


Figure 48: Key drivers for Dzongkhag with high climate risk – Focus on VBDs (Source: PwC analysis)

[76] https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0009021
[77] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7796457/

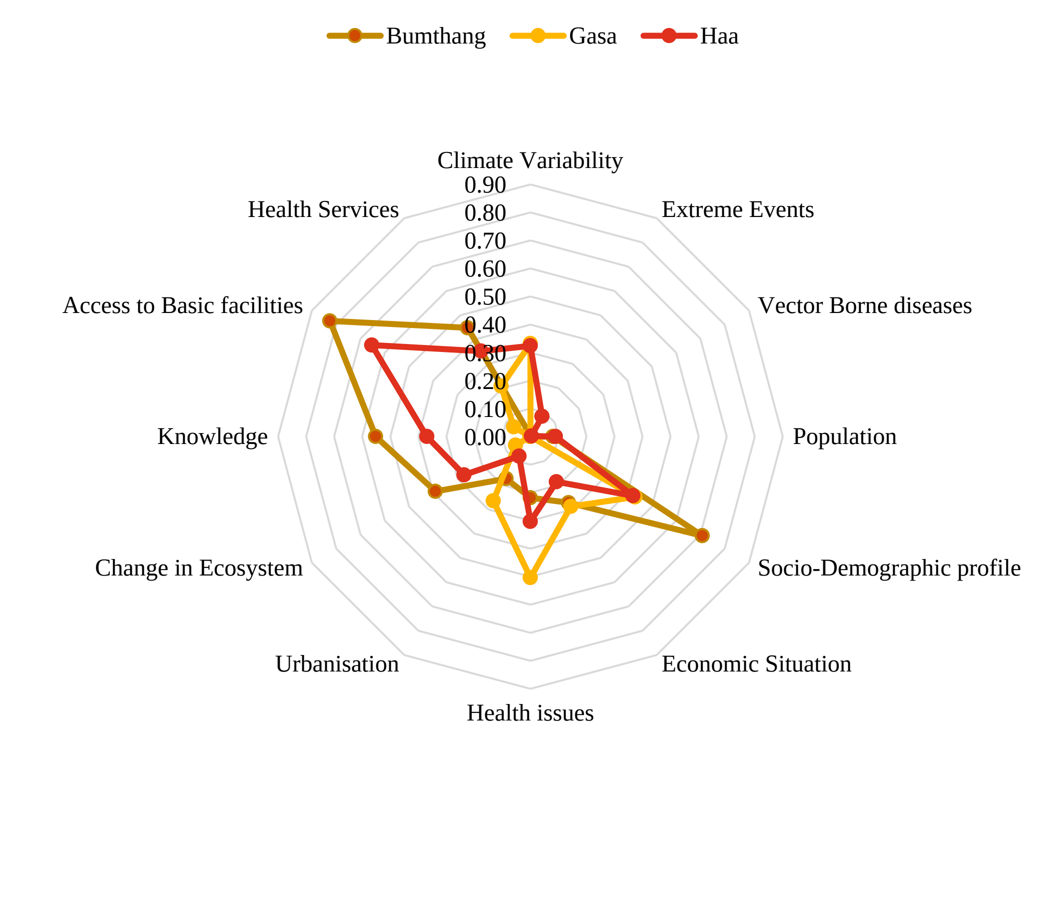


Figure 49: Key drivers for Dzongkhags with low climate risk – Focus on VBDs (Source: PwC analysis)

Population at risk of VBD

Based on the VBD risk assessment, it was found that almost 25% of Bhutan's population (182,672 people; 41,754 households) lie in very high risk Dzongkhags and 48% in medium to high risk Dzongkhags.

Table 3: Current impacts - Population at risk of VBD

VBD Risk	Dzongkhags	Population at VBD risk	No. of households
Very High	Chhukha, Samtse, Punakha, Tsirang	182,672 Male – 94,668 Female – 88,004	41,754
Medium - High	Samdrup Jongkhar, Sarpang, Dagana, Thimpu, Trongsa, Paro, Pemagatshel,Trashiyangtse	351,992 Male – 184,285 Female – 167,707	78,786
Very low/Low	Trashigang, Wangdue, Lhuentse, Monggar, Zhemgang, Haa, Bumthang, Gasa	192,841 Male – 101,500 Female - 90,981	42,461

Dzongkhag level risk mapping for WBDs: The overall risk assessment map for water-borne diseases shows that Punakha, Samtse and Paro, Chhukha have the highest risk and Gasa, Haa and Bumthang have the lowest.

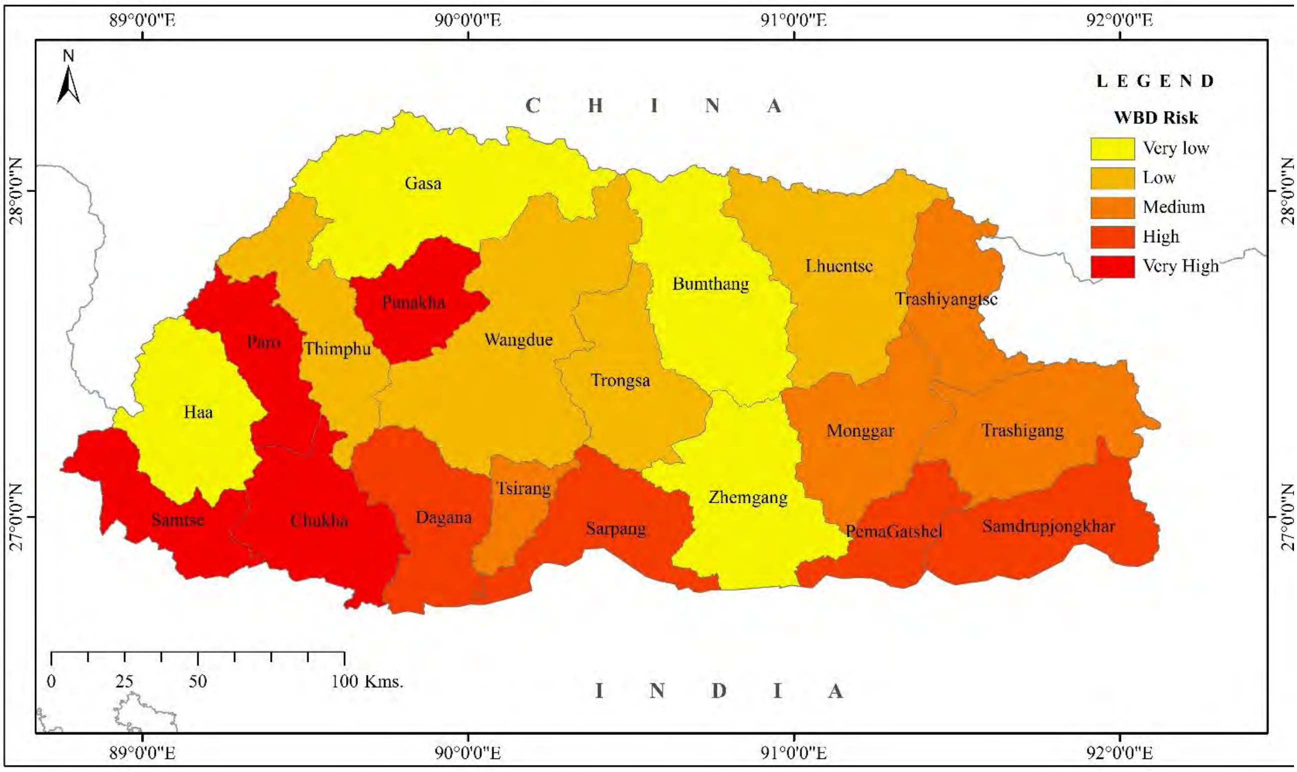


Figure 50: Dzongkhag level climate risk assessment map – Focus on WBDs (Source: PwC analysis)

Both Punakha and Paro are more prone to hazards. Paro had the highest cases of WBD among other Dzongkhags (850 per 10,000 population). Punakha was the only Dzongkhag that was impacted due to a GLOF during 2006-19 making it more prone to hazards. Punakha's high sensitivity arising from GLOFs and Paro's higher exposure due to high population density add on to their overall risks. Samtse has high exposure due to high population density of 50 people per square kilometer.

Key drivers that lead to increased riks of WBD transmission were plotted for top 5 Dzongkhags with highest risk and compared against the five Dzongkhags with lowest risk. Extreme events, urbansiation in addition to the prevalance of WBD in the Dzongkhags are found to be the key drivers of disease transmission risk in the Dzongkhag.

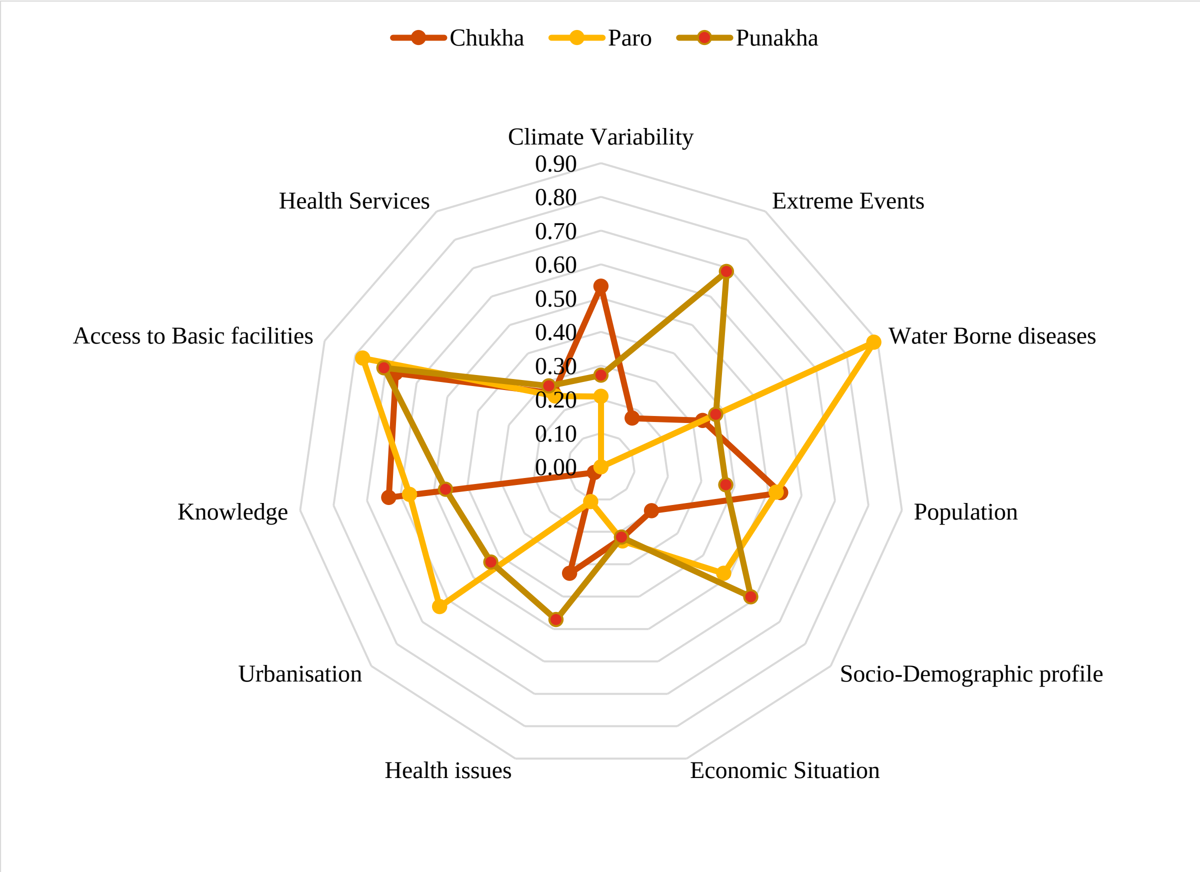


Figure 51: Key drivers of WBDs in high climate risk Dzongkhags – Focus on WBDs (Source: PwC analysis)

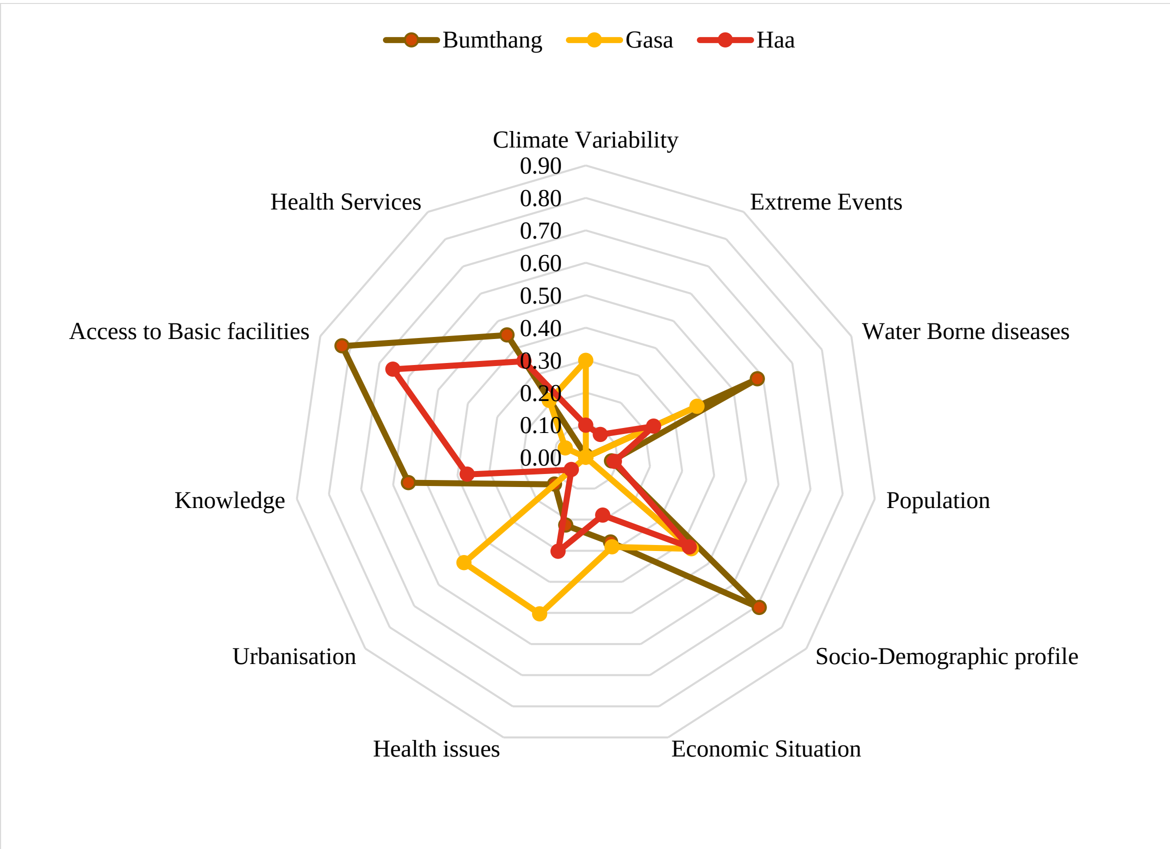


Figure 52: Key drivers of WBDs in low climate risk Dzongkhags – Focus on WBDs (Source: PwC analysis)

Population at risk of WBD

Based on the WBD risk assessment, it was found that almost 28% of Bhutan's population (206,612 people; 46,965 households) may get impacted in very high risk Dzongkhags and 34% in medium to high risk Dzongkhags.

Table 4: Current impacts - population at risk of WBD

WBD Risk	Dzongkhags	Population at WBD risk	No. of households
Very High	Punakha, Paro, Chhukha, Samtse	Total population: 206,612 Male – 107,083 Female – 99,529	46,965
Medium-High	Samdrup Jongkhar, Pemagatshel, Trashiyangtse, Trashigang, Sarpang, Tsirang, Monggar	Total population – 252,024 Male – 129,131 Female – 122,893	58,573
Very low/Low	Wangdue, Lhuentse, Thimphu, Trongsa, Zhemgang, Bumthang, Haa, Gasa	Total population - 268,509 Male – 144,239 Female – 124,270	57,463

3.5. Future projections

This section projects Dzongkhag level dengue and malaria cases in the future under RCP4.5 and RCP8.5 scenarios. This is done based on the historical dengue and malaria data for the disease and future climate data till 2099. Table 5 shows the descriptive statistics of monthly climatic factors, and dengue, malaria and diarrhoea cases in Bhutan. The mean monthly maximum and minimum temperatures and rainfall for six years (2015–2020) are 22.6°C, 11.8°C, and 153.4 mm respectively. There are months receiving 2545.5 mm rainfall and the highest maximum and minimum monthly temperatures rise to 35.9 °C and -8.1°C respectively.

Table 5:. Descriptive statistics of monthly climatic factors and dengue, malaria and diarrhoea cases in Bhutan

Variables	Minimum	Maximum	Mean	Std. Deviation
Dengue cases	0.0	1487.0	4.5	54.4
Malaria cases	0.0	19.0	0.3	1.0
Diarrhoea cases	1.0	882.0	175.0	135.9
Tmax (°C)	6.0	35.9	22.6	5.5
Tmin (°C)	-8.1	26.4	11.8	7.1
Tmean (°C)	0.5	30.0	17.2	6.1
Rainfall (mm)	0.0	2545.5	153.4	273.0
Model climate for RCP 4.5				
Tmax (°C)	1.6	31.7	19.7	6.2
Tmin (°C)	-15.5	23.9	8.7	8.2
Tmean (°C)	-6.8	27.7	14.2	7.2
Rainfall (mm)	0.0	1251.9	193.5	212.6
Model climate for RCP 8.5				
Tmax (°C)	1.2	33.4	20.6	6.2
Tmin (°C)	-16.5	26.0	9.7	8.2
Tmean (°C)	-7.7	29.5	15.2	7.1
Rainfall (mm)	-5.1	1336.7	258.9	225.7

Future projection for Dengue in Bhutan:

Incidence of Dengue in the past six years shows concentration of disease in Dzongkhags on the southern border of Bhutan and Thimphu, Trashiyangtse and Trashigang as shown in Figure 50.

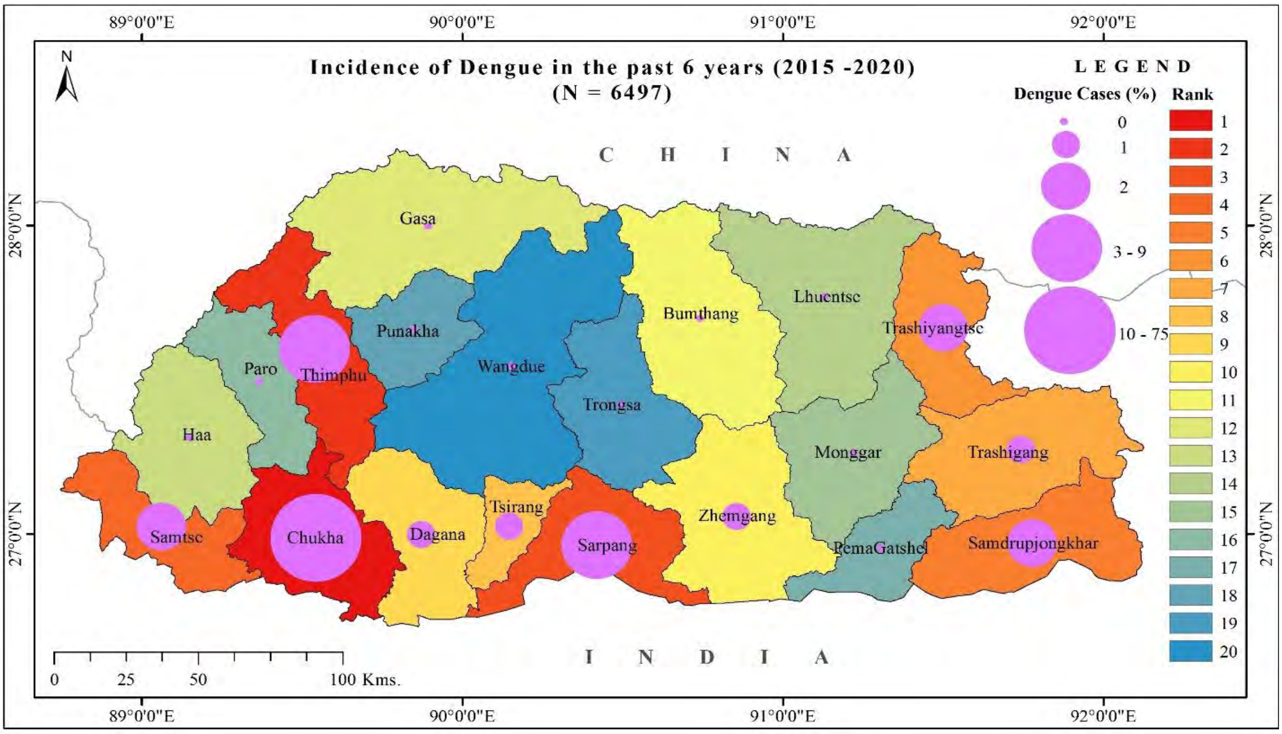


Figure 53:Dzongkhag level map of Dengue incidence (2015-20) (Source: PwC analysis)

Based on the analysis of future projections of Dengue in Bhutan it was found that rainfall, maximum and minimum temperatures, rainfall at the 2-month lag, maximum temperature at the 1-month lag are positively correlated with dengue incidences. All the positive and negative association with dengue cases is significant at 95% confidence level. Results of Zero-inflated Poisson regression model (ZIP) for Dengue cases in the future are summarised in Table 6.

Table 6: Results of Zero-inflated Poisson regression model (ZIP) for Dengue

Variables	Estimate	Std. Error	z value	Pr (>|z|)
Intercept	-11.40	0.27	-41.588	< 2e-16 ***
Rainfall	0.00	0.00	31.509	< 2e-16 ***
Tmax	16.30	2.19	7.457	8.83e-14 ***
Tmean	-31.39	4.37	-7.186	6.66e-13 ***
Tmin	15.34	2.18	7.028	2.10e-12 ***
lag1_Rainfall	0.00	0.00	-3.5	0.000466 ***
lag1_Tmax	84.07	2.23	37.719	< 2e-16 ***
lag1_Tmean	-168.10	4.47	-37.62	< 2e-16 ***
lag1_Tmin	84.07	2.24	37.591	< 2e-16 ***
lag2_Rainfall	0.00	0.00	-21.162	< 2e-16 ***
lag2_Tmax	58.98	2.00	29.542	< 2e-16 ***
lag2_Tmean	-118.50	3.99	-29.712	< 2e-16 ***
lag2_Tmin	59.37	1.99	29.891	< 2e-16 ***
lag3_Rainfall	0.00	0.00	-5.77	7.94e-09 ***
lag3_Tmax	-10.73	2.07	-5.172	2.31e-07 ***
lag3_Tmean	22.42	4.15	5.401	6.61e-08 ***
lag3_Tmin	-11.49	2.07	-5.544	2.96e-08 ***

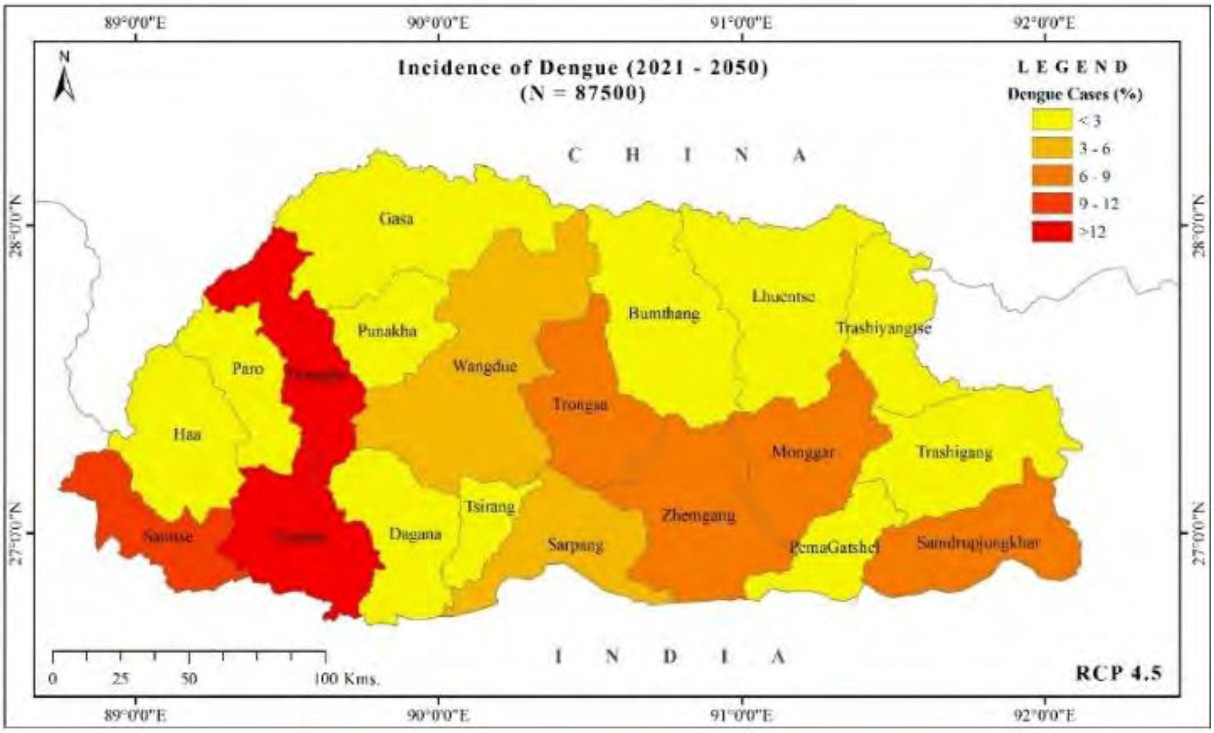
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The future projections for Dengue show that over the next 30 years, in a business-as-usual scenario, the number of cases in Bhutan can increase to around 3000 cases per year. These cases would be concentrated in the Dzongkhags of Chhukha, Samtse and Thimphu due to climate variability and pre-existing cases of Dengue that puts these Dzongkhags at increased risk of transmission. The increased risk on Dengue in Chhukha and Samtse can be explained from the favourable climatic conditions, presence of the Dengue vector *Ae. Aegypti*, and local transmission of the disease. The increased risk in Thimphu, where the Dengue vector is reported to be absent[78], shows an increased risk of Dengue under the RCP4.5 and RCP8.5 scenarios. This could be attributed to increased climate variability in the Dzongkhag. A recent study on Dengue risk assessment using multicriteria decision analysis also finds increased vulnerability of Dengue in higher elevation areas of Thimphu (Kawang, Mewang, and Chang) during summer season[79]. Similar instance of Dengue outbreak in areas where communities did not expect the disease to spread in their region occurred in 2019 where a remote village in Trashiyangtse (elevation of 915m above sea level) reported a dengue outbreak and *Ae aegypti* was detected in Trashiyangtse during the epidemic for the first time.

For the period 2051-69, the total number of cases per year continue to stay around 3,000 per year, however the severity in terms of the concentration of diseases in previously less affected Dzongkhags increases. Monggar and Trashigang show a higher share of dengue cases as opposed to 2021-59. Under RCP8.5, Trongsa and Samdrup Jongkhar become high risk Dzongkhags with higher percentage of dengue cases.

For the period 2070-99, the total number of cases is likely to increase to 4,400 cases per year. The distribution of the cases across Dzongkhags remains concentrated in the three most affected Dzongkhags of Thimphu, Samtse and Chhukha. Under RCP8.5, Thimphu shows a reduction in share of Dengue cases, while Monggar and Samdrup Jongkhar will be in the high-risk category.

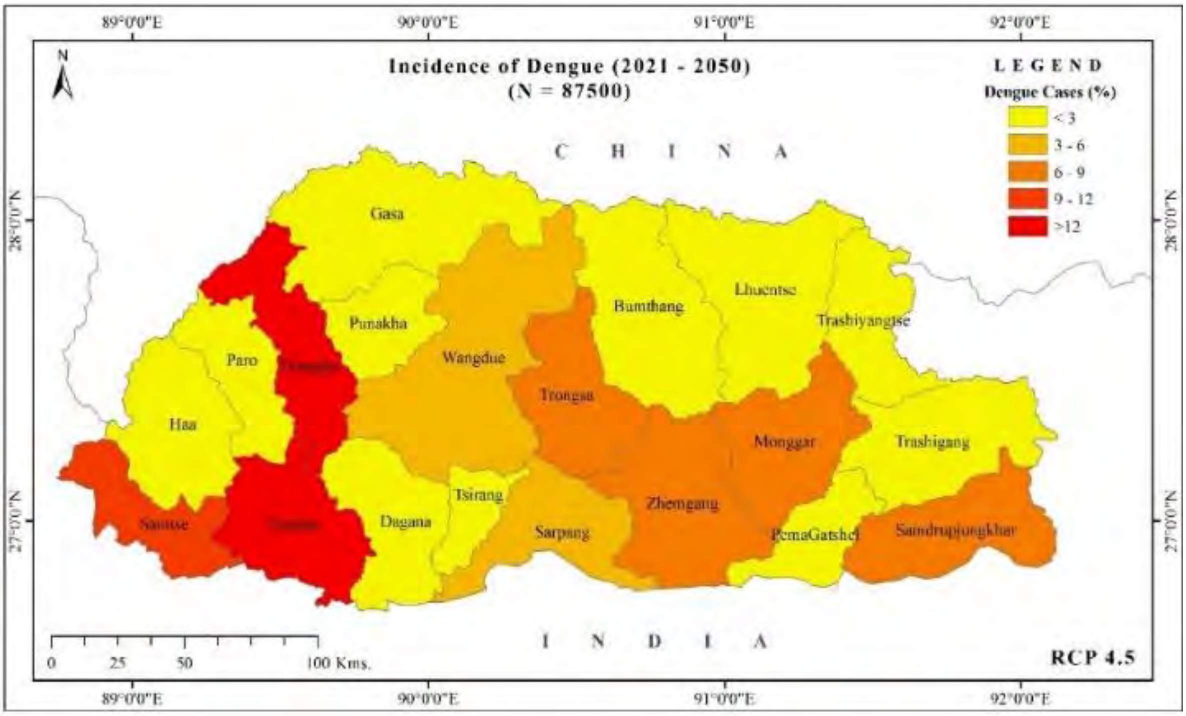
Incidence of Dengue (2021-2050) – RCP 4.5



[78] Consultations with MoH during Validation workshop and Training workshop

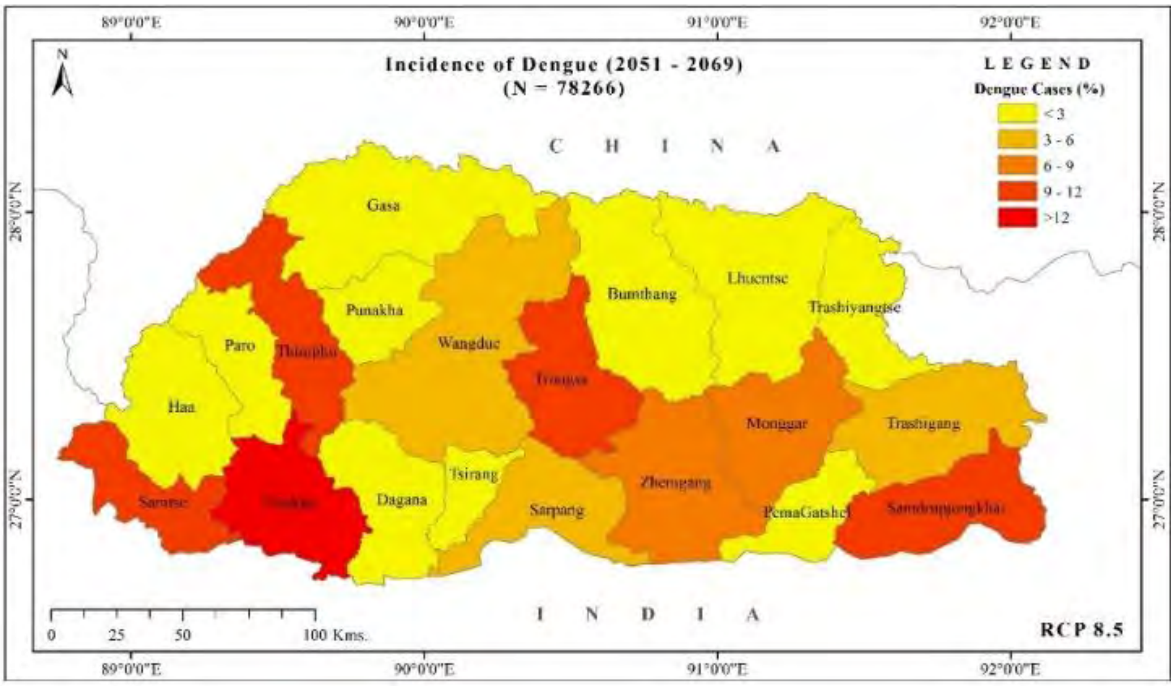
[79] Tsheten Tsheten, Archie C. A. Clements, Darren J. Gray, Kinley Wangdi, PLOS Neglected Tropical Diseases. 2021 Feb. Dengue risk assessment using multicriteria decision analysis: A case study of Bhutan

Incidence of Dengue (2021-50) – RCP8.5

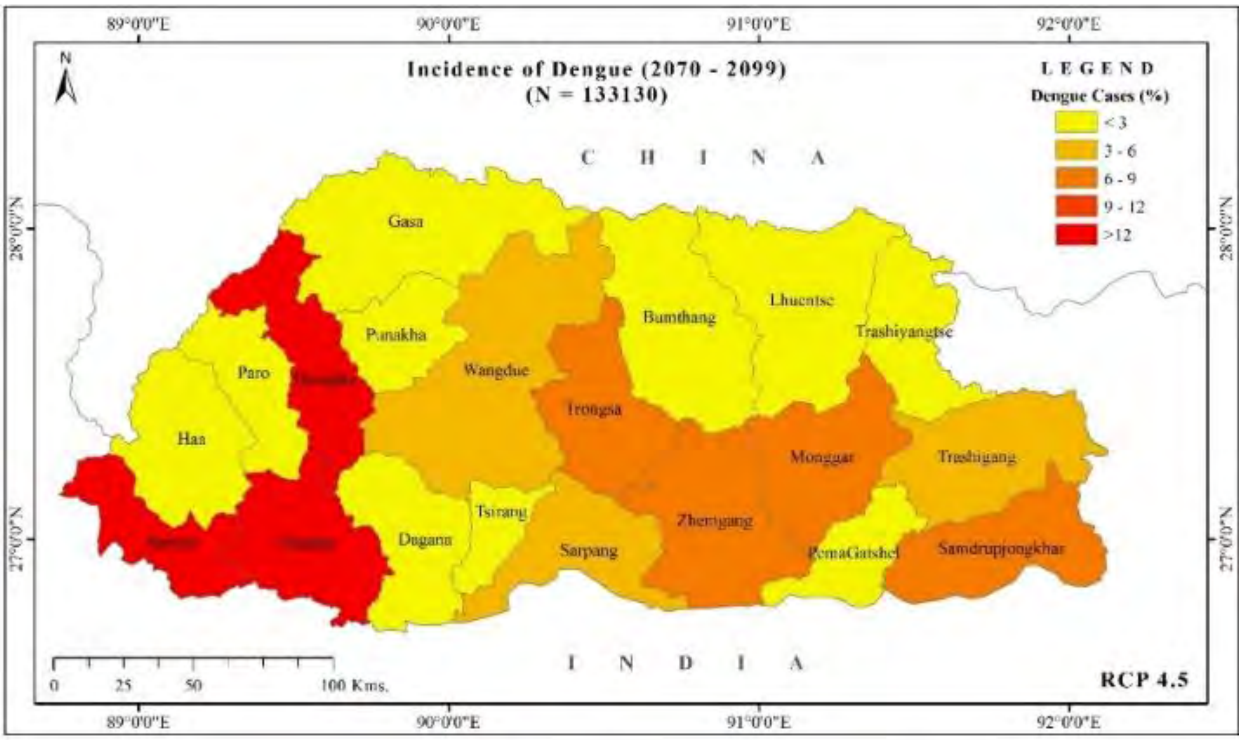


Incidence of Dengue (2051-69) – RCP 4.5

Incidence of Dengue (2051-69) – RCP 8.5



Incidence of Dengue (2070-99) – RCP4.5



Incidence of Dengue (2070-99) – RCP 8.5

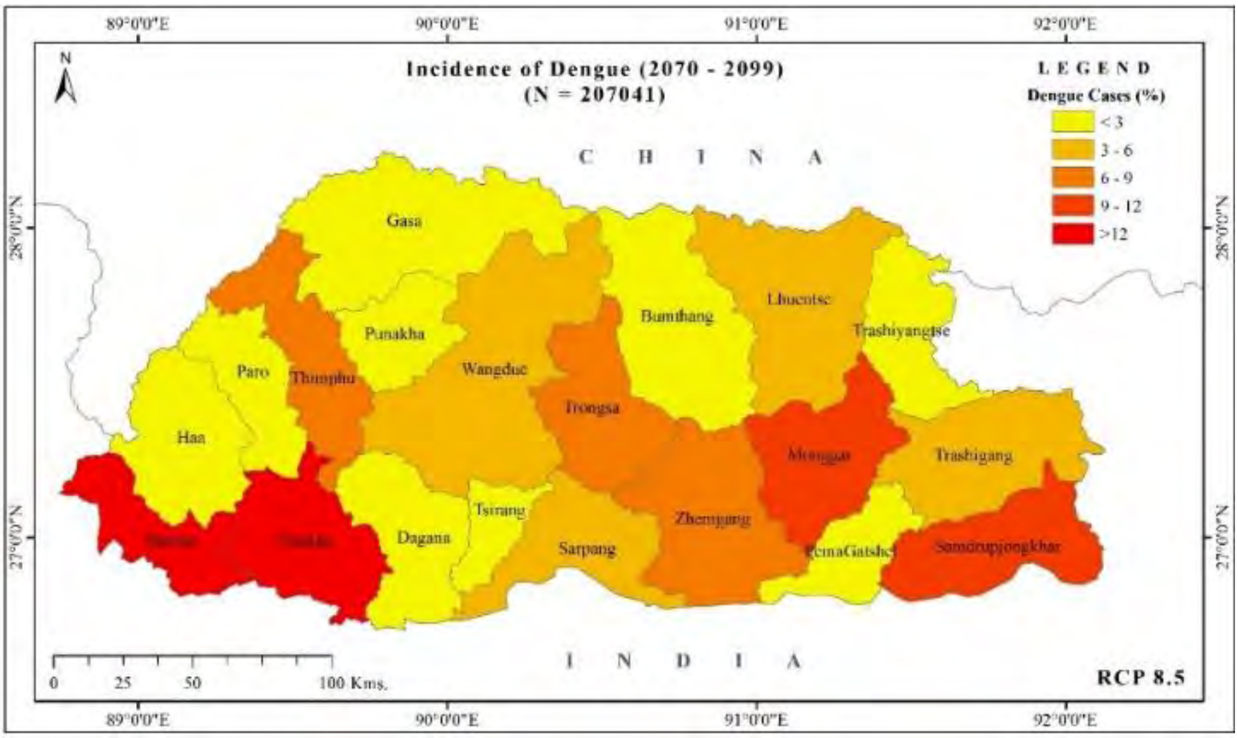


Figure 54: Incidence of Dengue under RCP4.5 and RCP 8.5 in the short, medium, and long term (Source: PwC analysis)

Population at risk of Dengue under RCP 4.5 and RCP 8.5 is calculated based on the population projections for Bhutan for the year 2047. Result shows that ~44% of the population of Bhutan is at risk of Dengue and there is an increase in population at medium risk from RCP4.5 to RCP 8.5 scenario.

Table 7: Population at risk of Dengue in 2050 under RCP scenarios

Dengue risk	Population at risk of Dengue (RCP4.5)	Population at risk of Dengue (RCP8.5)
High risk	390,565	390,565
Medium	98,681	137,125
Very low/Low	396,438	356,174

Future projection of Malaria cases in Bhutan:

In the last five years cases of malaria are concentrated in Sarpang, Chhukha, Samtse, Samdrup Jongkhar and Wangdue Dzongkhag. Figure below is a Dzongkhag level map of Bhutan that represents the percentages of malaria cases across Bhutan.

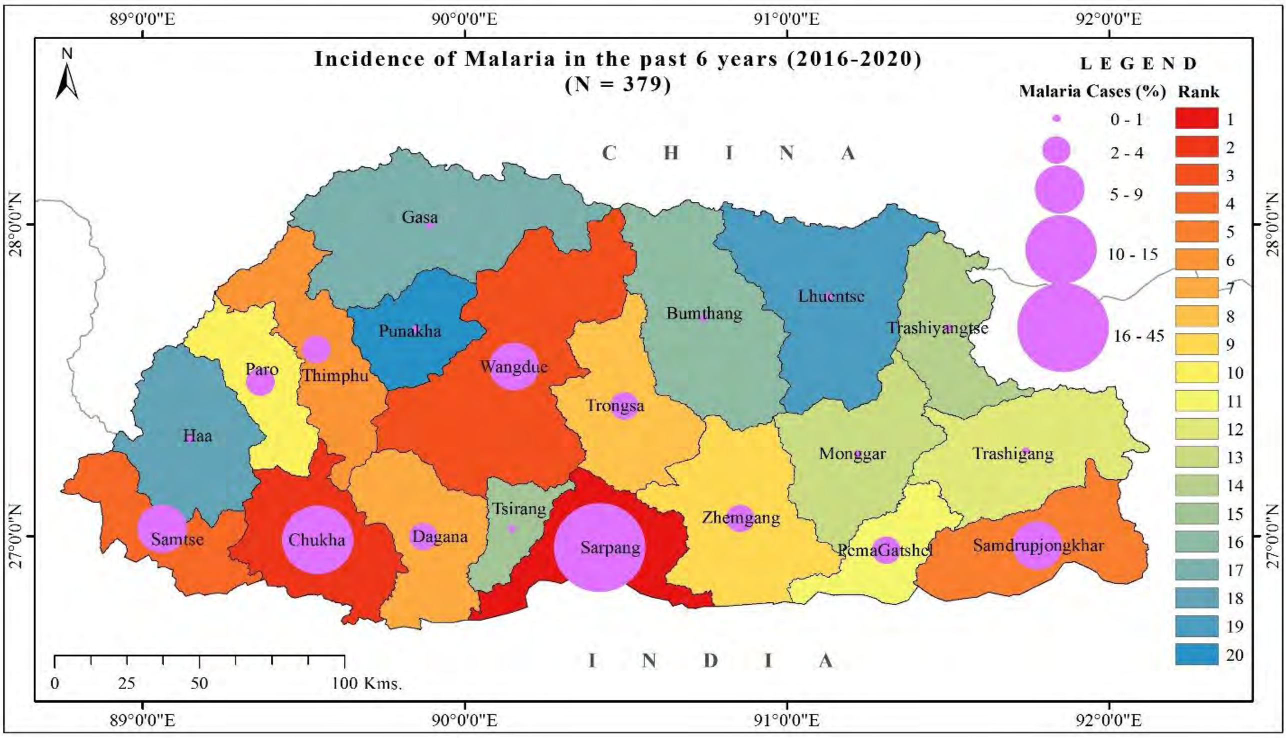


Figure 55: Incidence of Malaria 2016-20 (Source: PwC analysis)

Based on the analysis for future projections of malaria, it was found that rainfall, maximum and minimum temperatures, rainfall at the 3-month lag, maximum temperature at the 3-month lag are positively correlated with malaria incidences at 95% confidence level. Variables which are insignificant, determined from the p value, are excluded from the final model for future projections.

Table 8: Results of Zero-inflated Poisson regression model (ZIP) for malaria

Variables	Estimate	Std. Error	z value	Pr (>|z|)
Intercept	0.01	0.86	0.02	0.99
Rainfall	0.00	0.00	6.50	8.18e-11 ***
Tmax	30.37	12.51	2.43	0.0152 **
Tmean	-60.57	25.02	-2.42	0.0155 *
Tmin	30.35	12.50	2.43	0.0152 *
lag1_Rainfall	0.00	0.00	-1.72	0.0850.
lag1_Tmax	-17.47	12.20	-1.43	0.15
lag1_Tmean	34.57	24.38	1.42	0.16
lag1_Tmin	-17.10	12.18	-1.40	0.16
lag2_Rainfall	0.00	0.00	-1.02	0.31
lag2_Tmax	25.39	11.36	2.24	0.0254 *
lag2_Tmean	-50.91	22.72	-2.24	0.0250 *
lag2_Tmin	25.27	11.34	2.23	0.0259 *
lag3_Rainfall	0.00	0.00	0.52	0.60
lag3_Tmax	28.84	12.37	2.33	0.0197 *
lag3_Tmean	-57.58	24.71	-2.33	0.0198 *
lag3_Tmin	28.90	12.35	2.34	0.0193 *
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

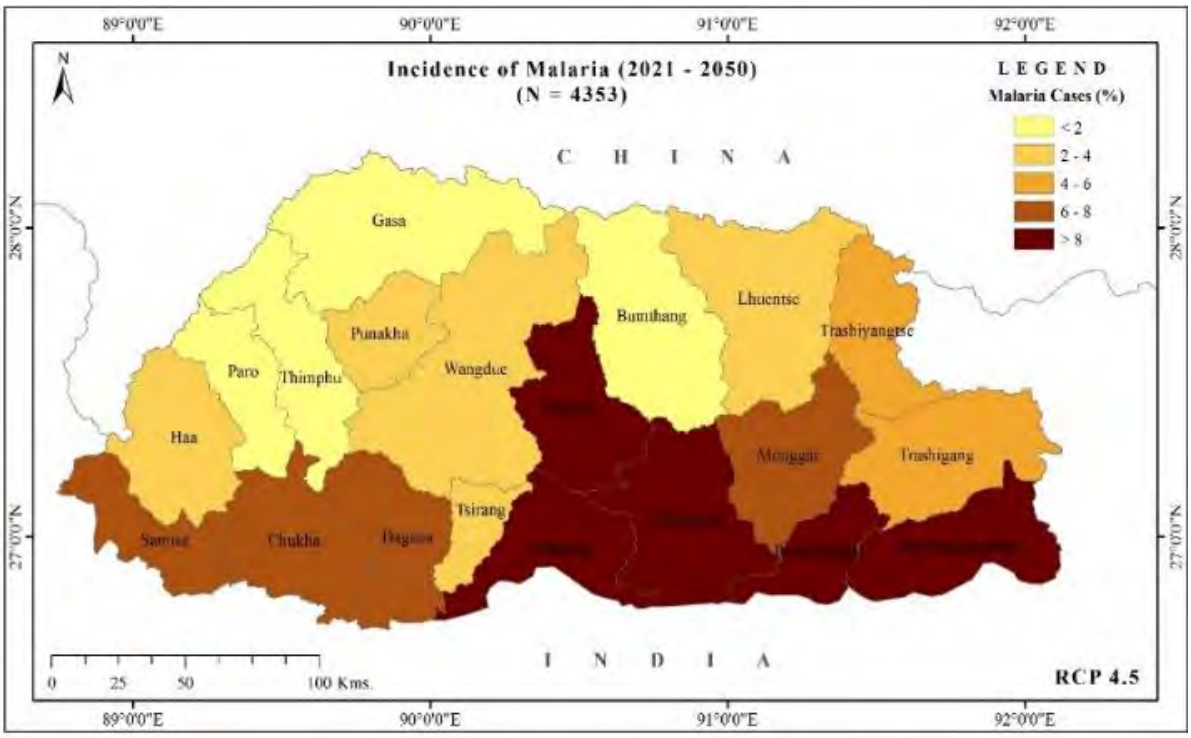
The future projection of malaria shows that over the next 30 years, in a business-as-usual scenario, the number of cases per year could double under RCP4.5 scenario increasing to around 150 cases per year. Higher percentage share of malaria cases can be seen in the eastern Dzongkhags on the southern border of Bhutan.

These are Zhemgang, Sarpang, Pema Gatshel and Samdrup Jongkhar. Under RCP 8.5, total cases increase by around 7% and percentage share of cases increase in Samtse.

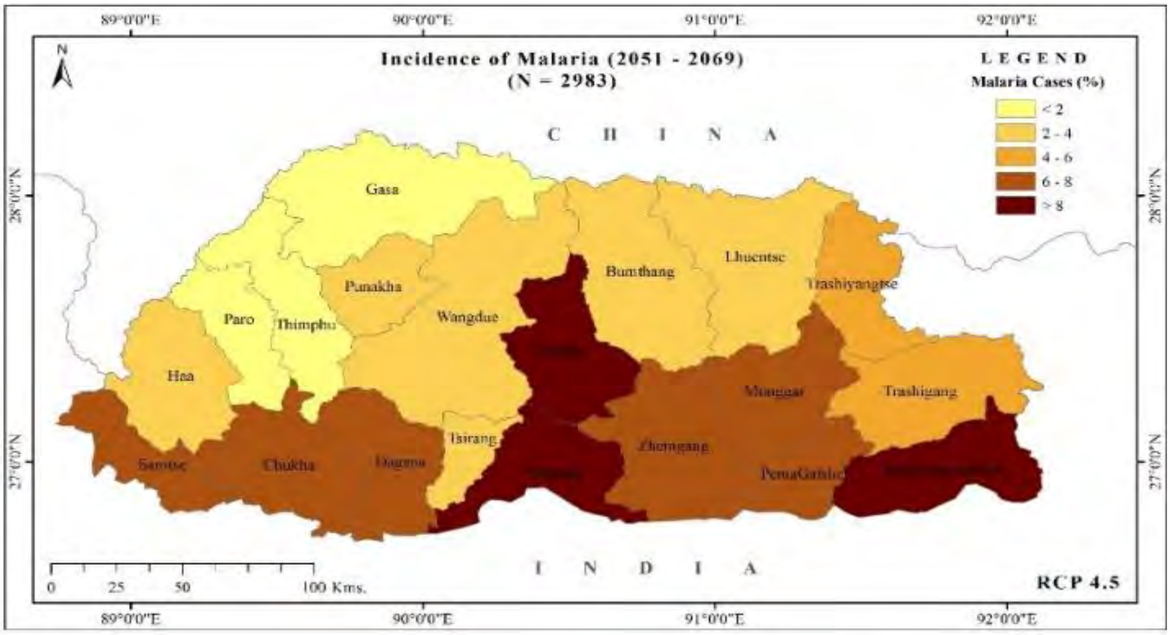
For the period 2051-69, the overall cases reduce, however the geographical distribution of malaria across Dzongkhags is higher under RCP4.5 and RCP8.5 scenarios. Trongsa, Sarpang and Samdrup Jongkhar have the greatest number of cases.

For the period 2070-99, cases increase to around 162 per year under RCP4.5 and 191 per year under RCP8.5 scenario. Dzongkhags with more than 8% of the total cases continue to be Trongsa, Sarpang and Samdrup Jongkhar.

Incidence of Malaria (2021-2050) – RCP 4.5



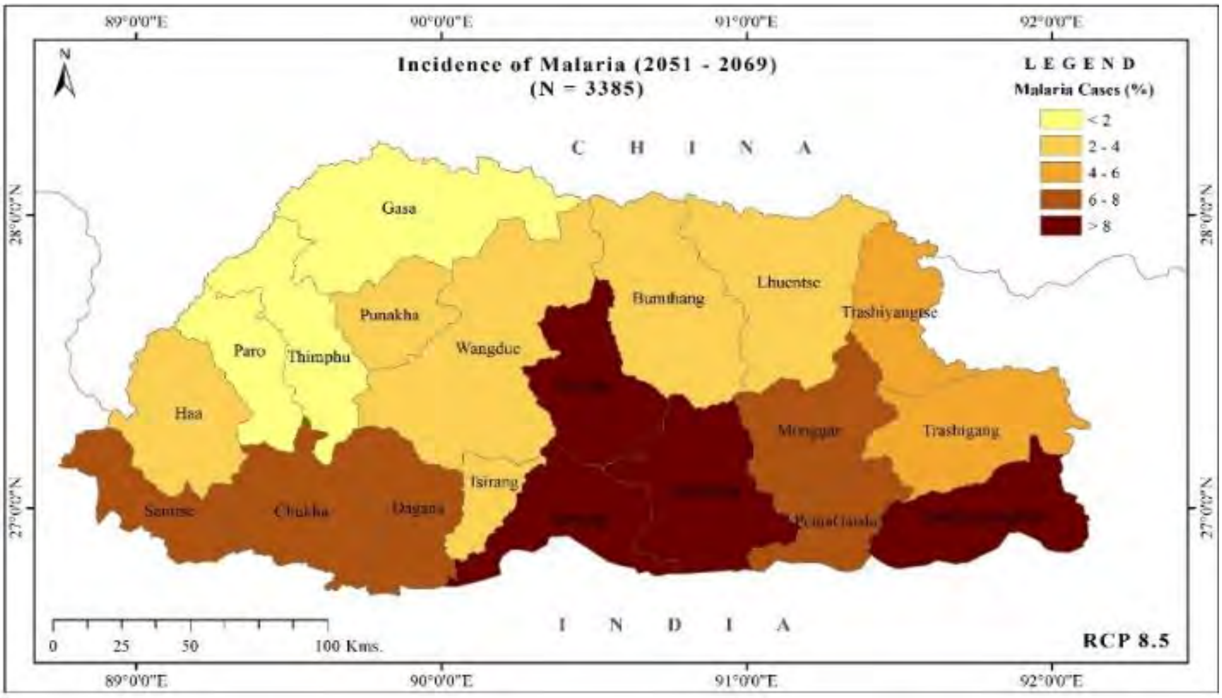
Incidence of Malaria (2051-69) – RCP 4.5



Incidence of Malaria (2070-99) – RCP4.5

Incidence of Malaria (2021-50) – RCP 8.5

Incidence of Malaria (2051-69) – RCP 8.5



Incidence of Malaria (2070-99) – RCP 8.5

Figure 56: Incidence of malaria under RCP4.5 and RCP8.5 in the short, medium and long term (Source: PwC analysis)

Population at risk of malaria under RCP 4.5 and RCP 8.5 is calculated based on the population projections for Bhutan for the year 2047. Result shows that ~14% of the population of Bhutan is at risk and there is an increase in population at high risk from RCP4.5 to RCP 8.5 scenario.

Table 9: Population at risk of malaria in 2050 under RCP scenarios

Malaria risk	Population at risk of Malaria (RCP4.5)	Population at risk of Malaria (RCP8.5)

High risk	124,649	134,712
Medium	248,997	238,934
Very low/Low	510,218	510,218

Future projection of Diarrhoea cases in Bhutan:

Based on the Diarrhoea data for the period 2016-20, different future projection models such as the Poisson regression model were applied. However, none of the models show a significant correlation between climatic factors and cases of Diarrhoea at the Dzongkhag level. This could be because the observed data on temperature and precipitation at the Dzongkhag level do not show a consistent correlation pattern with cases of Diarrhoea. The other possibility could be that there is an issue in the disease data for the period 2016-20. Results of the Poisson regression model are as summarized in table 10 below.

Table 10: Results of Poisson regression model (ZIP) for Diarrhoea

Variables	Estimate	Std. Error	z value	Pr (>|z|)
Intercept	2.28	0.11	20.191	<2e-16 ***
Rainfall	0.00	0.00	-1.006	0.314
Tmax	0.68	2.40	0.284	0.777
Tmean	-1.24	4.79	-0.259	0.796
Tmin	0.57	2.40	0.237	0.812
lag1_Rainfall	0.00	0.00	0.079	0.937
lag1_Tmax	-0.09	2.39	-0.04	0.968
lag1_Tmean	0.25	4.79	0.052	0.958
lag1_Tmin	-0.11	2.39	-0.047	0.963
lag2_Rainfall	0.00	0.00	0.781	0.435
lag2_Tmax	-1.31	2.40	-0.545	0.586
lag2_Tmean	2.69	4.80	0.56	0.576
lag2_Tmin	-1.35	2.40	-0.561	0.575
lag3_Rainfall	0.00	0.00	1.042	0.297
lag3_Tmax	-1.43	2.40	-0.597	0.55
lag3_Tmean	2.93	4.80	0.611	0.541
lag3_Tmin	-1.49	2.40	-0.621	0.535
Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

4. Adaptation planning

In 2011, the Department of Public Health carried out an assessment of health vulnerability and adaptation to climate change and developed the baseline to understand the health impacts of climate change and the adaptive capacity and to improve early warning, preparedness and response to potential health risks. A Health National Adaptation Plan has been developed for the period of 2018-2023. However, a few key barriers to implementation of various strategies, policies and plans are related to availability of systematic meteorological data, linking the data with climate-sensitive health outcomes and converging surveillance data of climate sensitive disease programs like National Vector Borne Disease Control Program (VBDCP).

A lot of progress is done under the 'Climate Change adaptation to protect human health' for Bhutan project by WHO and UNDP. Improved data collection through the integrated surveillance system allowed the health sector to monitor and receive early warnings and thus the opportunity to prepare and respond to potential health risks. Establishing the surveillance system was envisaged to be a continuous process and was one of the pre-requisites for designing and implementing a climate related Early Warning Systems (EWS) for health.

In this context, the study on preparing a risk mapping of vector and water borne diseases associated with climate change is pertinent to the progress made and builds on and complements the initial projections of VBD and WBD through analyses of exposure and vulnerability.

Key Findings:

- Vector and water-borne diseases result from a range of determinants that include individual behaviour, socio-economic and environmental conditions including climatic conditions as seen in the previous section. Risk and vulnerability assessments help identify Dzongkhags at risk and accordingly prepare targeted adaptation strategies to reduce risk and build capacity. Dzongkhag-level evaluation of impacts of climate change on health in Bhutan shows that the effect varies from one Dzongkhag to another as a result of various climatic and non-climatic factors.
- In addition, other factors related to sensitivity, adaptive capacity and availability of resources are critical in determining the extent and severity to which a population will experience the health impacts from changing climatic conditions. For example, Dzongkhags along the southern border are at higher risk of VBDs due to sub-tropical climatic conditions and cross border movements. Dzongkhags with higher population density such as Thimphu, Samtse, Chhukha and Paro face high risk due to higher exposure, imported disease caseloads, and issues linked to rapid urbanisation.
- Bhutan has undergone rapid urbanization in the last few decades. While the process of urbanisation is inevitable, lack of urban planning leads to issues such as inadequate water and sanitation infrastructure, overcrowding, high population density, increased exposure to extreme events and disease risks etc. As seen in section 3.1 and 3.4, the absence of adequate sanitation and drainage facilities leads to polluted and stagnant water that offers ideal breeding sites for mosquitoes and increased risk of diseases. Several studies have been carried out in Bhutan to address the negative impacts of urbanisation[80]. However, none of these studies have linked it to the associated impact on human health due to increased exposure to vector or water borne diseases. High percentage of rural-urban migration is observed in Chhukha, Sarpang, Thimphu. Further, in each of the Dzongkhags, Phuentsholing Thromde, Gelegphu Thromde and Thimphu Thromde have the highest population and account for 21% of the total population of Bhutan[81].
- Human exposure to water borne diseases occurs through contact with contaminated water. Around 2,231 households in Bhutan still depend on unimproved drinking water sources. Chhukha Dzongkhag and Samtse Dzongkhag have more than 200 households each without access to improved drinking water sources. Poor sanitation facilities also lead to increased risk of WBDs. Around 25% households in Bhutan still use unimproved toilet facilities. Interventions are needed to ensure 100% coverage of sanitation facilities.
- In 2008, Ministry of Health started the Rural Sanitation and Hygiene Programme (RSAHP) recognizing the importance of sanitation and hygiene in reducing the overall disease burden. The Programme has reached 16 dzongkhags. Four remaining Dzongkhags viz. Gasa, Paro, Thimphu and Bumthang will be reached in

[80] National Statistics Bureau of Bhutan, (2018), Rural-urban migration and urbanization in Bhutan, Royal Govt. of Bhutan; World Bank, (2019), Bhutan Urban Policy notes, RGoB; MoWHS, (2016), Bhutan Habitat III National report, RGoB.

[81] National Statistics Bureau 2017

the coming years are[82]. The study recommends that Punakha, Paro, Chhukha, Dagana and Samtse are among the most affected Dzongkhags due to climate impact and WBDs. It is important that the RSAHP covers Paro on priority as it already has high incidence of WBD and higher exposure due to high population density.

- Several studies have identified dzongkhags on the southern border of Bhutan to be at higher risk of diseases due to cross-border movement[83,84]. It is a major challenge for the disease control programs because of the continuum of human settlements along the borders which is largely porous and unfettered. Despite that there is no well-established mechanism on cross-border collaboration to discuss and share information on disease prevention, control, outbreak or surveillance information[85].
- In addition to international collaboration, there is inadequacy in integration of climate related aspects in policy and strategy documents highlighting the need for inter-sectoral collaboration. For example, PHED's Rural Sanitation and Hygiene Impact Study in 2020, VDCP's National Guidelines for Aedes vector surveillance and control in 2020, Chhukha Dzongkhag Disaster Management & Contingency Plan, 2018 have not included climate change impact related aspects.
- As part of this study, percentage of tourist arrivals was taken as a proxy indicator at Dzongkhag level to identify Dzongkhags that are at higher risk of imported cases of VBDs. Paro, Punakha and Thimphu accounted for 75% of the total tourist arrivals in Bhutan which adds to the overall disease burden of the dzongkhags.

Key Recommendations:

The integrated analysis based on risk mapping, vulnerability assessment and adaptive capacity identifies the high-risk Dzongkhags of Bhutan. Chhukha, Punakha, Samtse, and Tsirang Dzogkhags are at higher risk of VBDs. Punakha, Paro, Chhukha and Samtse are at highest risk of WBDs. The Dzongkhags which are common for both diseases viz., Chhukha, Punakha and Samtse have higher vulnerability and risk. Hence, based on the findings, the study recommends, prioritizing Chhukha, Punakha, Samtse followed by Paro and Tsirang. These recommendations focus on adaptation planning for these Dzongkhags predominantly.

Overall Recommendations Framework:

In-depth analysis of the identified Dzonkhags and consultations with key stakeholders have helped in identifying the attached framework for our recommendations. In the section below we discuss each components of the framework and elaborate further on specific strategies and actions to be considered for National Adaptation Plan for Health in Bhutan. The strategies are classified by actions to be taken at National, Regional/Dzongkhag/Thromde level with prioritization timeframe.

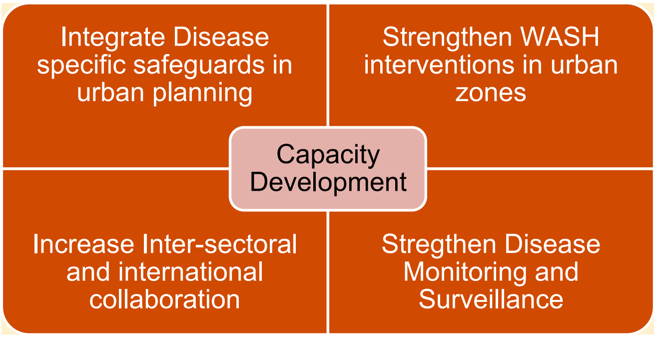


Figure 57:Overview of adaptation planning in NAP

[82] https://www.unicef.org/bhutan/press-releases/bhutan-achieve-100-improved-sanitation-2022
[83] DoPH, (2012), Environmental Health Program, RGoB
[84] VDCP, DoPH (2019), Annual Report of Malaria Elimination Progress and Activities, MoH
[85] VDCP, DoPH (2019), Annual Report of Malaria Elimination Progress and Activities, MoH

Capacity Development is the underlying need to bolster Bhutan's actions in managing VBDs and WBDs due to threats of climate change. Key actions recommended are:

- Identify response units capable of national and international negotiation on funds and technology transfer, within-country knowledge management, and programme planning and implementation
- Strengthen Disease Monitoring and Surveillance system with focus on VBDs and WBDs; create interdisciplinary platform linking health data base to meteorological database; integrating relevant non-health sector as well
- Strengthen capacity of healthcare system to respond better to VBD and WBD management with operational plans at each level and leverage technology
- To develop capacity of healthcare workers to do vulnerability assessment for VBD and WBD at local level
- To strengthen research capacity to fill the evidence gap on climate change impact on human health
- Integrate, adopt, and implement environment friendly measures across sectors with a gender lens
- To strengthen research capacity to fill the evidence gap on climate change impact on human health

Integrate Disease specific safeguards in urban planning	Strengthen WASH interventions in urban zones
• Institutions, regulations, and policies on urban planning must consider disease related risks arising from urbanisation, migration and climate change and build capacity at the administrative level to address them. • Ensuring a basic level of services such as access to health care, sanitation facilities, drainage, safe drinking water, connectivity of sewage and drains to the municipality network systems especially for lower income settlers. • Regular monitoring and surveillance to prevent rapid spread of diseases • Effective communication with the public to provide any information from early warning systems, entomological surveillance, on climate related impacts and disease outbreaks. • Awareness campaigns on how diseases such as Dengue, Malaria and Diarrhoea spread, prevention and management	• Ensuring hygiene and sanitation through safe drinking water and climate-proofing WASH infrastructure especially in disaster-prone Dzongkhags such as Punakha and Sarpang. • Ensuring safe hygiene and sanitation provisions, monitoring of water quality and awareness on WASH practices in specific areas such as labour camps at hydro-power sites, low-income settlers in urban areas. • Provide alternative safe and reliable sources of water supply in water scarce regions to prevent increased risk of WBD and VBDs. • Empower women and facilitate their equal participation in management of water resources at national, dzongkhag and grassroots levels and promote water-saving practices • Prioritize WASH interventions and awareness campaigns in Dzongkhags with higher population of children in the age group (0-4) and higher risk of WBDs
Increase Inter-sectoral and international collaboration	**Strengthen Disease Monitoring and Surveillance**
• International collaboration with neighbouring states in India to address diseases related issues associated with cross-border travel • Priority focus on surveillance and monitoring of travellers and migrants especially when travelling from endemic to non-endemic areas	• Collected data must be disaggregated by sex, age, socioeconomic status, education, ethnicity, and geographical location, where appropriate. Lack of gender disaggregated data at the Dzongkhag level poses challenges in understanding the gender-based impacts.

• Collaboration and coordination across sectors (tourism, immigration, agriculture, forestry, hydropower, water and sanitation, health, CSOs, private sector etc.) and line ministries to strengthen ongoing and future disease control programmes • Integration of climate related aspects and findings from climate risk assessments wherever relevant in national and dzongkhag level policy/ guidance/ strategy documents. • PHED, DoPH (2020), Rural Sanitation and Hygiene Impact Study, MoH	• As part of this study, gathering disease data at the Dzongkhag level was a challenge. For example, Dengue data was available at the Dzongkhag level only for the last 5 years. Inadequacy of data can reduce the level of significance of future projections and ability to establish disease pattern. • In line with the entomological surveillance methods under National Guidelines for *Aedes* vector surveillance and control (VDCP, DoPH 2020), the Dzongkhag level surveillance strategy could prioritize high risk dzongkhags (Chhukha, Samtse, Thimphu, Punakha, Sarpang) identified as part of this study.

Recommendation Operational Framework

Recommended operational framework	Short Term (6-12 months)	Medium Term (1-3 years)	Long Term (3-10 years)
National Level	• Identify the response unit within Health Department to advocate, plan and oversee implementation of VBD and WBD agenda in the overall Health NAP formulation process • Identify technical assistance, funds, skilled staff and logistics to develop guidelines, operational plans and strengthening data collection and integration • Use of sex disaggregated data for VBDs/ WBDs in developing plans for national, regional and local levels; involve gender experts and experienced manpower to solicit inputs for plans for address adaptation planning • Devising and Designing Mass media campaigns to address knowledge gaps on prevention of WBDs and VBDs	• Train all concerned personnel on surveillance system (data collection, collation and analysis) • Integrate relevant non-health data in the health surveillance system - Initiate Sentinel & real-time surveillance for WBD and VBD • Build an interdisciplinary platform i.e., link health databases with real-time monitoring of weather, climate, geospatial, and exposure data so as to accurately forecast health illness/ event • Develop/ modify mechanism and indicators to monitor trend of VBDs and WBDs. • Climate-proof facilities to ensure safe drinking water	• Update monitoring and surveillance system as per new evidence • Evaluate inter-disciplinary platform and upgrade as per evolving technologies. • Identify gaps for research
Regional Level: Prioritized for Chhukha, Samtse, Punakha, Paro, Tsirang	• As per priority list, Regions to prepare guideline/ action plan and upload the same on	• Meeting/ Consultation with local governing body for reassessment of roles and services	• Identify or assess aspects/ areas underserved in VBD

	its website for ready reference. • Build capacity to regularly monitor movement of migrant population through standard screening forms and tools • Develop training modules, organize training for health care personnel with a focus on disease prevention, WASH practices, use of ITBNs etc. • Provision of extra support for data collection, analysis, and reversal to local level for action. • Regular monitoring and reporting of water quality at household level • Assess gaps in existing disease surveillance systems and channelize resources to strengthen them	• Incorporate sex-disaggregated data collection and gender analysis of data • Evaluate differentiated impact of adaptation actions on women and men	and WBD management

Annexures

List of documents reviewed

- 12th five-year plan (2018-2023)
- Bhutan Vulnerability Baseline Assessment, 2016 (14 vulnerability groups)
- RGOB National Statistical Bureau, Statistical Yearbook of Bhutan, 2019
- Population and Housing Census of Bhutan, 2017
- Bhutan Living Standards Survey Report 2017
- Dzongkhag at A Glance, 2019
- Annual Dzongkhag Statistics, 2017
- Economic Census of Bhutan, 2018
- Population Projection 2017-47 (Dzongkhag Report)
- Second National Communication (SNC), 2011.
- Third National Communication, 2019
- NAPA I, II, III
- Bhutan's Nationally Determined Contribution (NDC), 2015.
- Draft enhanced NDC Bhutan
- Revised National Environment Strategy, 2020
- Climate Data Book of Bhutan, 2018
- Bhutan State of the Climate, 2017
- Analysis of Historical Climate and Climate Change Projection for Bhutan, 2019
- Extreme Weather Events in Bhutan, 2018
- Intergovernmental Panel on Climate Change (IPCC), 2001, 2007, 2014. Climate Change: Impacts, Adaptation, and Vulnerability, Third, Fourth, Fifth Assessment Reports.
- United Nations Framework Convention on Climate Change (UNFCC), National Adaptation Plans, 2018, Bonn, Germany.
- UNDP, Gender and Climate Change in Bhutan, 2020
- UNFCC, Technical guidelines for the national adaptation plan process, 2012.
- Meenawat, H., & Sovacool, B. K. (2011). Improving adaptive capacity and resilience in Bhutan. Mitigation and Adaptation Strategies for Global Change, 16(5), 515-533.
- Hoy, A., Katel, O., Thapa, P., Dendup, N., & Matschullat, J. (2016). Climatic changes and their impact on socio-economic sectors in the Bhutan Himalayas: an implementation strategy. Regional Environmental Change, 16(5), 1401-1415.
- Working Draft of Health NAP, 2018-2023 (support from MoH and KGUMSB)
- Bhutan National Malaria Elimination Strategy, 2015-2020
- Bhutan National Plan for Dengue Prevention and Control, 2016-2020
- Bhutan. Ministry of Health . Annual health bulletin Thimphu: Ministry of Health;
- Environmental Health Programme. Assessment of health vulnerability and adaptation to climate change: final report. Thimphu, Bhutan: Department of Public Health, Ministry of Health, 2012
- Bhutan Ministry of Health. Bhutan National Strategic Plan 2015–2020. Gelephu: Vector-borne Disease Control Programme; 2014
- World Health Organization . The world malaria report 2018. Geneva: WHO; 2018
- Climate change adaptation to protect human health: Bhutan project, 2010 WHO and UNDP
- World Health Organization. (2008). Climate change and health.
- Tshering, D., & Sithey, G. (2008). Climate change and health in Bhutan. Royal Society for Protection of Nature, Thimpu.

  National Sanitation and Hygiene Policy 2020 (requesting to include this for review as many issues pertaining to sanitation and hygiene may be addressed soon...available in MoWHS website-publications-policies)

List of indicators and data sources

Sub-component	Years	Data Source
• Max Temperature • Min Temperature • Mean Temperature • Std dev Temperature	1996-2020 and under RCP4.5, RCP8.5 for 2021-2099	• Observed data from meteorological stations, NCHM
• Mean Precipitation • Std Dev Precipitation	1996-2020 under RCP4.5, RCP8.5 for 2021-2099	• Observed data from meteorological stations, NCHM
• Area of land affected due to Floods, GLOFs • Number of Health facilities damaged due to Floods, GLOFs	2006-2019	• Dept of Disaster Management
• Dengue Cases • Malaria Cases • Chikungunya cases • Kala-Azar cases	2015-2020*	• DoPH, MoH
• Diarrhoea cases • Dysentery cases	2016-2020	• DoPH, MoH
• Population density	2017	• PHCB 2017
• % of Elderly • % of Children • % of Female population • Female Headed Households	2017	• PHCB 2017, Bhutan Living Standard Survey Report, 2017
• Consumption Poverty Rate • Unemployment Rate • Dependency Ratio • Food insufficiency	2017	• PHCB 2017, Statistical Yearbook 2019, Labour force participation survey
• % change in urban population (2005-2017)	2005, 2017	• PHCB 2005, PHCB 2017
• No. of tourist arrivals • % of rural-urban migration	2017	• PHCB 2017
• % HHs with no toilet facility • % HHs with access to untreated sources of water • % HHs living in Kutcha houses (wall material)	2017	• PHCB 2017
• % change in cultivated agriculture land (2010 - 2016) • % change in forest cover (2010 – 2016)	2010, 2016	• Land Use Land Cover 2016, Forest Facts and Figures, 2018, Land Cover Atlas of Bhutan, MoAF 2010

• Food insufficiency • Infant Mortality rate • Disability Prevalence Rate	2017	• Statistical Yearbook 2019, PHCB 2017
• Literacy rate	2017	• PHCB 2017
• Households with access to • Safe drinking water • Improved sanitation facilities • Drainage facilities • Nearest road head in less than 30 minutes	2017	• PHCB 2017
• Availed health services during the past year (%) • Employed in Health services (%) • Health facilities per 1000 pop	2017	• PHCB 2017

List of stakeholders consulted

Data collection

S/No	Name	Gender	Designation/Office	Email
1.	Dr. Karma Lhazeen	Female	Director, DoPH, MoH	klhazeen@health.gov.bt
2.	Karma Wangdi	Male	Dy. Chief Program Officer, DoPH, MoH	kwangdi@health.gov.bt
3.	Kinley Dorji	Male	HMIS, DoPH, MoH	kdorjee@health.gov.bt
4.	Tobgye	Male	Program Analyst, VDCP, Gelephu	tobgye@health.gov.bt
5.	Phurba	Male	Data Manager, VDCP, Gelephu	tenzin.47pt@gmail.com
6.	Jit Bdr Darnal	Male	Surveillance and Epidemiolog Unit, RCDC, DoPH, MoH	jbdarnal@health.gov.bt

Validation workshop 1 (April, 21)

S/No	Name	Designation/Office
1.	Chador Wangdi	Nutrition Division
2.	Loday Zangpo	VDCP, MoH
3.	Kinley Penjor	VDCP, MoH
4.	Tobgay	VDCP, MoH
5.	Ugyen Zangpo	VDCP, MoH
6.	Tenzin Wangdi	VDCP, MoH
7.	Rinzin Namgay	VDCP, MoH
8.	Tshering Yangzom	NECS
9.	Netra Sharma	UNDP

Key informant interviews

1. VDCP
2. DoPH
3. MoWHS

Agenda followed for KIIs

Sl. No.	Discussion leads	Probes and remarks
1.	• Views of the respondent on malaria elimination • Are there threats observed of malaria cases increasing due to climatic changes? • Any insights on importee and indigenous malaria cases	Probe on facility level responses (as in which services are delivered from facilities and through which cadre of health workers)

	• Comments on increase in the numbers reported in 2020 • Key public health activities done to strengthen elimination efforts • Comments on adequacy of infrastructure and HR available to support elimination • Comments on Inter departmental/inter sectoral convergence and coordination done and/or required to eliminate malaria	
2.	• Views of the respondent on rising dengue cases. Specially probe for 2019, where there was a substantial rise in number of reported dengue cases • What does the respondent think on linkages with climate incidents and rising dengue? • Key public health activities done to prevent dengue • Key activities done to treat and manage dengue • Comments on adequacy of infrastructure and HR available to control Dengue cases *(as per projections)* • Comments on Inter departmental/inter sectoral convergence and coordination done and/or required to prevent, manage and control dengue	In 2019, the number of reported cases in Bhutan was 4,655 compared to an average of around 275 cases for 2012 – 2018 period. Please probe the possible reasons specially in Chhukha Dzongkhag. Probe on facility level responses (as in which services are delivered from facilities and through which cadre of health workers)
3.	• Views of the respondent on rising chikungunya cases • What does the respondent think on linkages with climate incidents and rising chikungunya? • Efforts done under VDCP to manage chikungunya • Comments on adequacy of infrastructure and HR available to manage Chikungunya *(as per projections)* • Comments on Inter departmental/inter sectoral convergence and coordination done and/or required to prevent, manage and control dengue	Probe on facility level responses (as in which services are delivered from facilities and through which cadre of health workers)

WBDs (Diarrhoea and Amoebic/ Bacillary Dysentery) predominantly, along with the trends and zones from where reported)

Please record any remarks and or insights provided during the briefing.

Sl. No.	Discussion leads	Probes and remarks
1.	• Views of the respondent on causal factors for diarrhoea • Comments on links between bad drinking water source to climatic events • Links with safe drinking water availability, sanitation infrastructure and hygiene practices • Key public health activities done to manage diarrhoea • Comments on Inter departmental/inter sectoral convergence and coordination done and/or required to strengthen management of diarrhoeal diseases	Probe on facility level responses (as in which services are delivered from facilities and through which cadre of health workers)

2.	• Views of the respondent on causal factors for dysentery • Comments on links between bad drinking water source to climatic events • Links with safe drinking water availability, sanitation infrastructure and hygiene practices • Key public health activities done address high cases of dysentery reported	Probe on facility level responses (as in which services are delivered from facilities and through which cadre of health workers)

Climate Change perspective:

1. Are there any linkages between extreme events and the no. of VBD/WBDs? Which Dzongkhags are more prone to such events and is there any linkage with disease outbreak?
2. Are there any specific local socio-economic factors/sensitivities that cause the disease? We can use this insight to strengthen our impact chain
3. Any insights on why a disease is prevalent in certain Dzongkhags and not the others. Are there any specific measures being taken/planned at the Dzongkhag-level especially for those at higher risk?
4. What are the non-climatic factors that are responsible for incidence of vector and water borne diseases in Bhutan?