GLOBAL INSTITUTE FOR DISEASE ELIMINATION

FALCON AWARDS FOR DISEASE ELIMINATION

THE CLIMATE EDIT

Compendium of Research

December 2023

FOREWORD

SIMON BLAND CBE

CEO OF THE GLOBAL INSTITUTE FOR DISEASE ELIMINATION

This compendium presents the findings of the second iteration of GLIDE's Falcon Awards for Disease Elimination - The Climate Edit. These awards were designed to expand the evidence base of the intersection of disease elimination and climate and to provide catalytic support to researchers to examine new and under-explored areas of the relationship between climate and infectious diseases.

The research undertaken by the nine awardees is an important step toward shaping a more resilient, adaptable, and sustainable future for the global community. The links between climate change and infectious diseases represents a complex, multifaceted frontier. Understanding these interlinkages demands attention, better data, modelling, and resources.

Our hope is that this edition of The Falcon Awards will serve as a catalyst for innovation and collaboration, bringing together experts from diverse fields to address a shared concern. We hope that the awards have empowered communities by unravelling the complexities, challenging assumptions, and paving the way for informed, effective interventions.

At the heart of this initiative is a commitment to elevating the consideration of infectious diseases in the broader climate change discourse. The timing of the research outcomes coincides with the UNFCCC COP28 taking place in the UAE, along with the first-ever Health Day at a COP. This provides a unique opportunity to bring the findings to a global stage, fostering dialogue and collaboration among stakeholders committed to driving change, and reinforces the UAE's commitment to global health and sustainable development.

We will help support any of the awardees seeking to publish their initial findings in the hope that the research helps advance knowledge and accelerates progress towards disease elimination.

ABOUT GLIDE

GLIDE is a global health Institute based in Abu Dhabi, focused on accelerating the elimination of preventable infectious diseases of poverty: currently malaria, polio, lymphatic filariasis, and river blindness, by 2030 and beyond. Founded in 2019 as the result of a long-standing collaboration between His Highness Sheikh Mohamed bin Zayed Al Nahyan, President of the UAE, and the Bill & Melinda Gates Foundation, GLIDE works to elevate awareness and engagement, advance elimination strategies, and foster and scale innovation.

Community Perspectives on Climate & Health

THE RELATIONSHIP BETWEEN CLIMATE CHANGE AND TRANSMISSION OF LYMPHATIC FILARIASIS AND MALARIA IN SUB-SAHARAN AFRICA AND THE LOCAL PERCEPTIONS OF THE RELATIONSHIP IN GHANA

Authors

Mustapha Immurana, Alfred Kwesi Manyeh, Desmond Klu, Seth Owusu-Agyei, Evelyn Korkor Ansah

Affiliated Institution(s)

Institute of Health Research, University of Health and Allied Sciences, Ho, Ghana

Background

Infectious diseases such as lymphatic filariasis (LF) and malaria significantly impact millions of people worldwide, particularly on the African continent. Both LF and malaria are transmitted predominantly by Anopheles mosquitoes and these diseases co-exist the same human populations in Africa. Climate change is a crucial factor that could influence the spread of these diseases. However, while Africa remains susceptible to climate change,there is a lack of empirical evidence regarding its impact on the transmission of LF and malaria across several African countries. Additionally, local understanding of the relationship between these diseases and climate change is limited. This study aims to investigate the relationship between climate change and transmission/prevalence of LF and malaria in sub-Saharan Africa (SSA) with a focus on local perceptions in Ghana. Anticipated findings aim to contribute positively by increasing the attention to infectious diseases in the formulation of climate change policies and highlighting potential interventions to address existing gaps in local knowledge and understanding of the nexus between climate change and infectious diseases.

Methodology

This study employed mixed methods, incorporating both quantitative and qualitative approaches. The quantitative aspect employed a panel design with data spanning at least 30 countries in SSA from 1990 to 2019. The study examined the effect of climate change, represented by average temperature, on the prevalence of LF and malaria in SSA using the panel design. The qualitative component focused on determining local knowledge, attitudes and perceptions regarding the link between climate change and LF and malaria transmission in Ghana. Quantitative data were obtained from secondary sources, while qualitative data were collected through 16 Focus Group Discussions (FGDs) and 15 Key-Informant Interviews (KIIs), each involving 8- 12 participants. The panel system Generalised Method of Moments (GMM) regression was used to analyse the quantitative data while the qualitative data were analysed thematically.

Key findings

In the quantitative study, a percentage increase in temperature was associated with an increase in the overall prevalence increase of 3.73% for LF and 2.20% for malaria at 1% and 5% significance levels, respectively. Moreover, while a percentage increase in temperature was associated with higher prevalence of LF among females (4.52%) than males (3.07%) at 1% significance level, a percentage increase in temperature was associated with higher prevalence of malaria in males (2.22%) relative to females (2.19%) at 5% significance level. Qualitatively, both FGDs and KIIs participants observed higher incidences of malaria and LF transmission during the rainy season compared to the dry season. Additionally, some FGDs participants believed that high temperatures, resulting from sunshine, directly contributed to malaria transmission, while bites from insects (other than mosquitoes) and worms in water bodies were perceived as the causes of LF.

Discussion

The findings of the study imply that, while climate change is associated with a rise in the transmission of LF and malaria in SSA, there are knowledge gaps among community members in Ghana regarding the cause of malaria and LF. Nonetheless, this study did not cover all malaria and LF endemic countries in SSA, hence caution should be exercised in extending the findings to be representative of the sub-region.

Recommendations

This study recommends the need to increase attention given to infectious diseases in designing policies to mitigate the deleterious effects of climate change. Additionally, community education initiatives aimed at enhancing knowledge and perception of the relationship between climate change and LF as well as malaria transmission among community members in Ghana, need to be deepened.

COMMUNITY-LED SURVEILLANCE AND RESPONSES TO ELIMINATE LYMPHATIC FILARIASIS UNDER CLIMATE CHANGE

Authors

Salum Azizi[1,2], Yahya A. Derua[3], Hashim Ng'ongole[4]

Affiliated Institution(s)

1. Kilimanjaro Christian Medical University College (KCMUCO), Tanzania,
2. Pan African Malaria Vector Research Consortium (PAMVERC), Moshi, Tanzania,
3. National Institute for Medical Research, Tanzania
4. Tanzania Meteorological Agency, Climatology and Climate Change Section, Dar es Salaam, Tanzania

Background

Lymphatic filariasis (LF) is a neglected tropical disease that affects more than 120 million people globally. In Tanzania, approximately six million people are affected by the disease. Despite 20 years of using Mass drug administration (MDA), transmission is still ongoing in most of the coastal areas in the country. Vector population dynamics, MDA coverage, absence of specific LF vector interventions, and climatological factors might be attributable to the ongoing heterogeneous transmission of LF. This study assessed the link between climate change and LF transmission in areas with persistent LF burden in north-eastern Tanzania. Successful community-based vector surveillance for LF xenomonitoring was implemented and evaluated. The study identified LF transmission hot-spots and recommended responses to address LF surveillance and control applicable at community level.

Methodology

A cross-sectional community-based study for mosquito collection and *Wuchereria bancrofti* screening to determine the prevalence of LF infection in selected villages was conducted from July to October 2023. A structured questionnaire was used to assess community perceptions on climate change and its effect on health. Climatology and entomological secondary data from 1993 to 2022 were analysed.

Key findings

This study highlights rainfall as a critical climate factor.An observed shift in filarial vectors of importance from Anopheles to *Cx. quinquefasciatus*, accompanied with a high density and *Wuchereria bancrofti* infection rate could be linked to observed climate change. Residual transmission of LF in the study area is confined in a few specific villages, emphasing the importance of targeted interventions. The research demonstrates the effectiveness of CDC light traps for LF vector surveillance over a short durationof time by community members with minimal level of training.

The susceptibility tests revealed high pyrethroid resistance in Culex mosquitoes. However, test with piperonyl butoxide (PBO)-permethrin bed nets resulted into high mortality, suggesting suitability of this intervention in addition to larvae source management for effective vector control.

Discussion

The study analysed entomological indices, from newly collected and published data relevant to LF transmission and linked them with climatological data to establish the effect of climate changeon LF burden and transmission in endemic north-eastern Tanzania.

Previous studies in Tanga documented principal vectors of *W. bancrofti* in order of decreasing importance to be *An. funestus*, *An. gambiae* complex. and *Cx. quinquefasciatus*. However, this aligns with a recent longitudinal study in the same area that has reported a shift in *W. bancrofti* vectorsfrom Anopheles to mostly *Cx. quinquefasciatus. Cx. quinquefasciatus* is considered to be more efficient in transmitting LF than Anopheles mosquitoes, particularly at low prevalence of infection. This shift is supported by the current study which recorded very few and uninfected Anopheles vectors (0.5% (n=47)) in the collections. Examination of *Cx. quinquefaciatus* for *W. bancrofti* infection estimated an overall infection rate of 0.24%. However, infection rate at village level, shows a highly heterogenous transmission between villages, Kizingani (0.79%), followed by Mongavyeru (0.07%) and Bambamwarongo (0.21%), while it was 0% in other villages.

The shift in filarial vector from Anopheles to *Cx. quinquefasciatus* observed in the current and previous studies was assessed in the light of environmental and climatological factors. Extensive larval habitat surveillance conducted in the study areas identified many potential larval habitats for both *Cx. quinquefasciatus* and Anopheles mosquitoes. Most of the potential *Cx. quinquefasciatus* larval habitats were occupied by immature stages of the vector whereas Anopheles larvae were collected in only one potential larval habitat. This finding suggests presence factors that affect Anopheles larval habitat availability and suitability, and climate change might be one of them.

Rainfall, temperature and relative humidity (RH) are important climatological factors known to influence vector productivity. Analysis of annual rainfall from 1991 to 2022 revealed an increase in annual rainfall and RH. In general, the most dominant climate parameter that affects the LF vectors at all locations in the study areas is rainfall. Examination of correlation between rainfall and RH and LF vectors in the study areas revealed association ranging from moderate to inverse relationship. This might be due to the fact that LF vectors in this study were collected over a short period of time,and a longitudinal study could have been more appropriate for this analysis. Breeding in domestic and peri-domestic habitats that do not entirely depend on precipitation enables this vector to thrive in urban and rural areas with little or no surface water bodies, compared to Anopheline mosquitoes. Shift in filarial vectors from transmission by Anopheles to *Cx. quinquefasciatus*, whether being a result of climate change or other factors undermines interruption of LF transmission in reasonable time-frame. Our findings call for intervention that targets *Cx. quinquefasciatus* in efforts to eliminate LF in study areas and beyond.

Recommendations

The findings advocate for climate-tailored vector control effective targeting *Cx. quinquefasciatus* mosquitoes in identified hot-spots. In rain season where breeding sites are excessive, it is recommendable to utilize PBO-permethrin Long Lasting Insecticide Nets (LLIN) due to its efficiency in *Cx. quinquefasciatus*. Also, the highly susceptibility to WHO pirimiphos-methyl papers indicates suitability of larviciding with chloropyrifos as an effective and simple method of control this vector in dry season. We also recommend the use of repellents and house modifications to cover the eaves and large openings to minimize mosquito entry.

CLIMATE CHANGE AND MALARIA IN CHIREDZI DISTRICT, ZIMBABWE. EMERGING EVIDENCE AND PATHWAYS TOWARDS MALARIA PREVENTION

Authors

Walter Musakwa[1], Ntlakala Selamolela[1], Auspicious Ndlovu[2], Chenjerai Zanamwe[3], Brian Dhlandhlara[4], Bob Mandinyenya[5]

Affiliated Institution(s)

1. Department of Geography, Environmental Studies and Energy Studies, University of Johannesburg, Johannesburg, South Africa.
2. CifoSUDE, Chiredzi, Zimbabwe.
3. Chiredzi Rural District Council, Chiredzi, Zimbabwe.
4. Ministry of Health and Child Care, Chiredzi District, Zimbabwe.
5. Gonarezhou National Park, Chiredzi, Zimbabwe

Background

Climate change can influence malaria incidence directly and indirectly, impacting vector and parasite dynamics, along with socioeconomic factors influencing malaria risk. In Zimbabwe there is a paucity of research linking climate change, environmental factors, and malaria incidence, hindering coordinated efforts for malaria elimination. This hampers policy responseand leads to uncoordinated and untargeted efforts in trying to eliminate malaria. Most studies on the link between climate change are national there by negating local factors and knowledge. Furthermore, many studies on climate models and malaria are not suitable for planning specific practical and targeted approaches in eliminating malaria. Similarly, many studies on malaria risk and climate change in Zimbabwe are not trans-disciplinary and exclude citizen science and local parameters. This study adopts a trans-disciplinary approach, integrating secondary data,citizen science and local knowledge to address this gap in understanding the link between climate change, environmental factors, and malaria incidences. Our study has two main research questions namely, 1) Can secondary data and citizen science or knowledge be combined to explore the link between climatic, environmental factors and malaria incidence in Chiredzi District, Zimbabwe? and 2) how can a joint vision from the data obtained be used to develop a targeted approachin eliminating malaria?

Methodology

A trans-disciplinary approach is applied to explore the link between climate change and malaria in Chiredzi District, Masvingo Province, Zimbabwe from 2000 to 2022. Consequently, this study applies an (inter-trans-disciplinary) approach to tackle the nexus between climate change and malaria in Chiredzi district in Zimbabwe from 2000 to 2022. Thus, we combine quantitative weather data from weather stations, malaria incidence data and insights from focus group discussions that gleaned people's perceptions and knowledge on climate change and malaria in Chiredzi District. Participatory mapping showing hot-spots of malaria incidence was also utilized. Statistical analysis in MATLAB was used to analyse the weather data while ATLAS.ti was used to qualitatively analyse data from the focus group discussions.

Key Findings

From 2010 to 2016, average annual rainfall in Chiredzi district was less than 20mm, increasing significantly to 140mm in 2017 and 200mm in 2020. Overall, there is an increase in annual rainfall from 2017 onwards which is six times more than the rainfall from 2010 to 2016. This shows significant change in rainfall variation which can be attributed to climate change. Likewise, Chiredzi district has experienced an increase in the frequency and intensity of extreme storms such as the devastating cyclone Eline of 2000 which destroyed infrastructure such as bridges which denied communities access to healthcare facilities. Similarly, there has been an increase in the average temperature from 2010 to 2022. Average maximum temperature was 34 degrees Celsius °C in 2010 and increased to 35°C in 2019. Malaria cases in Chiredzidistrict shows an overall upward trend from 2010 to 2017 and a declining trend from 2018 to 2022. Significant increases in confirmed cases are in 2014 (26,613 cases), 2017 (35,548 cases) and 2018 (26,678 cases).

In 2019 the malaria cases decreased by over 50% to 11,415 cases followed by an increase in 2020 and declines in 2021 and 2022. The relationship between malaria incidence and climate change requires evidence. In 2014 there was an increase in malaria cases accompanied by an increase in average maximum temperature from 2013 to 2014. Similarity malaria incidence peak in 2017 which is also accompanied by an increase in average maximum temperature from 2016 to 2018. From a rainfall perspective, rainfall increases sharply from 2016 to 2018 accompanied by an increase in malaria incidence. The changes in weather patterns and malaria incidence where also corroborated in the focus group discussions. Residents of Chiredzi district noted that the climate has changed as they have noticed that the seasons have changed. Residents concurred that there is an increase in summer temperatures over the past fifty years resulting in more drier summers. Rainfall has now increased characterized often short heavy rainfall downpours. Participants also mentioned that there are more strong winds and whirlwinds unlike the past 50 years. Other notable changes are that the communities now experience periodic cloud cover and mist in September/October with unpredictable rainfall patterns. This rarely happened 50 years ago. The communities attributed the changes in climate to the increase in malaria incidence. Communities also highlighted other environmental and social economic factors such as poverty, dense vegetation, poor hygiene, ineffective malaria programs, migration and canal irrigation are factors causing the increase and spread in malaria. Lastly, communities developed malaria hot-spot maps based on the climatic, environmental, and socio-economic factors.

Discussion

Our study presents emerging evidence that there is a strong correlation between climate change and malaria incidence, emphasizing the positive relationship between increased in average annual maximum temperature, rainfall, and malaria cases. From the discussions it also emerges that the change in climate has meant that the spatial spread of malaria incidence has also increased. However, the increase in malaria incidence is not only attributed to climate but other environmental and socio-economic factors such as migration, poverty, and ineffective malaria control programs. The change in climate also exacerbates these environmental and socio-economic factors which leads to malaria incidence. It is argued that future malaria prevention programs be informed by the change in climate, socio-economic and environmental factors. Likewise, a combination of conventional scientific malaria control programs and indigenous malaria control methods can be suggested as a pathway towards malaria control.

Recommendations

Further studies with extended datasets that span a longerperiod need to be carried out to bolster the evidence linking climate change to malaria. Forecasting malaria incidence based on current climate, environmental and socio-economic conditions is crucial for advocating transformative malaria prevention programs, emphasizing the importance of inclusive partnership and adaptation to a changing climate. New malaria prevention programs that consider the impact of a changing climate on malaria, local environmental and socio-economic factors need to be devised.

Climate Variability & Transmission Dynamics

ACCELERATING MALARIA ELIMINATION IN THE FACE OF EXTREME WEATHER EVENT DISRUPTIONS

Authors

Benjamin L. Rice[1,2], Estelle Raobson[3,4], Sylviane Miharisoa[5], Mahery Rebaliha[2,6], Joseph Lewinski[6], Bryan Greenhouse[7], Christopher D. Golden[2,8], Gabriel A. Vecchi[9], Amy Wesolowski[10], Bryan Grenfell[1,11], C. Jessica E. Metcalf[1,11]

Affiliated Institution(s)

1. Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ, USA
2. Madagascar Health and Environmental Research (MAHERY), Maroantsetra, Madagascar
3. Mention Zoologie et Biodiversité Animale, University of Antananarivo, Antananarivo, Madagascar
4. Association Vahatra, Antananarivo, Madagascar
5. Institut Pasteur Madagascar, Antananarivo, Madagascar
6. Multisectoral Malaria Project, Catholic Relief Services, Baltimore, MD, USA
7. EPPIcenter Program, Division of HIV, Infectious Diseases, and Global Medicine, Department of Medicine, University of California San Francisco, San Francisco, CA, USA
8. Department of Nutrition, Harvard TH Chan School of Public Health, Boston, MA, USA
9. Department of Geosciences, Princeton University, NJ, USA
10. Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA
11. Princeton School of Public and International Affairs, Princeton University, NJ, USA

Background

Extreme weather events, particularly tropical cyclones,can disrupt public health activities and threaten progress towards disease elimination goals. The southern Indian Ocean has experienced changes to the timing, frequency, and intensity of tropical cyclones, which attribution studies have linked to increased greenhouse gas and aerosol emissions. Madagascar, with more than 90 tropical cyclones equivalent to hurricane category 1 or higher intensity since 1980, faces clear risks to the deployment of healthcare resources needed for disease control programs. Few studies to date, however, have investigated the consequences of extreme weather events for malaria control and elimination efforts.

Methodology

Leveraging more than 20,000 malaria infection observations from a prospective cohort study in Madagascar, we characterize spatial and temporal variation in malaria transmission in the context of two major cyclones (Cyclone Batsirai in February 2022 and Freddy in February 2023). Deriving estimates of the forceof infection by locality, age group, and season, we evaluate the impact of disruptions for the suite of malaria control tools recommended by the World Health Organization. We examine the required intervention frequency and coverage to reduce prevalence below a target level and subsequently evaluate the impact of disruptions to these interventions.

Key Findings

Variation in infection rate is characterized at the sub-district scale, and simulations demonstrate the benefit to reducing incidence through mass treatment or chemo-prevention campaigns. Localities with a high observed force of infection necessitate short intervals for intervention follow-up, as delays as brief as two weeks can erode progress. Among the evaluated intervention scenarios, we identify post-discharge prophylaxis and vaccination as crucial interventions in high-risk areas. These findings demonstrate the importance of accounting for disruptions to malaria control measures, including those driven by climate, when evaluating intervention strategies.

Few studies have focused on the potential impacts of climate change in the high-burden, endemic core areas of malaria transmission. Such highly endemic areas are responsible for the vast majority of global cases and will be key areas for progress in efforts to eliminate malaria, especially in the context of a changing climate.

Recommendations

Increased investment in malaria transmission reduction and vaccination may be warranted in climate-vulnerable geographies. We recommend incorporating spatial variation in risk for climate-related disasters, such as tropical cyclones, into elimination planning. Advocating for proactive efforts to mitigate climate impacts is crucial for sustained progress in malaria elimination.

INFLUENCE OF CLIMATE CHANGE ON RAINFALL PATTERNS AND ITS EFFECTS ON MALARIA INCIDENCE AND ELIMINATION IN SUB-SAHARAN AFRICA; A FOCUS ON ZAMBIA.

Authors

[1,2]Therese Shema Nzayisenga, [1,2]Nyuma Mbewe-Simukoko, [1]Paul Msanzya Zulu, [1,3]Nathan Kapata

Affiliated Institution(s)

1. Zambia National Public Health Institute
2. Climate Justice Foundation,
3. Lusaka Apex Medical University.

Background

Climate Change poses one of the biggest threats to health security due to its impact on the geographic distribution, severity, and seasonality of vector-borne infections such as Malaria. These diseases are influenced by changes in ambient temperature, humidity, vegetation, and precipitation. This study, spanning 15 years, malaria hot-spots and rainfall, patterns were identified across the country. From this information, the relationship between with malaria incidence and with rainfall, temperature and humidity patterns was investigated to gain understanding on environmental and climactic factors at play in the fight towards malaria elimination. In addition, the qualitative component aimed to understand the current status quo on malaria elimination efforts in Zambia.

Methodology

This was a mixed-method approach involving a review of health facility data by district, metrological data, and analysis of historical data from manual metrological observation stations and the District Health Information System. To identify malaria hot-spots and areas of high rainfall patterns over the last 15 years, we used the SATSCAN Analysis Software. We further assessed the impact of climate variables on malaria using a geo-additive or structured additive semiparametric Poisson regression model. We constructed an ARIMA modelin which the malaria cases in a given month are modelled as a linear combination of the number of cases in past months along with current and past values of temperature, rainfall and humidity. Focus group discussions and key informant interviews including participants from national and sub-national levels, are conducted to understand their perceptions on the influence of climate change on malaria incidence.

Key Findings

Over the 15 years period, a shift has been observed in districts recording high incidence of malaria, from the districts on the eastern and northern end of the country in 2009 to 2011 to the regions on north-western and western parts in 2020 to 2023. There is a gradual increase in district-specific incidence from an upper limit of 1,187 cases per 100,000 persons in a district from 2009 to 2011 to 1,316 from 2021 to 2023 is observed. There was a strong positive correlation between precipitation and humidity ($\rho = 0.78$, $p < 0.001$), and between precipitation, minimum and maximum temperature ($p < 0.001$).

Discussion

Malaria incidence over the last 15 years has evolved across the country. It is evident that although great measures and strides have been taken towards malaria elimination, there has been an initial downward trend up until 2017-2020 where there has been an upward then steady plateau despite implemented malaria elimination efforts. This study has brought to light that these trends are as a result of multiple confounding factors include improved case identification through community-based volunteers, implementation challenges in elimination strategies such as insecticide treated net distribution and annual indoor residential spraying of households. Climate data revealed that rainfall patterns have increased in intensity, shifted in terms of the calendar seasons and increased in unpredictability. It was also noted that extreme weather events have increased in frequency, ferocity and scale in comparison to the past from key informant information. This prompts the need to make considerations in both housing, health and living conditions for those vulnerable to these rainfall patterns.

It is notable that rainfall pattern trends and yearly changes marry with malaria hot-spots over the years further affirming the seasonality of malaria. Stronger positive correlation between malaria incidence and relative humidity occurs at a national level than just rainfall patterns and there is a strong positive correlation between the maximum temperatures and malaria incidence of the eastern and North-Western regions of the country while there were strong positive correlations between minimum temperature and malaria incidence for the northern and Copper-belt regions of Zambia. However, it was noted that peak malaria incidence in alignment to rainfall pattern changes was falling in between December and June, challenging current preventive efforts. Over the past years which is a shift form current understanding of rainfall patterns and inadvertently Indoor Residual Spraying and other Malaria preventing efforts which target implementation periods around late September. In addition, the unpredictability and increased intensity of the rainfall reduces the efficacy of these interventions in rural parts of the country.

Projections reveal an upward trend of malaria incidence even after factoring in seasonality, the current strength of malaria elimination efforts and the impact of changing rainfall and temperature patterns which are the building blocks of humidity. Climate change is present in Zambia and is likely to negatively impact the elimination efforts of vector-borne diseases such as malaria. Plans have yet to be operationalized and translated into methods which the community can understand easily.

One limitation of note in the meteorological data was that on-site data was only available in 42 districts and up to 2022. This was overcome by extrapolating and combining with satellite data validated at a 90% confidence level to come up with data for all 116 districts for the data required from 2009-2023.

Recommendations

There is a need for climate adaptation in malaria elimination strategies. Efforts towards climate advocacy and adaptation are pertinent. Well laid plans have been made to integrate climate adaptive strategies forsectors such as health – with the malaria program being one such identified sector. The biggest lesson from this study, however, would be to realize that whatever innovative strategies will be introduced to mitigate the effect of climate change on malaria incidence, the aspects of involvement of the community health workers for community mobilization and risk communication of these strategies would be paramount.

PROJECTING IMPACTS OF ENVIRONMENTAL FACTORS AND CLIMATE CHANGE ON TRANSMISSION DYNAMICS OF VISCERAL LEISHMANIASIS IN SOUTH ASIA AND IMPLICATIONS FOR REGIONAL ELIMINATION

Authors

Dr Carolin Vegvari[1], Dr Meghnath Dhimal[2,3,4,5], Dr Bipin Kumar Acharya[2,6,7,8], Haydn James[1], Dr Ramesh Dhiman[8], Dr Naseer Ali Shah[9], Dr Iqbal Kabir[10,11]

Affiliated Institution(s)

1. Oriole Global Health, London, United Kingdom.
2. Oriole Global Health, Kathmandu, Nepal.
3. Tribhuvan University, Kathmandu, Nepal.
4. Kathmandu University, Kathmandu, Nepal.
5. Nepal Health Research Council, Kathmandu, Nepal.
6. Nepal Geographical Society, Kathmandu, Nepal.
7. Nepal Open University, Kathmandu, Nepal.
8. TERI, Delhi, India.
9. Department of Biosciences, COMSATS, University Islamabad.
10. Ministry of Health and Family Welfare, Dhaka, Bangladesh.
11. Armed Forces Medical Institute, Dhaka, Bangladesh.
12. Bangladesh University of Professionals, Dhaka, Bangladesh.
13. Dhaka University, Dhaka, Bangladesh. 14. The University of Newcastle, Newcastle, Australia.

Background

Visceral leishmaniasis (VL), also known as kala-azar, is a deadly vector-borne disease (VBD) caused by the protozoan parasite *Leishmania donovani* and transmitted by sand flies. The VL elimination programs in Bangladesh, India and Nepal have been highly successful in reducing the number of cases and deaths over the past two decades.Nevertheless, climate change and rising temperatures have played a role in (re-)emergence of the disease in South Asia. In this study, we predicted areas at risk of VL transmission in South Asia and forecast future changes in risk due to climate change.

Methodology

We conducted research to study the impacts of climate change on the spatio-temporal distribution of VL and its vector *Phlebotomus argentipes*. Our research involved searching various databases such as PubMed, Google Scholar, and the Global Biodiversity Information Facility. We explored WHO websites and used Google for direct searches when needed. We visited the Ministry of Health and concerned departments in the study countries to find unpublished reports.We focused on recent scientific papers, reports, and literature published within the last 20 years. To gather location information for each vector occurrence, we relied on the site names and contextual details provided in the sources. We determined latitude, longitude, and altitude above sea level using tools like Google Maps and Google Earth. Most occurrence data points (124) were from India, followed by Nepal (92), Bangladesh (44), Pakistan (8) and Bhutan (6).

We use data on occurrence locations of the main VL vector in South Asia in five countries (Bangladesh, Bhutan, India, Nepal, and Pakistan) in combination with environmental variables and data on human activities and apply machine learning methods to predict VL risk in these countries. Data has been retrieved on nineteen bioclimatic variables from the Worldclim geoportal, the Normalised Difference Vegetation Index (NDVI) from MODIS earth observation satellite, and Human Footprint data form a from previous modelling study.

We used an ecological niche modelling approach to model and map current distribution of VL transmission risk and its evolution in the near and distant future under the different emission scenarios (SSP126 and SSP585, assuming 1.5K or 8.5K increase in Global Mean Surface Air Temperature till the end of the century, respectively).

Key Findings

The variable importance analysis showed that the precipitation of the warmest quarter and human footprint are the most influential predictor variables which together explain more than 60% of spatial variation in VL risk.

An area of about 276470 km^2, which is approximately 6% of the study region,is environmentally suitable for the VL transmission in South Asia. India has the largest share of at-risk area covering about 73% of total suitable area, while Pakistan and Bhutan were the countries with the lowest share of area at risk of VL with about 1.8% and 1.6% respectively. Nepal and Bangladesh each have a share of about 11% of the total area at risk of VL in South Asia.

In the context of climate change, about 417910 km^2 is estimated to be suitable for VL transmission by the 2050s under the low emission scenarios (SSP126) and 438450 km^2 under the high emission scenario (SSP585). The increase in suitable areas under the projected scenarios tends to be along the edges of the current risk distribution. Our model projects further increase in the suitable areas for VL transmission by the 2070s compared to current and compared to what is to be expected by the 2050s.

We expect an increase in the risk of VL transmission in the hilly and mountainous areas of Bhutan and Nepal, near the south-western coastal areas of Bangladesh, in eastern India, east-central India and along the western coast of India,and in northern Pakistan and at the south-eastern coast of Pakistan. Conversely, a decrease in the risk of VL transmission is expected in areas in the very North and in the very

Discussion

Many of the areas projected to experience an increase in the risk of VL transmission are close to national borders. International collaboration and cross-border surveillance for VL vectors and cases will be essential to sustainably achieve elimination in South Asia. The greatest amount of increase in the risk of VL transmission is predicted to occur by 2050. Until then, the area at risk of VL transmission is predicted to have increased by 50% compared to the current risk geographic distribution. From 2050 to 2070 VL risk is predicted to increase further by an additional 5% compared to baseline. Even in the optimistic climate change scenario (SSP126) we expect an increase in the at-risk area by 2050 of 51% compared to 58% in the pessimistic climate change scenario (SSP5859).

Recommendations

Measures to mitigate the risk of VL (re-)emergence, including cross-border surveillance, need to be planned and implemented as soon as possible and regardless of the measures taken to mitigate global warming, as even a relatively small degree of global warming will substantially increase the at-risk area for VL transmission. Geographic risk maps accounting for climate change can inform surveillance strategies for VL and *P. argentipes* to prevent (re-)emergence of this deadly disease.

Climate-Informed Surveillance Systems

INTEGRATION AND USE OF CLIMATE DATA BY THE NATIONAL HEALTH SYSTEM IN MOZAMBIQUE

Authors

Judite Pinto, Tatiana Marrufo, Melanie Picolo, Iracema Barros, Mara Ferrari, Patricia S. Coffey, Nelson Cossa, Angela Mondlane.

Affiliated Institution(s)

PATH and Mozambique National Institute of Health, Ministry of Health

Background

In recent years, Mozambique has been affected by extreme weather events of increasing frequency and severity. There is a large gap in knowledge about the existence of a functional system/platform to manage climate data—including the level of recording, periodicity, possible reasons for reporting (or not), and the flow of data collection, analysis, and use—at the national health system level. To address this gap, this study was conducted to (1) describe current practices for sharing climate data to inform infectious disease control in Mozambique, (2) identify barriers to and facilitators for using climate data for preparedness and response to climate-related infectious disease outbreaks, and (3) describe actions or interventions underway by the national health system and nongovernmental organizations (NGOs) to improve sharing and use of climate data for outbreak preparedness and response. Cyclone Freddy in 2023 was used as a case study.

Methodology

The study used a mixed-methods design involving a literature review and in-depth interviews with 29 key informants that included representatives of government bodies, multilateral agencies, and NGOs. Individual interviews (either remote or in person) were carried out using a semistructured questionnaire designed for each type of participant. As part of the data collection and analysis process, the interviews were recorded and transcribed in Microsoft Word. Two researchers listened to each audio recording and then reviewed the transcript to ensure accuracy. A triangulation approach was used to validate data obtained from interviews and documents. A content and thematic analysis method was applied to analyse the data.

Key Findings

There is no specific platform or system for integrating climate data into the national health system. Data on notifiable diseases is collected using two platforms - the electronic Integrated Disease Surveillance and Response (e-VIDR) system and the Health Information System for Monitoring and Evaluation (Sistema de Informação de Saúde para Monitoria e Avaliação (SIS-MA). Using the experience of Cyclone Freddy as a case study, several barriers and facilitators were identified related to how climate data is shared and used to inform the national health system's preparedness and response to climate-related infectious disease outbreaks. The most notable barriers were the poor geographical coverage of the hydro-meteorological network, lack of systematic records of the impact of extreme weather events, lack of a specific platform for integrating climate data into the national health system, the dependence on the National Institute of Meteorology (Instituto Nacional de Meteorologia (INAM) to provide climate data, and the dysfunctionality of the e-VIDR platform due to problems in synchronizing and updating the software, lack of electricity in some health facilities, and poor training of staff expected to use the platform. Identified facilitating factors were the existence of multiple policies that mention aspects related to the intersection between climate change and health, and the existence of health data management platforms. Although still in an early stage, some interventions are already being implemented by the national health system and partners to improve the sharing and use of climate data to prepare for and respond to outbreaks of infectious diseases in the country. This includes the National Institute of Health (Instituto Nacional de Saúde (INS) National Health Observatory dashboard for climate-sensitive diseases and an early warning system that integrates climate and epidemiological information currently being piloted in selected provinces.

Discussion

The information provided by the study participants is in line with what has been mentioned in the literature, which suggests that INAM is primarily responsible for producing and supplying meteorological and climatic information to different sectors, including the health system in Mozambique. However, although the literature and the study participants agree that the health sector has access to INAM's data, there is no clarity on how this is handled within the national health system, since the data collected in the main data platforms of the national health system (SIS-MA and e-VIDR) relate only to the incidence of diseases and do not include climate data. This suggests that climate data may not be considered in planning and decision-making for infectious disease control within the national health system in Mozambique. The Ministry of Health (Ministério da Saúde (MISAU) and the National Institute of Health in Mozambique in the study *Assessment of Vulnerability and Adaptation to Climate Change in the Health Sector in Mozambique* align with what was mentioned by the study participants related to the poor geographical coverage of the country's hydrometeorological network as the main challenge or barrier to the production and use of climate data. The existence of policies that mention climate change and health is considered as one of the main facilitating factors, corroborating the results of the study conducted by the National Institute of Health, the United States Agency for International Development (USAID), and Chemonics International. The literature corroborates the findings mentioned by the study participants regarding the ongoing efforts in the health sector. In fact, the national health system and its partners are implementing interventions to enhance the sharing and use of climate data to prepare for and respond to infectious disease outbreaks in the country. Some of those efforts include the World Health Organization's (WHO) support to the MISAU and the National Institute of Health to enhance the national health system's capacity to develop a health-sector climate change adaptation plan, and the revitalization of the Public Health Emergency Operations Center (Centro Operativo de Emergências em Saúde Pública (COESP) established for COVID-19, to be used now for all emergencies, including climate-related emergencies. According to the Ministry of Land and Environment, Mozambican government institutions are taking measures to adapt to climate change, reduce risks, and increase resilience in communities, including the use of climate data.

Recommendations

The study resulted in the following recommendations: (1) leverage the existing National Health Observatory to ensure access, integration, and analysis of climate and health data to inform decision-making for preparedness and response to climate-related infectious disease outbreaks; (2) strengthen early warning systems for extreme weather events and link those with seasonal disease data to help public health services implement early measures to mitigate disease outbreaks—for example, raising community awareness during periods of greatest risk; (3) strengthen the capacity of the health system by training health professionals on the health risks associated with climate change to incorporate climate considerations into decision-making; (4) strengthen the collaboration between MISAU, other government entities, and partners to make concerted efforts to finalize and operationalize the contingency plans for emergencies that are currently in process of development; and (5) conduct further research and documentation of lessons learned to gain more knowledge on how best to integrate climate data to prepare and respond to outbreaks of infectious diseases in the country.

USE OF NOVEL LOW-COST TECHNOLOGIES TO REDUCE THE BARRIERS IN VECTOR-BORNE DISEASE FORECASTING IN THE PERUVIAN AMAZON

Authors

Gabriel Carrasco-Escobar, Paloma M. Carcamo

Affiliated Institution(s)

Health Innovation Lab, Alexander von Humboldt Tropical Medicine Institute, Universidad Peruana Cayetano Heredia

Background

Vector-borne disease (VBD) incidence in the Americas has been increasing in the last years, with almost 3.5 million reported cases of arboviroses reported in 2022, a 119% increase compared to reported cases in 2021. In Peru, the situation is just as concerning – for instance, dengue cases reported thus far in 2023 are 365% higher than the average for the last five years. Although rarely fatal, VBD cause significant burden; one study estimated the cost of an individual episode of dengue in Peru at US$105. Diseases like malaria, once close to elimination are resurging, causing significant burden especially in the Amazon. Previous studies have identified climate factors driving the spread of these diseases, but there are currently no publicly available climate-based forecasting models for evidence-based policy-making to mitigate the impact of VBD. Furthermore, climate and environmental data are not currently available at the required resolution in the country. There are no easily accessible tools for high-resolution data analysis with vector survey data. This project aimed to combine existing and new Earth observation data sources to create high resolution explanatory and forecasting models for dengue in Peru.

Methodology

This study, conducted in Peru, collected field data from ten villages in the Peruvian Amazon with varying levels of urbanization. We developed protocols to collect data from weather stations (wind speed and direction, temperature, relative humidity, precipitation, and atmospheric pressure), air pollution sensors (PM2.5 and PM10), and passive acoustic sensors (with recordings for biophony, geophony, and anthropophony) for five minutes every hour. Data collection commenced in May 2023 with consistent collection from weather stations, air pollution sensors,and acoustic recorders.

Additionally, we used drones to collect thermal and multispectral images of all communities every three months. We completed three drone surveys and obtained orthomosaics for all study villages. We standardized processing of drone-acquired images to build orthomosaics showing the spatial distribution of features of interest, such as water bodies that could serve as potential breeding sites or vegetation hot-spots.

In parallel, we extracted nationwide precipitation data from the CHIRPS database and land surface temperature from ERA5-Land, and sea surface temperature anomalies from NOAA, and obtained province-level dengue case reports from the Peruvian Center for Disease Control. We used these data to construct a Bayesian model with dengue cases as the response variable, assuming a negative binomial distribution. We included spatio-temporal random effects and lagged climate variables, and estimated parameters using INLA. We compared models to the baseline using goodness-of-fit measures including deviance information criteria, and differences in mean absolute errors.

Prior to starting work on the model, we convened a meeting with health authorities from the Loreto region to discuss their needs and concerns. They identified dengue, malaria, and leptospirosis as the infectious diseases of the highest public health concern. and specified requirements for a potential early warning system.

Key Findings

Descriptive analyses revealed that most dengue cases were reported in the coast and jungle areas, with a steep increase in case reports in recent years. Using a baseline model including natural region-specific monthly cyclic random effects, region-specific inter-annual random effects, and province-level spatial random effects and comparing multivariable models with lagged climate variables, we found that a model including mean temperature at lag 2, mean precipitation at lag 0, and anomalies in SST at region 3 at lag 5 had the lowest MAE and DIC. However, predicted values using this model still did not adequately fit observed data, particularly for recent years. Exploration of the data showed that specific geographic areas are uniquely susceptible to anomalies, in precipitation and temperature due to El Niño, which suggests that it might be useful to attempt separating the country into clusters based on climate patterns, or perhaps fitting a separate model for the northern coast of Peru, which is uniquely affected by El Niño.

Discussion

We will continue our work to find a model that accurately predicts dengue outbreaks in the country.Future approaches may include creating geographic clusters based on shared climate patterns and including cluster-specific effects in the model, fitting separate models for these clusters, or using different models such as zero-inflated or DLNMs. Once we have benchmarked our model for dengue, we will use the same workflow to fit models for other climate-sensitive infectious diseases in Peru. Furthermore, we will continue collecting data in Loreto. Once we have a year's worth of data, we will use these observations to test for biases in the climate reanalysis databases, and to build a comprehensive model at a more granularlevel for the region of Loreto.

The study demonstrated the feasibility of deploying low-cost technologies for Earth Observation and remote sensing data to support infectious disease surveillance, including monitoring of vector breeding sites, in a tropical rainforest setting, and established robust protocols for data collection and processing. Obtaining fine-scale data is crucial to generating modelswhose output will be usefulto health authorities deciding where to allocate very limited resources. Building robust forecasting models for climate-sensitive infectious diseases is a challenge, especially when workingin a heterogeneous setting like Peru. Various approaches remain unexplored. Providing authorities with early warnings for potential outbreaks with sufficient advancetime and at the local spatial resolution will be an invaluable tool in mitigating the impact of these diseases on communities at risk.

THE IMPACTS OF CLIMATE CHANGE ON SPATIO-TEMPORAL DISTRIBUTION OF DENGUE AND MALARIA AND ITS IMPLICATIONS ON DENGUE CONTROL AND MALARIA ELIMINATION IN NEPAL

Authors

Dr Meghnath Dhimal[1,2], Dr Bipin Kumar Acharya[2,3,4], Bishal Dahal[1], Sailaja Ghimire[1,2], Uttam Pyakurel[5], Dr. Gunaraj Dhungana[1], Dr. Mandira Lamichhane Dhimal[2,6], Prof. Dr. Rajeev Shrestha[2]

Affiliated Institution(s)

1. Nepal Health Research Council, Kathmandu, Nepal.
2. Dhulikhel Hospital, Kathmandu University School of Medical Sciences, Kathmandu, Nepal.
3. Nepal Geographical Society, Kathmandu, Nepal.
4. Nepal Open University, Kathmandu, Nepal.
5. Epidemiology and Disease Control Division (EDCD), Kathmandu, Nepal.
6. Policy Research Institute (PRI), Kathmandu, Nepal

Background

Nepal's diverse geography, ranging from low-lying plains to high mountains, has a significant influence on climate and ecosystems, which, in turn,affect disease vectors and transmission patterns. Climate change, especially the rise in temperature, plays a crucial role in shaping the behaviour of disease-carrying vectors and the transmission of pathogens. Malaria represents a significant global health burden, with its distribution influenced by climate change. Dengue, a rapidly spreading viral disease, has been increasingly reported in Nepal, with severe outbreaks in recent years. Both malaria and dengue are climate sensitive mosquito-borne disease and are endemic to Nepal. Malaria is transmitted by Anopheles mosquitoes and dengue fever virus is transmitted by Aedes mosquitoes. This research focuses on understanding the impacts of climate change on the spatial distribution of dengue and malaria vectors in Nepal and the implications for disease control and elimination.

Methodology

This study employs machine learning techniques and publicly available data to model the present and future distribution of dengue and malaria vectors in Nepal. We carried out search to locate occurrence of vector of dengue and malaria in Nepal. Our research involved searching various databases such as PubMed (https://pubmed.ncbi.nlm.nih.gov/), Google Scholar (https://scholar.google.com/), and the Global Biodiversity Information Facility (https://www.gbif.org/). About 78% data were geo-coded with latitude and longitude information. In addition to collation of dengue and malaria vector data we also searched in gbif portal for the additional point.Altogether we were able to collect 206 number of geo-locations for malaria vector and 3045 locations for the dengue vector. The study employed an ensample approach to predict both the current distribution and future changes in the spread of dengue and malaria in Nepal. Using three well-known and widely used machine learning algorithms; Random Forest (RF), Boosted regression trees (BRT) and Maxent were fitted using the sdm package in R. To evaluate the model performance, we divided the geo-location data into training and test set in the proportion of 70 and 30 respectively using the bootstrap sampling, repeating this process ten times to gauge uncertainty in the models. We used gridSample of dismo package for the spatial filtering. The total geo-location of dengue vectors 1000 were reduced to 68 after the spatial filtering for malaria vectors and 3040 location dengue vectors to 148. We selected 19 bioclimatic layers as predictor input in the model fitting. To address this the multi-collinearity, highly collinear variables above a threshold of 0.89. Recognizing the influence of factors beyond climate variables, we added NDVI and Night Time Light (NTL) to uncorrelated bioclim layers. The Area Under the Curve (AUC) was calculated to evaluate model performance, and standard deviation (sd) map was computed to assess the uncertainty in model prediction from the 30 sub-models. To assess the potential changes in spatial distribution of dengue and malaria vector, the probability of occurrence in raster layers were converted into the presence and absence map by computing the threshold from maximising the sensitivity and specificity. Finally, the presence class from base year was simply subtracted from both time periods and scenarios resulting in the potential change map with class gain,loss and stagnant. The final output maps were prepared in ArcGIS.

Key Findings

The results reveal a considerable environmental suitability for both vectors,with about 46% of the country being conducive to dengue transmission and 48% for malaria vectors. Key factors shaping distribution of dengue include climate variables like temperature seasonality and mean annual precipitation, as well as human activities, represented by NTL data. In the case of malaria, the study identifies a spatial association between transmission risk and three critical factors: mean annual precipitation, temperature seasonality, and Normalized Difference Vegetation Index (NDVI). Increased mean annual rainfall is strongly correlate with a higher risk of malaria transmission, peaking when annual precipitation falls within the range of 100-200. Similarly, rising temperature seasonality is linked to an elevated risk. For dengue vectors, there is a positive spatial association with NTL up to a value of 3500, indicating a growing risk with higher NTL values. However, this risk diminishes as NTL values continue to rise, showing a negative association after the certain threshold. Additionally, there is a negative association with precipitation during the coldest quarter but a gradual positive association with the mean temperature of the driestquarter. The research predicts an expansion in the geographic areas suitable for both dengueand malaria vectors,with a more pronounced increase expected in worst scenarios (4-5°C) due to more significant temperature rise compared to the optimistic scenarios (1.4°C) for both time periods.

Discussion

Our findings underscore the intricate interplay of climate and environmental factors in shaping the distribution and transmission dynamics of these diseases. This research contributes to a better understanding of the spatial patterns and environmental drivers of dengue and malaria in Nepal, providing valuable insights for evidence-based policymaking and disease control strategies. The results also emphasize the importance of considering climate change in disease modelling and control efforts, as it has the potential to significantly impact disease transmission patterns and ultimately to dengue control and malaria elimination efforts in Nepal.

Recommendations

The use of climatic data for forecasting of potential outbreak and evidence informed decision making may contribute towards dengue prevention and elimination of malaria in Nepal.