J Nepal Health Res Counc 2025 April-June; 23 (67):I-IV

Addressing Health Risks of Climate Change through Digital Transformation in Nepal

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Climate change is a public health crisis that demands urgent, transformative action. Based on the commitments made by 50 Ministries of Health at the 26th Conference of Parties (COP26) in Glasgow, UK,[1] the Alliance for Transformative Action on Climate Change and Health (ATACH) was formed. Nepal is also a member of ATACH.[2] The main aim of ATACH is to support countries in building climate-resilient and decarbonized health sectors. Nepal signed the Male Declaration on building climate-resilient health systems in 2017 and made further commitments at COP26 for developing climate-resilient and low-carbon health systems, ensuring funding for health. As a part of this commitment, Nepal conducted climate change and health vulnerability and adaptation assessment (V&A)[3], prepared costed health national adaptation plan (HNAP) for 2023-2030[4] and carried out a baseline assessment of greenhouse gas emissions from the health sector, which shows 4.1% of national emission. Nepal has incorporated health in the National Adaptation Plan (2021-2050). [5] Very recently (in May 2025), Nepal submitted its third National Determined Contribution (NDC 3.0) to United Nations Framework Convention to Climate Change (UNFCCC).[6] One of the common activities identified in these policy documents is developing predictive models for climate-sensitive diseases. For example, the target of NDC 3.0 is that by 2030, climate-sensitive disease surveillance will be strengthened in 134 sentinel sites, expanding to all municipalities by 2035.

Although Nepal has made significant achievements in reducing the burden of vector-borne diseases in the country, some vector-borne diseases such as dengue, malaria, and visceral leishmaniasis are expanding in previously considered non-endemic areas of highlands. Several studies[7-11]show effects of climate change on the expansion of vector-borne diseases in the highlands of Nepal. Both climatic and non-climatic factors are responsible for the transmission of vector-borne diseases. Developing early warning system using climatic and non-climatic factors may contribute to the prevention and control of vector-borne diseases.[12] In order to predict epidemics of climate-sensitive diseases and risks, digital transformation can offer a significant contribution by enabling more efficient resource management, facilitating the development of innovative solutions, and improving evidence-informed decision-making processes. Digital transformation can play a crucial role in data security and privacy; promoting digital literacy and inclusion; improved data analysis and modeling; developing sustainable digital infrastructure; developing robust regulatory frameworks, enhanced disaster preparedness; fostering collaboration and knowledge sharing, and evidence-informed decision making. [13]

Digital technologies and data analytical approaches such as modelling applying machine learning approaches enable the analysis of large, complex datasets to identify climate-driven trends in dengue transmission and to design precise intervention strategies. By combining meteorological and environmental variables such as temperature, rainfall, humidity, land cover and human footprint —with historical case records, digital platforms including modelling can generate real-time surveillance dashboards and geographic “hotspot” maps that forecast outbreak risk and guide proactive vector-control measures. These systems also facilitate community engagement through mobile and web applications that alert residents to impending risks, collect crowdsourced reports of mosquito breeding sites, and disseminate tailored health-promotion messages. Furthermore, predictive models derived from these data help public health authorities allocate limited resources—such as insecticide spraying or clinic staffing—to areas with the highest projected need. Finally, shared digital repositories support cross-jurisdictional collaboration, allowing countries to exchange data and best practices for a coordinated regional response to dengue in a changing climate.

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Dengue is an emerging public health problem with major outbreaks each year, with reports of more than 50,000 cases and several deaths each year. The escalating incidence of dengue fever necessitates the development and implementation of an effective digital monitoring and Early Warning Response System (EWRS). This initiative leverages initial support from the Climate and Health project at the HISP Centre, University of Oslo, funded by the Wellcome Trust, for a feasibility study and pilot in Nepal, focusing on dengue fever as a starting point for developing early warning system using meteorological data in combination with health data. This initiative is in response to the increasing cases of dengue in Nepal over the last two decades, with the long-term goal of establishing a digital system to inform governments and relevant stakeholders on health challenges caused by climate change. The Climate-Health project funded by the Wellcome Trust develops an integrated, real-time system which is including machine learning modelling and bringing together meteorological data (temperature, rain, humidity, etc.) and health surveillance data, and potentially also other types of data such as environmental data, to predict and respond to climate-sensitive diseases like dengue. Both popular impression and data over the last 20 years indicate that dengue cases have been spreading from the plains, through the hills towards the mountains, and that climate change may be an important driver, together with, of course, the movement of people. Given the focus on altitude-based climate zones in Nepal, three districts on the plains, hills, and mountains, respectively, were selected for the pilot study, in addition to the capital Kathmandu. The pilot study was carried out in close coordination with the Ministry of Health and population (MoHP), Department of Hydrology and Meteorology (DHM), Nepal Health Research Council (NHRC), Planetary Health Research Centre (PHRC), and academic institutions. Moreover, it serves to enhance the initial "action line" concerning surveillance and monitoring outlined in the Belém Health Action Plan. By integrating forecasting and automated alerts within DHIS2, it establishes a foundation for the nationwide expansion of building a climate-resilient health system. The upgraded Nepal's DHIS2 platform, which is used for health data in Nepal, Version 40 is integrated with the modelling platform called Climate and Health Analytical platform (CHAP).[14] In this integrated climate and health platform, the DHIS2 is harmonising data from various data sets (health, climate, environmental, etc.) and feeding them into CHAP for analysis. CHAP is then feeding the results back to DHIS2 for analytical output in dashboards, maps, etc.

The preliminary results provided important lessons on what worked and what did not work. The first lessons was that only using data from the four pilot districts for modelling in CHAP did not provide good results because cases and data points were too few for the model to learn from. Then, dengue data from all health facilities in seven provinces were imported, and with several thousand data points, the 'learning' made significant improvements when applied for prediction in one area. Analysis of the pilot districts showed that results are depending on altitudinal variation and case history. In some of the municipality, the cases are accurately predicted in the different phases of the outbreak. For example, Gokorneshowor municipality from Kathmandu and Byas municipality from Tanahu districts. However, in many municipalities, prediction did not work, reflecting poor predictive power when there is no long history of cases – too few data to learn from. This situation is mostly found in the municipalities where dengue has been recently introduced. Similarly, while in geographically homogenous areas such as Kathmandu and Chitwan the modelling worked well, in highly altitudinal diverse districts such as Rasuwa and Tanhau it did not predict well. These preliminary findings suggest that relatively homogenous areas with some case history are well suited for prediction and more generally the need for micro-level prediction. Furthermore, to address low data points in time (history of cases), 'data driven' approaches based on cases may not work and Vulnerability Assessment (VA, knowledge-based approaches) may be applied. The VA approach may include the use of suitability indicators based on climate, environmental, and population data known to be factors important for mosquito breeding and for vector borne diseases to spread in the population. Results can then be displayed in maps showing risks by area and time of the year, which can then be used for public awareness and preventive action. An interesting development will be to see how modelling in areas with dengue cases can be used to inform risk assessment in areas with emerging, few, or no dengue cases (yet).

The deployment of a climate-informed Early Warning Response System using CHAP directly contributes to the objectives of COP30 and the Belém Health Action Plan by creating integrated, interoperable data structures that encompass both meteorological and epidemiological data. Additionally, it supports enhanced real-time monitoring capabilities, thus enabling anticipatory action. In this regard, the pilot program not only achieves national health security objectives but also enables the broader international push toward the creation of climate-resilient health systems. It is essential to scale up this climate and health program to all 753 municipalities, and to generate significant evidence not just on dengue and climate, but also in many other areas related to climate and health, thus creating a truly climate-resilient health system. The following are suggested ways forward for promoting digital solutions using CHAP integrated with DHIS2 for addressing the health threats of climate change in Nepal

Local Contextualization Is Important

Adapting data input and output to CHAP in DHIS2 to the Nepali (Bikram Sambat) calendar will ensure perfect alignment with government planning cycles and secured end-user buy-in.

Multistakeholder Coordination & Collaboration

It is essential to convene Ministry of Health & Population, Department of Hydrology and Meteorology, and academic partners—especially where we have limited resources and data sources are fragmented. In the absence of formal data-sharing agreements and regular coordination meetings, consolidated datasets continued to be incomplete and disjointed. Multisectoral governance that works well is essential to facilitate access, harmonize formats, and improve overall data quality. Hence, a multi-sectoral technical working group led by the Ministry of Health and Population is important.

Non-Climatic Drivers Must be Included

Analysis showed that socio-economic factors like financing cycles, population movement (e.g., seasonal labor migration), water supply and sanitation coverage, land use patterns, and localized vector-control efforts also had significant effects on dengue transmission. By incorporating these socio-economic and operational considerations sequentially into the forecast models—and updating them regularly—we could improve forecast precision and decision usefulness.

Vulnerability assessment (knowledge-based approaches)

To address low data points in time (history of cases), 'data-driven' approaches may not work, & Vulnerability assessment (knowledge-based approaches) may be applied.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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