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Climate change and infectious disease research in Nepal: Are the available prerequisites supportive enough to researchers?

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ABSTRACT

Although Nepal has been identified as a country highly vulnerable to adverse health and socioeconomic impacts arising from climate change, extant research on climate sensitive infectious diseases has yet to develop the evidence base to adequately address these threats. In this opinion paper we identify and characterise basic requirements that are hindering the progress of climate change and infectious disease research in Nepal. Our opinion is that immediate attention should be given to strengthening Nepal's public health surveillance system, promoting inter-sectoral collaboration, improving public health capacity, and enhancing community engagement in disease surveillance. Moreover, we advocate for greater technical support of public health researchers, and data sharing among data custodians and epidemiologists/researchers, to generate salient evidence to guide relevant public health policy formulation aimed at addressing the impacts of climate change on human health in Nepal. International studies on climate variability and infectious diseases have clearly demonstrated that climate sensitive diseases, namely vector-borne and food/water-borne diseases, are sensitive to climate variation and climate change. This research has driven the development and implementation of climate-based early warning systems for preventing potential outbreaks of climate-sensitive infectious diseases across many European and African countries. Similarly, we postulate that Nepal would greatly benefit from a climate-based early warning system, which would assist in identification or prediction of conditions suitable for disease emergence and facilitate a timely response to reduce mortality and morbidity during epidemics.

1. Introduction

Although the role of climatic variables and associated environmental factors in exacerbating the spread of infectious diseases has been known for centuries, extensive research investigating the impacts of climate variability on infectious diseases soared towards the end of twentieth century (Hay et al., 2002; Linthicum et al., 1999; Patz et al., 1996). Abundant literature on climate variations and infectious diseases published over the last two decades has clearly demonstrated that climate-sensitive diseases, namely vector-borne and food/water-borne diseases are highly affected by climate variability and climate change (Lafferty, 2009; Shuman, 2010; Wu et al., 2016). Based on the evidence generated from extensive epidemiological studies, several American, European and some of the African countries have envisaged and implemented climate-based early warning systems for preventing potential epidemics of infectious diseases in the near future (Johansson et al., 2016; Semenza and Menne, 2009; Shaman et al., 2017; Thomson et al., 2006).

In the context of Nepal, despite a high prevalence of climate sensitive infectious diseases, limited evidence is available on the effect of climate change on infectious diseases transmission. A systematic review on climate change and vector borne disease in Nepal published in 2015 identified 8 studies that have examined the association between vector borne diseases and climate variables (Dhimal et al., 2015). However, most of these studies were entomological studies that explored spatio-temporal distributions of disease vectors, and offer little epidemiological insights on the risk of infectious disease incidence in changing climate. Although the primary objective of this paper is not to synthesize current evidence on climate variability and infectious disease in Nepal, a brief summary of updated evidence has been presented in Table 1.

In this opinion paper, we identify challenges with basic

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Table 1
Summary of updated evidence on the impacts of climate change on infectious disease in Nepal.

Study	Study site	Study period	Disease	Methods	Evidence on climate change impacts
Bhandari et al. (2012)	Jhapa district	1999-2008	Diarrhoea	Time series (ARIMA model)	Despite a significant correlation, temperature was not found to be a predictor for diarrhoea incidence.
Acharya et al. (2018)	Nepal	Not mentioned	Dengue	Spatiotemporal analysis (maximum entropy ecological niche modelling)	Under the different climate change scenarios, dengue in Nepal is likely to shift towards higher elevation region.
Tuladhar et al. (2019b)	Chitwan district	2010-2017	Dengue	Time series (negative binomial models)	The incidence rate ratio of dengue cases was found to rise by more than 1% for every 1 °C increase in minimum temperature.
Tuladhar et al. (2019a)	Upland hilly and lowland terai	2015-2016	Dengue vectors	Entomological survey (gamma regression)	Temperature and rainfall effect showed a more significant influence on vector indices compared to humidity.
Bhandari et al. (2020)	Kathmandu district	2003-2013	Under 5 diarrhoea	Time series (Quasi-Poisson regression with distributed lag linear model)	Maximum temperature and rainfall were found to be significantly associated with childhood diarrhoea, with an additional 1357 (UI: 410-2274) climate attributable diarrhoea cases projected by the year 2050 under low-risk scenario of climate change.

prerequisites that might be hindering the progress of climate change and infectious disease research in Nepal. We highlight key problems in the public health agency that need immediate attention, to support public health researchers in generating evidence to guide relevant public health policy formulation for mitigating the impacts of climate change on human health in Nepal.

2. Climate change vulnerability in Nepal

The land topography of Nepal is highly variable, ranging from high altitudes in the Himalaya Mountains in the north-western border area, to the low south-eastern plain at around 300 m above sea level (World Atlas). This range of altitudes strongly influences climate variability across the country, which has a total surface area of 14, 7181 sq. km and extends across a short latitudinal distance, an average north–south width of 140 km (Fig. 1). The lowland region of the south-eastern plains has a warm and humid subtropical climate with summer temperature between 22–27 °C, dropping to 10–15 °C in winter. The high hills in the northern belt are considerably colder, ranging between 5–15 °C during the summer with winter temperature dropping below zero (McSweeney C et al., 2012). A vulnerability assessment report on climate change effects in Nepal suggests that mean annual temperature of Nepal will increase by 0.5 °C–2.0 °C by the 2030s and 1.7 °C–4.1 °C by the 2060s, under a high emission scenario (NCVST, 2009). The rate of warming in the Himalayan region has been reported to be greater by 0.06 °C per year than the average warming rate at global scale (Shrestha et al., 2012). A recent landmark report on the assessment of climate change impacts on the Hindu Kush Himalaya region has highlighted that the livelihood of almost 2 billion people (including 30 million Nepali people) inhabiting this region are under serious threat as a consequence of natural and anthropogenic climate change (Wester et al., 2019). The report highlighted increased environmental, social and economic vulnerability among people living in this region. In the context of Nepal, issues like rapid melting of the Himalayan glacier, poor nutrition, food insecurity and increased frequency of extreme rainfall events (an increment of 31% by 2021–2050 for Representation Concentration Pathway 4.5 and 88% by 2071–2100 for Representation Concentration Pathway 8.5, for Langtang basin of Nepal) were identified a major concerns (Wester et al., 2019).

With a Human Development Index (HDI) score of 0.578 and a Gross National Income of US$2,472 per capita, the socioeconomic development status of Nepal is below the average value for South Asian countries (HDI = 0.638) and only above Pakistan (HDI = 0.562) and Afghanistan (HDI = 0.498) among the countries in the Hindu Kush Himalaya region (United Nations Development Programme, 2018). Given the unique geophysical condition of Nepal in the Hindu Kush Himalaya region (the so called 'third pole' of the planet), its highly diverse climatic conditions (tropical to tundra), rapid population growth, unplanned migration to urban cities and a high level of poverty, climate change is likely to exacerbate the burden of climate-sensitive infectious diseases in Nepal (Government of Nepal National Planning Comission, 2014; Ministry of Environment, 2010).

3. Climate sensitive infectious disease: knowledge gaps

Nepal is afflicted by various climate-sensitive infectious diseases including malaria, dengue, visceral leishmaniasis, Japanese encephalitis and infectious diarrhoea caused by pathogens including bacteria, parasites and viruses (Ministry of Health and Population, 2018). Although the National Adaption Programme of Action (Nepal) to climate change in 2010 (Ministry of Environment, 2010) highlighted inadequacy of research on the impacts of climate change on infectious diseases transmission to inform evidence-based decision making, no significant progress has been achieved over last eight years (Dhimal et al., 2017). National Adaption Programme of Action identified the public health sector as one of the sectors vulnerable to future

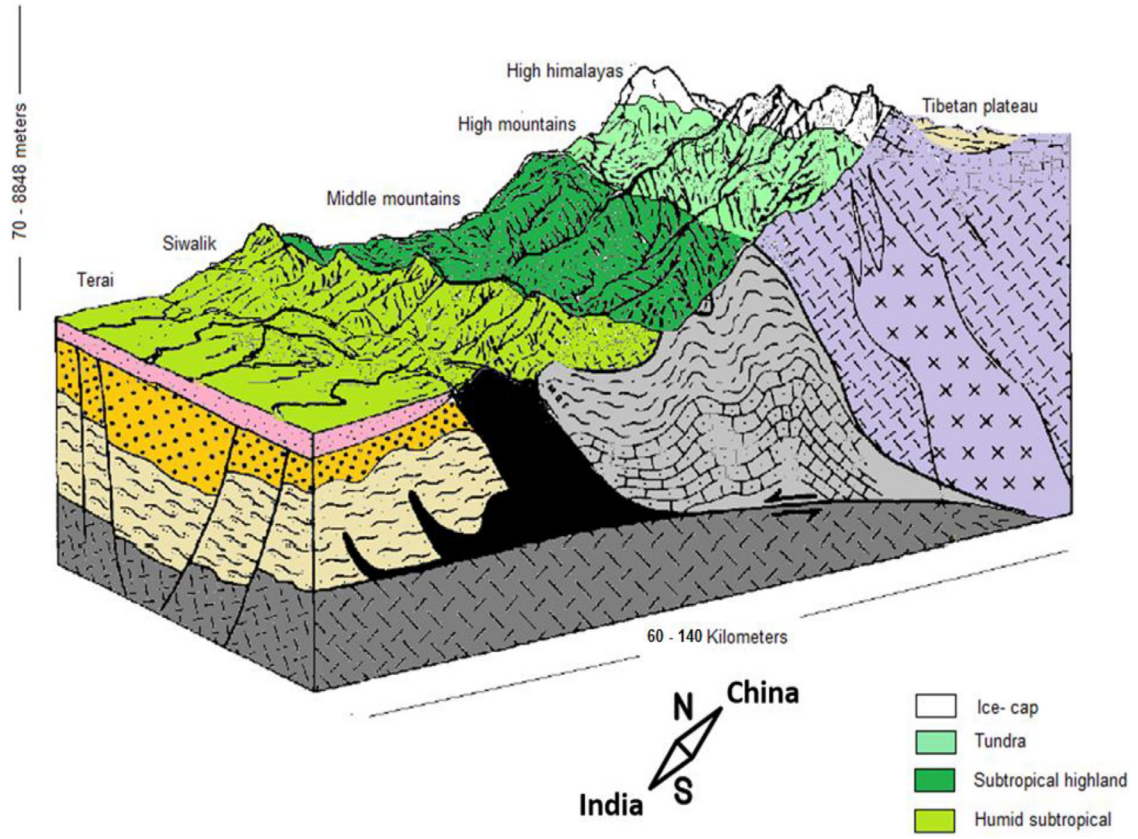

Figure 1. Cross-section of Nepal's topography with corresponding climate types.

climate change related events. In an effort to promote climate change research in Nepal, National Adaption Programme of Action recognised the importance of an integrated network of resources and links to databases from various sources, and this led to the establishment of the Nepal Climate Change and Development portal. However, the portal in its current configuration may support environmental aspects of climate change research but does not offer the necessary support to epidemiologists and public health researchers, as it does not include links to major infectious diseases databases and demographic data sets in Nepal (Ministry of Science Technology and Envrionment, 2014). The recent unprecedented outbreak of dengue fever in Nepal, killing 6 people and hospitalizing more than 8000 (in June–September 2019), has demonstrated that Nepal lacks preparedness and resources to manage the threat of climate-sensitive infectious diseases (Wallen, 2019.). Dengue fever was reported in Nepal for the first time in 2004, and since then it has been reported every year during the monsoon season, which indicates that rainfall can be an important predictor for dengue infection. The existing infectious diseases control approach in Nepal focuses on disease-specific vertical programs, and has ignored the opportunity to design and utilize a climate-based early warning system for prevention and control of infectious diseases. Hence, it is important to conduct public health research to assess the health risk of climate change on vector-borne and food/water-borne diseases in Nepal, identify the attributable contributions from climate change, project the future challenges due to climatic and demographic changes, and improve the capacity of existing health care system in Nepal to deal with such challenges.

3.1. Infectious diseases data sources

The Nepalese Department of Health Services, under the Ministry of Health and Population, has dedicated divisions to collect infectious diseases data and maintain a national registry of infectious diseases in Nepal (Government of Nepal Ministry of Health). The Integrated Health Management Information Section and the Epidemiology and Disease Control Division work in tandem to collect data and relevant information on infectious diseases from public health facilities and some private facilities (<50% coverage) across the nation. The Epidemiology and Disease Control Division in particular is responsible for carrying out routine hospital-based sentinel surveillance of major notifiable diseases (malaria, kalazar, dengue, scrub typhus, acute gastroenteritis, cholera, and severe acute respiratory infection), across public health facilities participating in the surveillance system through a weekly reporting mechanism (average coverage rate is above 80%). Besides this there is an Early Warning and Reporting System and active syndromic surveillance of diseases after disaster events is regularly carried out by the Epidemiology and Disease Control Division (Government of Nepal Ministry of Health and population, 2016). In addition to these potential sources of infectious diseases data that are under the direct control of Epidemiology and Disease Control Division, several vertical surveillance programmes especially for immunization preventable diseases are in operation, mainly regulated by the World Health Organisation Immunization Preventable Disease division. Likewise, vertical surveillance of several other diseases of interest (i.e. of interest to funding agencies) are being carried out, mainly regulated by research and academic institutes in collaboration with external donor/funding agencies or foreign universities (Sharma et al., 2016).

4. Challenges for public health researchers

Unlike in developed nations, epidemiologists and public health researchers in low-income countries like Nepal face several challenges when conducting studies related to climate change and human health (Dhimal, 2008). Besides the poor economy, inadequate funding, political instability, shortage of trained staff and inadequate provision of capacity-building opportunity for public health researchers, there is an

additional barrier—poor quality infectious diseases datasets—that epidemiologists and public health researchers in Nepal have to overcome (Dhimal, 2008).

4.1. Infectious diseases data–related challenges

In order to shift from a surveillance and response strategy to a prevention strategy through establishment of a climate-based early warning system, an effective mechanism to systematically collect, analyse and interpret infectious disease data is indispensable (Morin et al., 2018). Among several intrinsic challenges commonly experienced in low and middle-income countries, public health data quality-related issues are a major hindrance to the progress of climate change and human health research in Nepal. Moulton et al. (Moulton and Schramm, 2017), in their recent assessment of the strengths of public health agencies in the United States, identified four core components of public health surveillance systems, which support climate change and health-related research and, adaptation to climate change. These are: appropriate indicators and data availability; an electronic system or network for data sharing and analysis; a skilled workforce; and supportive policies. They regarded good quality public health data being the back bone of an effective public health system. In the context of Nepal, several aspects of a utilitarian public health database are substandard or missing in certain cases. Environmental epidemiologists and researchers utilizing these datasets for research and health intervention purposes have to contend with issues such as: a lack of a centralized electronic database on infectious disease burden (which is routinely collected and dis-aggregated, daily or weekly); the unavailability of long-term historical data on infectious diseases epidemiology; poor quality existing health data; a lack of spatial data on disease incidence cases; and a lack of data linkage and sharing among data custodians and researchers (Gurung and Bell, 2013; Nori-Sarma et al., 2017).

The Epidemiology and Disease Control Division regularly dispatches reports on infectious disease epidemiology in the form of weekly bulletins with an objective to support decision-makers in identifying public health priorities and resource allocation. However, data made available through these reports are of limited use for secondary analysis by public health researchers and environmental epidemiologist, as the reports simply mention aggregated counts on disease burden. They have insufficient information on: disease onset dates, socio-economic and demographic characteristics, detailed spatial information, and the water quality or hygiene status of disease incidence locations. The best approach to identify climatic drivers of infectious diseases and estimate the effects of climate change on infectious diseases dynamics is epidemiological studies using empirical or mechanistic (process based simulation) statistical models (Metcalf et al., 2017; Wilson and Martha, 2005). However, the publicly available information on infectious diseases in Nepal does not support sophisticated statistical analysis of infectious disease patterns in relation to climatic drivers, to generate sufficient evidence and to guide climate change and human health-related policy formulation. Similarly, sources of data on immunisation coverage, vector density, and rodent density surveillance are limited to ad hoc surveys and research work carried out by the private sector, and are not easily accessible by public health researchers and policy makers.

4.2. Financial/economic challenges

Nepal has been heavily dependent on international donor agencies and philanthropic organisations for the conduct of health research since the commencement of the first-ever health research undertaken in Nepal in 1952 (Sharma et al., 2016). In the fiscal year 2018–19, the cluster-wise allocation of budget in the health sector for the Health Management Information System, disease survey/surveillance, and health research combined was 1% of the total NPR56.41 billion (1 NPR~ 0.0091 USD) budget allocated for the Ministry of Health and Population (FMoHP and NHSSP, 2018). Given the low financial capacity of the state to invest in health research and given also the absence of adequate research-based evidence on the health impacts of climate change in Nepal, Nepalese researchers are forced to try to attract international donors to invest in climate health research, which is challenging (Dhimal, 2008).

4.3. Public health capacity-related challenges

Public health professionals in Nepal are deprived of knowledge related to recent advancements in techniques and skills in the environmental health sector due to the lack of opportunity to upgrade their skills through appropriate training, including by attending international conferences (Mahat et al., 2013). Institutions in Nepal only offer general public health training, so that professionals and researchers interested in a specific field of public health, such as environmental epidemiology, will have to partially rely on the free sources of information, such as internet, in their attempt to compensate for inadequate training opportunities (Mahat et al., 2013). In addition, Nepal faces a shortage of skilled researchers capable of carrying out transdisciplinary public health research (Dhimal, 2008), primarily due to the preference of highly trained native researchers to settle in developed countries (Kattel and Sapkota, 2018).

4.4. Political challenges

Like any other aspect of the health sector, promotion of public health research in Nepal has been impeded by Nepal's ever changing political landscape (Chand and Kharel, 2105). Frequent changes in government have interfered with several national priorities, including public health policies such as promotion of the Planetary health in Nepal program established after the 2015 Gorkha earthquake (that resulted in 9000 deaths and left 18,000 injured) (Mishra and Adhikari, 2019). Although the Nepalese government has recognised the potential impacts of climate change on health in developing several policies and plans such as the NAPA, the Climate Change policy in 2011, and several other documents (Dhimal et al., 2017), implementation of these policies remains uncertain given that the country has continued to grapple with political uncertainties and frequent changes in government over the past two decades.

Despite these challenges, a handful of entomological and time series studies have attempted to estimate the association between climate change and infectious diseases in Nepal (Bhandari et al., 2012; Dhimal et al., 2014a,b). These studies have clearly demonstrated that vector-borne diseases such as malaria, lymphatic filariasis, and dengue, as well as food and waterborne diarrheal diseases, are highly associated with climate change (Bhandari et al., 2020; Dhimal et al., 2014a,b; Tuladhar et al., 2019b). However, attribution of these observations to climate change is still awaiting confirmation, which can only be achieved by carrying out well-designed epidemiological studies utilizing long-term surveillance data. Furthermore, the compounding effect of demographic changes and other non-climatic factors (social, economic and other environmental factors), along with climatic variation are likely to play important roles in future transmission of these diseases. Hence, future studies estimating the projected burden of these climate-sensitive diseases are necessary to allocate adequate resources for infection control and planning effective adaptation policy.

5. Future directives and priorities to promote climate change and infection disease research in Nepal

The latest lancet countdown report (2019) on health and climate change reported future climate scenarios to be more conducive and suitable for transmission of climate sensitive infectious diseases like dengue, malaria and cholera (Watts et al., 2019). Given, the increasing

threat of climate sensitive infectious disease and a paucity of epidemiological evidence to support public health decision makers in Nepal, we argue that following priorities should be addressed within next 5/10 years to support public health researchers in generating evidence to guide relevant public health policy formulation in the context of climate change on human health.

5.1. Strengthen Public Health Surveillance systems

We believe evaluation of the infectious diseases surveillance system as well as relevant public health data collection systems is necessary. Stakeholders, including the infection control division, the environmental health division, the national planning commission, researchers, and policy makers working in the public health sector of climate change and human health, should be consulted to identify their needs from the surveillance systems. Particularly, the quality of surveillance data and periodicity of data collection should be revised such that data available from these sources meets the minimum requirements for exploring attributable risk of infectious diseases to climate change, projection of future burden of diseases attributable to climate change, and the establishment of a climate-based early warning systems. Apart from disease surveillance, the system should extend its service to routine surveillance of arthropod vectors and effective vector control program to check spatiotemporal distribution of vectors. Public health division should encourage inter-sectoral collaboration and linkage of data from various sources to share information and data (health, meteorological, demographic, and socioeconomic data) between the data custodians, researchers, and policy makers.

5.2. Inclusion of additional climate sensitive infectious disease under the notifiable disease category

Given that it is feasible from a financial and technical point of view, we believe it is desirable to include information on additional epidemic-prone and climate-sensitive diseases such as salmonellosis, campylobacteriosis, meningococcal meningitis, enterohemorrhagic *E. coli*, shigellosis and viral causes of diarrhoeal and respiratory infections, in the routine surveillance system in order to better understand the impacts of climatic factors on infectious disease in Nepal.

5.3. Establishment of an integrated digital network of interdisciplinary experts to support data sharing and inter sectoral collaboration for public health research on climate change

In 2009, the European Centre for Disease Prevention and Control proposed an integrated network of epidemiologists, meteorologists, remote sensing experts, and entomologists to facilitate public health research in the climate change and human health sectors, and this led to the formation of the European Environment and Epidemiology (E^3) Network (Semenza and Menne, 2009). Similarly, the US Center for Disease Control and Prevention set up the National Environmental Public Health Tracking Network to support environmental health researchers by providing access to health data and environment data through a single platform (Center for Disease Control and Prevention). Establishment of such a network in Nepal could promote environmental health research and generate key evidences to guide policy on climate change and human health. As the Nepal Climate Change and Development portal is already in existence, linking data from Epidemiology and Disease Control Division, Integrated Health Management Information Section and the Central Bureau of Statistics to the portal could be a viable solution to some of the problems faced by public health researchers.

5.4. Public health capacity building, international co-operation and aid, and increasing funding sources

We believe public health courses in Nepalese academic institutions should switch their focus from a general Masters in Public Health programme to more specific fields such as environmental and occupational health, biostatistics and epidemiology, and health promotion to institutionalize climate change and human health adaptation research (Mahat et al., 2013). Provision of adequate training (for faculty staff from major health institutes of Nepal, for public health professionals and researchers from the Department of Health Services and the Nepal Health Research Council) should be arranged on a regular basis through faculty exchange programs with reputable universities in developed countries. Budget allocations for health research need a significant boost and the health sector budget allocation needs to be allocated with equal priority to various programs including environmental health research and infectious diseases surveillance. Inadequate funding from the state for research on environmental health and diseases surveillance can be compensated for to some extent by planning collaborative studies with universities in other countries on relevant climate change and human health projects based in Nepal.

5.5. Engaging community in infectious disease surveillance and climate change research programs

Evidence from previous studies on community engagement in public health surveillance and climate change research programs has highlighted the importance of social and cultural factors along with local knowledge in disease detection/reporting and adaptation strategies to deal with the effects of climate change (McClymont Peace and Myers, 2012; Ndiaye et al., 2003). Nepal has a strong community health volunteer network that has been successfully used to achieve several public health goals, including: improved maternal and child health outcomes; effective implementation of immunisation programs and; control of non-communicable diseases. This existing network of community health workers can be trained and deployed in surveillance of infectious diseases, in conjunction with epidemiologists. In our opinion, involvement of community members who are directly bearing the health effects of climate change in research can help generate enhanced localised evidence to improve adaptation policy in a specific context.

6. Concluding perspective

As envisioned in the 2013 World Health Report by the World Health Organisation, in order to achieve health goals and sustainable development goals, particularly the goal to take action to combat climate change and its impacts (Sustainable Development Goal 13), all countries including low and middle-income countries should be both consumers and producers of research (Dye et al., 2013). Given a quarter of the global burden of diseases can be attributed to various environmental risk factors (Prüss-Üstün and Corvalán, 2006), and given also the vulnerability of the Nepalese population to adverse impacts of climate change, promotion of epidemiological studies assessing the impacts of climate change on infectious diseases in Nepal is urgently needed. The difficulty of generalising about health outcomes from one setting to another, when many diseases have important local transmission dynamics that cannot easily be represented in simple relationships, further highlights the importance of conducting such studies in vulnerable countries like Nepal.

Impediments to the conduct of environmental health research in Nepal, such as political instability, can be expected to be overcome by the establishment of a stable government under the recently adopted federal system. Meanwhile, issues related to public health agencies, health care workforce capacity, and funding agencies need to be addressed urgently, to foster climate change and health research in Nepal and generate sufficient and updated evidence to guide health policy,

which accounts for the impact of climate change. To reiterate, evaluation of current notifiable diseases surveillance practice is desirable to improve the quality of infectious disease data so that this rich data source can be used by public health researchers and stakeholders. It would be advisable to also review: the frequency of reporting (preferably daily); completeness of reporting; inclusion of more public and private health service providers and; the possibility of collection of disaggregated data on the socio-economic, spatial, and demographic characteristics of cases.

South Asia (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) bears a significant proportion of the global burden of infectious diseases, which can be attributed to factors such as: a weaker health system capacity, rapid urbanization and land use, poor sanitation and hygiene, high population density, low socio-economic status and a higher vulnerability to climate change (Laxminarayan et al., 2017; Sen et al., 2017). The institutional capacity of this region, including its diagnostic laboratories and surveillance systems, are under resourced and often fragmented; hence they are less organised to support the establishment of early warning systems for epidemic-prone and climate-sensitive infectious diseases (Laxminarayan et al., 2017; Sen et al., 2017). Advancement in epidemiological techniques (in statistical and mathematical models) have led to optimism about holistic investigation and prediction for climate-sensitive infectious diseases, by making use of high quality observational data on climatic variables, disease incidence, spatial distribution, hygiene coverage, socio-economic status, land coverage, disease susceptibility, and the vulnerability index (Harley et al., 2011; Parham et al., 2015). Improved disease intelligence collection (integrated surveillance system), as well as cross-disciplinary and trans-border collaboration among South East Asian countries will be needed in future to curb the threat of climate change on infectious diseases transmission in this region.

CRediT authorship contribution statement

Dinesh Bhandari: Conceptualization, Methodology, Writing - original draft. **Peng Bi:** Conceptualization, Supervision, Writing - review & editing. **Jeevan Bahadur Sherchand:** Conceptualization, Supervision, Writing - review & editing. **Meghnath Dhimal:** Conceptualization, Supervision, Writing - review & editing. **Scott Hanson-Easey:** Conceptualization, Supervision, Writing - review & editing.

Declaration of Competing Interest

None.

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Supplementary materials

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