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Environmental Determinants of Malaria Prevalence and the Adaptation Strategies in Western Nepal

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ABSTRACT

Background: Current literatures seem devoted only on relating climate change with malaria. Overarching all possible environmental determinants of malaria prevalence addressed by scanty literature in Nepal is found apposite research at this moment. This study aims to explore the environmental determinants of malaria prevalence in western Nepal.

Methods: Cross-sectional data collected from community people were used to identify the environmental determinants of malaria prevalence in western Nepal. Probit and logistic regressions are used for identifying determinants.

Results: The results reveal that environmental variables: winter temperature (aOR: 2.14 [95% CI: 1.00-4.56]), flooding (aOR: 2.45 [CI: 1.28-4.69]), heat waves (aOR: 3.14 [CI: 1.16-8.46]) and decreasing river water level (aOR: 0.25 [CI: 0.13-0.47]) are found major factors to influence malaria prevalence in western Nepal. Besides, pipeline drinking water (aOR: 0.37 [0.17-0.81]), transportation facility (aOR: 1.18 [1.07-1.32]) and awareness programs (aOR: 2.62 [0.03-6.65]) are exigent social issues to influence malaria prevalence in Nepal. To be protected from disease induced by environmental problems, households have used extra season specific clothes, iron nets and mosquito nets, use of insecticide in cleaning toilet and so on.

Conclusions: Adaptation mechanism against these environmental issues together with promoting pipeline drinking water, transportation facility and awareness programs are the important in malaria control in Nepal. Government initiation with incentivized adaptation mechanism for the protection of environment with caring household attributes possibly help control malaria in western Nepal.

Keywords: Adaptation strategy; environmental changes; malaria; probit/logistic model; Nepal.

INTRODUCTION

Malaria remains one of the deadliest infectious diseases worldwide. It continues to be a serious public health problem in South Asian countries including Nepal.[1] A comparative trend analysis of regional malaria incidence in Nepal over the last half-century, the disease appears to be epidemic in western Nepal, reoccurring in every 15-20 years, and where climatic sensitivity is proven to be relatively high by several evidences.[2-3] High malaria cases are regularly confirmed especially in western Terai districts of Nepal bordering with endemic States of India, where malaria is in grave situation. More specifically, the mid- and far-western parts in Nepal are comparatively considered more environmentally sensitive.[4] Available evidences are limited with relating climatic variables with climatic indicators, ignoring the aggregate environmental and behavioral factors.[5] Therefore, this study seeks to comprehend the major environmental, socioeconomic and household behavioral determinants attributing malaria prevalence in western Nepal.

METHODS

Using primary data from household survey, a cross-sectional analytical study design was employed. A simple random sampling approach with systematic sampling with random start was used to select 420 households after obtaining a sampling frame. In-depth interviews among household heads were conducted using a semi-structured questionnaire incorporating environmental, socioeconomic and behavioral variables; maintaining both qualitative and quantitative aspect. The in-depth interview data were further supplemented by focus group discussions among health professionals and community residents using the key questions of original

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questionnaire for the validation of community level perceptions. Little needy information was also obtained from a review of documents from governmental and non-governmental sources. SPSS software program was used to compile the data and transferred into the STATA software program for the analysis. Logistic regression model was rigorously developed for the identification of the determinants of malaria prevalence in households. The study design is abridged in the conceptual framework (Figure 1).

Two districts in western Nepal, Jajarkot and Banke, were chosen because of the high level of incidence and prevalence of malaria in the area that connects high-mountain to Terai-region.[6] The districts have a variety of climates ranging from subtropical to an alpine. The specific cause of high occurrence of malaria in Terai, hilly and mountainous areas is not well reconnoitered in the literature. As a result, these areas considered one of most useful informative areas for this study's goal of identifying possible environmental determinants of malaria prevalence. Junichande and Veri Municipalities of Jajarkot, and Janaki and Nepalgunj Municipalities from Banke district were chosen based on the district public health official's recommendation and malaria case occurrence. Details about the study area and setting have also been explained in previously published paper.[7,8]

A pretested semi-structured questionnaire was used for data collection which was conducted from 18th March to 10th April 2018. The survey data was collected through face to face interview approach. The household heads or members of household who were aware of the environmental changes and health status participated in the survey. Aside from the household survey, four focus group discussions and KIIs with health professionals and local experts were held for the validation of the community people responses. Public health graduates were employed for data collection. They were dispatched to the study site after a one-day briefing on study objective and study tool. The sample households were chosen using a systematic sampling method with a random start. In each municipality, the first household was chosen at random, followed by every sixth dwelling. Between two consecutive households, the average distance is about 500 meters. Every day in the field, the field supervisor double-checked the accuracy and completeness of all the data on the filled questionnaire.

The information gathered was entered into EpiInfo and then transferred into STATA for analysis. When required, some of the variables were converted to dummy. By nature of the data to evaluate the malaria prevalence, multivariate models (Probit and logistic) were used to diagnose the potential factors attributable to influence malaria cases.

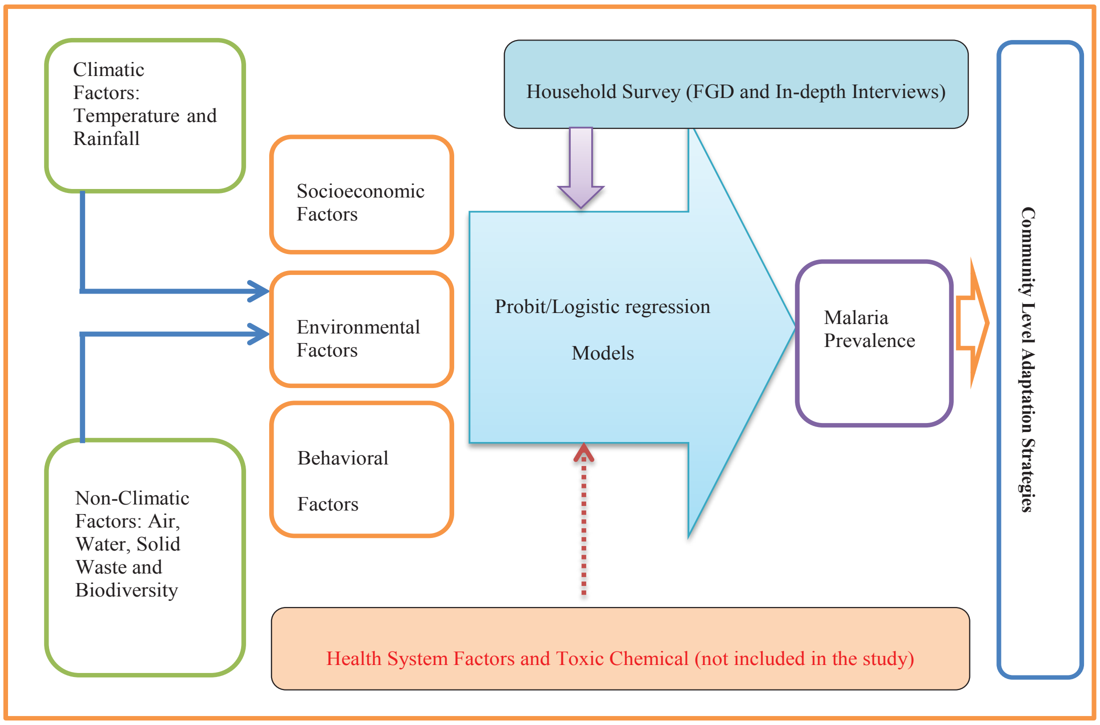

Figure 1. Conceptual Framework.

Here, the outcome variable Y is binary dependent variable, coding 1 for malaria prevalence in the households and 0 otherwise. So, probit regression model is used to find the probable environmental and other determinants of malaria prevalence. Hypothesized variables (dummy where necessary) used in the analysis are explicitly explained in table 1 with their expected sign based on the available literatures.

Written informed consent was obtained from the study participants during household survey and verbal informed consent was taken for focus group discussion. Participants' voluntariness was ensured in the study. This study obtained ethical approval from Nepal Health Research Council in Nepal (Ref. 138, 2018).

Table 1. Description of Hypothesized Variables attributable to malaria prevalence.

Description of Variables	Expected Sign	Mean	Std. deviation
Warmer winter temperature	+ve[9,10]	0.635	0.481
Increasing summer temperature	-ve [11]	0.714	0.280
Flooding	+ve [11]	0.440	0.497
Heat wave/loo	+ve	0.721	0.269
Polluting river water	+ve [12-14]	0.759	0.427
Non-flushed toilet type	+ve[15]	0.650	0.477
Piped drinking water	-ve	0.247	0.432
Distance to veterinary (Km)	+ve	5.103	6.510
Distance to motorway (Km)	Indeterminate	4.139	4.501
Distance to health post (Km)	+ve	2.773	1.982
Uneducated household head	+ve	0.530	0.499
Mud home structure	+ve	0.566	0.496
Not participated in awareness program	+ve[16,17]	0.607	0.290

RESULTS

In a publication devoted solely to descriptive analysis of the same dataset, the socio-demographic features of study participants were previously described.[7] To be more specific about malaria prevalence, 32 percent of the total number of homes surveyed (n = 420) were affected by the disease in 2018. Males made up 61 percent of individuals affected by the disease (Figure 2), with most of them working in agriculture and businesses. The average family size in the project regions is significantly larger (6.4) than the national average of 4.4.[18]

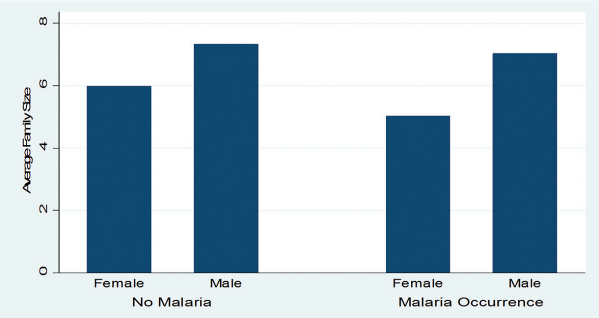

Figure 2. Malaria Occurrence by gender by family size.

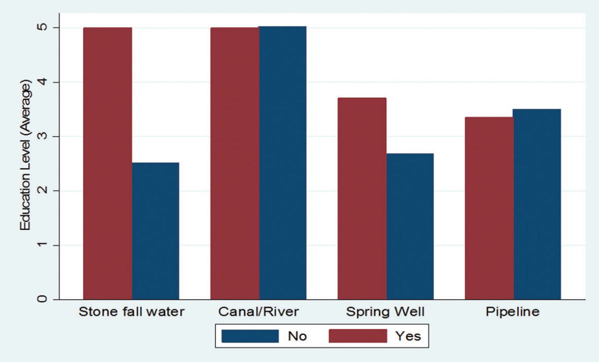

Figure 3. Malaria Occurrence or not by educational level and type of drinking water resources.

Occurrence of malaria among the households using clean and unclean cooking fuel is indifference in pattern. However, low education level is observed among the households facing malaria prevalence. Further, malaria afflicted households using wood as cooking fuel have relatively much lower level of education, compared to the households using clean fuel. Similarly, malaria afflicting households using canal/river as the major water source have high level of average education level among other sources of drinking water resources (Figure 3). Malaria-prone households using drinking water source of stone-water-fall have high level of educational difference compared to the non-afflicted households. This result showed that malaria cases fluctuate more relatively with drinking water sources than the household income level and its sources.

Table 2. Correlation Matrix.

	Mal	Wt	St	Fl	Ha	Wr	To	Dw	Vd	Dm	Dh	Ed	Hi	Ap
Mal	1													
Wt	0.25	1												
St	0.03	0.31	1											
Fl	0.23	0.38	-0.01	1										
Ha	0.05	-0.01	0.06	-0.09	1									
Wr	-0.25	-0.24	0.08	-0.12	0.18	1								
To	0.04	-0.1	0.06	-0.15	0.1	-0.02	1							
Dw	-0.09	-0.24	0.03	-0.44	0.08	-0.21	0.17	1						
Vd	-0.16	-0.43	0.05	-0.38	0.1	0.15	0.12	0.15	1					
Dm	-0.02	-0.33	0.01	-0.37	0.1	0	0.1	0.27	0.47	1				
Dh	-0.13	-0.22	-0.03	0.34	0.03	0.1	0.06	0.16	0.27	0.35	1			
Ed	-0.11	-0.04	0.03	-0.03	0	0.12	0	0.01	0.01	0.02	0.02	1		
Hs	-0.01	-0.35	-0.02	0.37	0.08	-0.12	0.29	0.34	0.2	0.26	0.16	0.02	1	
Ap	0.08	0.01	0.01	0.05	0.05	-0.12	0	-0.02	0.02	0.04	-0.07	0.14	0.06	1

Note: Mal: malaria, Wt: Winter temperature, St: Summer temperature, Fl: Flood, Ha: Hot air, Wr: Water in river, To: Toilet type, Dw: Drinking water sources, Vd: Veterinary distance, Dm: Distance to motorway, Dh: Distance to health post, Ed: Education categories, Hs: Home structure, Ap: Awareness programs

Possibility of multi-collinearity among the explanatory variables was analyzed with zero order correlation coefficient in Table 2, which shows that there is no multi-collinearity among the variables.

The relationship between malaria occurrence and environmental variables along with other control variables are explained by separating into two models where none of the household behavioral related factors were significant and relevant to explain in the model. The Model I explains the association of malaria occurrence environmental variables and the Model II presents the association of environmental and other all relevant control variables with malaria prevalence. The analytical explanation is based on the Model II of probit regression and odd ratios.

Among the environmental variables, increasing winter temperature, flood, and hot air are positively significant with malaria occurrence (Table 2). Warmer winter might increase the probability of survival environment for mosquitos, leading to higher chance of getting malaria occurrence. With precision and accuracy, if everything else held constant, a change of winter temperature from as usual to warmer condition increase the odds of malaria prevalence by 2.14 (95% C.I. = 1.003-4.567).

This study also shows that the probability of malaria occurrence is more likely to increase (adjusted odds ratio, aOR = 2.25, C.I. = 1.282-4.699) with the increase in the flood in comparison to the area unaffected by the flood. Higher the surface air temperature with heat waves below 35 degree Celsius[19], higher the probability of malaria occurrence is found with odds 3.143 (C.I. = 1.167-8.464) in a community compared to other communities which have not faced heat waves. Declining or drying the river and rivulets around the community seems less likely to increase the probability of malaria with odds 0.257 (95%CI: 0.138-0.479) in the study areas.

Concerning socioeconomic and other control variables to explain the malaria prevalence in western Nepal, pipeline drinking water source, excess to local veterinary services and uneducated household head are less likely to occur the malaria occurrence as specified the odds of 0.372 (C.I. = 0.170-0.815), 0.906 (C.I. = 0.827-0.992) and 0.638 (C.I. = 0.400-0.997), respectively, whereas distance to the motorway and no participation in awareness programs are more likely to increase probability of malaria occurrence as observed the odds of 1.189 (C.I. = 1.071-1.321) and 2.621 (C.I. = 1.031-6.658), respectively.

Table 3. Regression results for determinants of malaria.

Variables	Probit		Logistic
	Coefficients (Model I)	Coefficients (Model II)	Odds Ratio (95%C.I.)
Warmer winter temperature	0.397** (0.189)	0.443** (0.224)	2.140** (1.003-4.567)
Increasing summer temperature	-0.078 (0.275)	-0.094 (0.291)	0.835 (0.318-2.191)
Flooding	0.561*** (0.158)	0.547*** (0.190)	2.454*** (1.282-4.699)
Heat waves	0.769*** (0.290)	0.694** (0.301)	3.143** (1.167-8.464)
Decreasing river water level	-0.801*** (0.163)	-0.817*** (0.189)	0.257***(0.138-0.479)
Non-flushed toilet type		0.240 (0.157)	1.481 (0.885-2.479)
Piped drinking water		-0.547*** (0.224)	0.372*** (0.170-0.815)
Distance to veterinary clinic		-0.054** (0.025)	0.906** (0.827-0.992)
Distance to motorway		0.096*** (0.029)	1.189*** (1.071-1.321)
Distance to health post		-0.047 (0.045)	0.903(0.766-1.064)
Uneducated household head		-0.262* (0.142)	0.638* (0.400-0.997)
Mud home structure		0.216 (0.174)	1.439 (0.810-2.556)
Not participated in awareness Program		0.585** (0.276)	2.621**(1.031-6.658)
	R^2 = 12.26	R^2 = 17.71	

*** = *p<0.01*, ** = *p<0.05*, * = *p<0.10*

Numbers in the parenthesis in the Probit results = Standard Error

95% C.I. = 95% confidence interval

A descriptive analysis demonstrated that a 35% of households across western Nepal have already repaired their home to adapt from inescapable heat waves in summer season (Figure 4). Similarly, 59% of households have managed mosquito nets at home. Iron nets at the door and window are well fitted at 63% of homes to restrict the entry of mosquito and other insects. Pesticides are used by nearly 36% of families to control mosquito vectors at home. Skin-protective medicinal products are now in use to help people prevent insect bites and sunburn. Similarly, using an electric fan at home, buying new clothes for the season, increasing the use of the freezer, increasing the use of water purification equipment, and using toilet cleaners are all adaption sensitive activities to defend against mosquito bites as the environment changes.

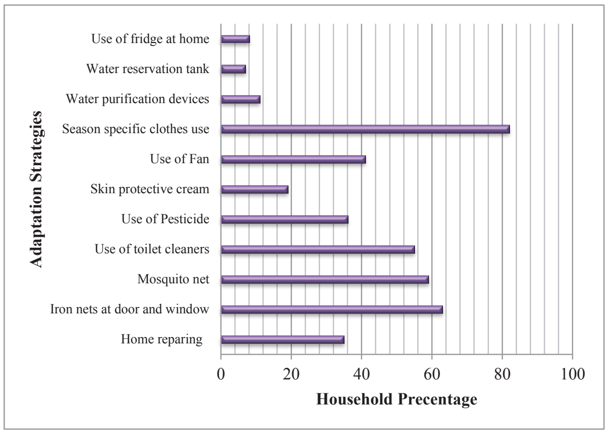

Figure 4. Percent households using protective gears

DISCUSSION

Warmer winter temperature, flooding, blowing hot air, and heat waves in the study area are major environmental factors supporting malaria prevalence.

Socioeconomic variables such as piped drinking water, lack of awareness program and distant motorway from the household are also supporting the chance of malaria occurrence.

Regarding the temperature, warmer winter temperature seemed a potential factor for encouraging malaria, might be logical to explain that warmer temperature in winter will be a favorable situation for vector survival and mosquito activeness responsible to high bite rate.[20,21] Warmer winter and spring temperature support the survival of vector-borne and other infectious disease pathogens.[14,22,23] Increasing summer temperature (below 35 degree Celsius) is also one of the potential factors to increase the malaria incidence.[19] Some other pieces of literatures[12-15] have shown the significant relationships between malaria and summer temperature, but summer temperature is seemed insignificant with malaria occurrence in this study.

Being consistent with a study[24] conducted in Sri-Lanka; this study also shows that the probability chance of malaria occurrence is more likely to increase with increasing flooding. Flood might bring several germs and can generate small water ponds where mosquito larvae can grow. Heat waves directly expedite the malaria vectors in any region of the world.[25] A study in Bangladesh and a European study found the same result as heat waves are responsible for malaria prevalence.[25,26] A normal increase in temperature in any season will be favorable for vector spreading capacity. However, the extreme hot waves for a long time may be responsible for the disease control owing to the death of mosquitos at high temperature. Decreasing the amount of water in the river reduces the buffer zones around the river which reduces the malaria incidence which is also supported by another study done in French Guina. [27]

This might be logical to say that drying river and rivulets might decrease the chance of breeding mosquitos in water which leads to decrease its numbers and biting rate. Besides, it will be absurd to say that drying or decreasing water level in the river is beneficial; however, drying the buffer at the bank river owing to the decrease in river water is beneficial in terms of malaria rampant for the community nearby the riverbank. It is a pertinent dispatch for the community in Terai regions of western Nepal who resides at the bank of the river.

Similarly, the source of drinking water from pipeline seemed the potential agent to control malaria. It is logical to say that drinking water from the pipeline could have less exposure to the open environment, so that there is a minimum chance of the approach of mosquito which prevents the breeding and transmission of the vectors to human. Availability of veterinary centers nearby the community seems potential agent to control malaria. Our research found that using pesticides and insecticides to kill mosquitos can help manage mosquito populations. It is also possible that more research is needed to substantiate this finding. Similarly, insects such as mosquitos may have been controlled by the use of spray and other insecticides available locally at veterinary clinics to protect household animals. As a result, having more veterinary centers is linked to a lower risk of malaria.

Distance to motorway from home normally leads to local basic treatment for malaria which might increase the probability of transmitting vector to other persons and severity of the diseases owing to limited health service for timely treatment. Expectedly, awareness programs in the rural areas seem much more effective to reduce the malaria cases, being consistent with evidence from developing countries.[28,29] Moreover, some other previous studies have also found that people not participated in local awareness programs are more likely to be affected by malaria.[16,17]

Descriptively, various adaptation methods at the household level are implemented, such as house repairs, reservation tank management for prolonged draughts, increasing the number of fans at home, staying inside during extreme weather, earthling system for increased lighting, and so on. The falling amount of water in the river has a substantial impact on disease prevalence, yet no household has implemented any adaptive measures to ensure future protection. Similarly, residents in flood-prone locations are unable to adapt any precautions on their own, maybe due to the high expense of construction along the riverbank. This result could not be compared with any literature owing to unavailability of related scientific paper, however, some studies[30] have identified projections over the cost of adaptation considering possible project horizon.

Based on the evidence from this research, Government of Nepal along with other global cohorts should implement urgent rural programs for the protection of the environment which will ultimately reduce malaria and other infectious diseases. Malaria is strongly linked with the health of the ecosystem under the natural resources such as air, water that may result in unprecedented levels of malaria emergence which potentially cause severe future impacts on infectious disease burden.

CONCLUSIONS

This research has developed a comprehensive framework of environmental change and its effects on malaria prevalence in western Nepal. Warmer winter temperature, flooding, blowing hot air and high amount of water in the river in the study area are the major environmental factors aggravating malaria problems. Similarly, lack of awareness program and households away from motorways increase the chance of malaria occurrence at household level in western Nepal. However, supply of piped water decreases prevalence of malaria. Accordingly, use of mosquito net in winter season, management of flooding water through waterways and protecting body from mosquito bite in hot sunny days are the urgent adaptation mechanisms, whereas promoting piped drinking water, adequate awareness programs, excess of health institutions are the potential factors and practices to be implemented in western Nepal to reduce the malaria cases.

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REFERENCE

1. WHO. World malaria report 2015. World Health Organization, 2016.

2. Shrestha SL, Shrestha IL, Shrestha N, Joshi RD. Statistical modeling of health effects on climate-sensitive variables and assessment of environmental burden of diseases attributable to climate change in Nepal. Environmental Modeling & Assessment. 2017 Oct;22(5):459-72. [Article]

3. Dhimal M, Ahrens B, Kuch U. Malaria control in Nepal 1963--2012: challenges on the path towards elimination. Malar J 2014; 13: 1-14.[Article]

4. Practical Action Nepal. Temporal and Spatial Variabilty of Climate Change Over Nepal,1976-2005.Kathmandu, https://practicalaction.org/file/region_nepal/ClimateChange1976-2005.pdf. (2009).

5. Paudel U. A review of effects of environmental change on human health. Am J Env Sci 2018; 14: 95-109.[Article]

6. MoHP. Annual Report, Department of Health Services 2073/2074 (2016/2017). kathmandu, https://dohs.gov.np/wp-content/uploads/2018/04/Annual_Report_2073-74.pdf.

7. Paudel U, Pant KP. Beyond smoking: environmental determinants of asthma prevalence in western Nepal. J Heal Pollut; 10. 2014.[Article]

8. Paudel U, Adhikari SR, Pant KP. Economics of environmental effects on health: a methodological review based on epidemiological information. Environ. Sustain. Indic. 2020;5,100020. [Article]

9. Devkota RP. Climate change: trends and people's perception in Nepal. J Environ Prot (Irvine, Calif); 2014. [Article]

10. Ezzati M, Lopez AD, Rodgers AA, Murray CJ. Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors. World Health Organization; 2004.[Download PDF]

11. Ramasamy R, Surendran SN. Global climate change and its potential impact on disease transmission by salinity-tolerant mosquito vectors in coastal zones. Front Physiol 2012; 3: 198.[Article]

12. Sheffield PE, Landrigan PJ. Global climate change and children's health: threats and strategies for prevention. Environ Health Perspect 2011; 119: 291-298.[Article]

13. Haines A, Kovats RS, Campbell-Lendrum D, et al. Climate change and human health: impacts, vulnerability and public health. Public Health 2006; 120: 585-596. [Article]

14. Reiter P. Climate change and mosquito-borne disease. Environ Health Perspect 2001; 109: 141-161.[Article]

15. Chan NY, Ebi KL, Smith F, Wilson TF, Smith AE. An integrated assessment framework for climate change and infectious diseases. Environmental Health Perspectives. 1999 May;107(5):329-37.[Article]

16. Kumar V, Mangal A, Panesar S, Yadav G, Talwar R, Raut D, et al. Forecasting malaria cases using climatic factors in Delhi, India: a time series analysis. Malaria research and

treatment. 2014;2014.[Article]

17. Wang R, Tang S, Yang J, Shao T, Shao P, Liu C, et al. Improving local health workers' knowledge of malaria in the elimination phase—determinants and strategies: a cross-sectional study in rural China. Malaria journal. 2017 Dec;16(1):1-1.[Article]

18. CBS. National Population and Housing Census 2011(National Report). Government of Nepal, National Planning Commission Secretariat, Central Bu Reau of Statistic. 2012;1:1–278. Available from: http://cbs.gov.np/?p=2017

19. Parham PE, Michael E. Modeling the effects of weather and climate change on malaria transmission. Environ Health Perspect 2010; 118: 620-626.[Article]

20. Patz JA, Epstein PR, Burke TA, Balbus JM. Global climate change and emerging infectious diseases. Jama. 1996 Jan 17;275(3):217-23.[Article]

21. Feachem RG, Chen I, Akbari O, Bertozzi-Villa A, Bhatt S, Binka F, et al. Malaria eradication within a generation: ambitious, achievable, and necessary. The Lancet. 2019 Sep 21;394(10203):1056-112.[Article]

22. Srimath-Tirumula-Peddinti RCPK, Neelapu NRR, Sidagam N. Association of climatic variability, vector population and malarial disease in district of Visakhapatnam, India: a modeling and prediction analysis. PLoS One 2015; 10: e0128377.[Article]

23. Dhital SR, Koirala M, Dhungel S, Gulis G. Climate change and its impacts on human health in Nepal. J Health Edu Res Dev. 2016;4(174):2.[Article]

24. Nabi SA, Qader SS. Is Global Warming likely to cause an increased incidence of Malaria? Libyan J Med 2009; 4: 9-16.[Article]

25. Chowdhury FR, Ibrahim QS, Bari MS, Alam MJ, Dunachie SJ, Rodriguez-Morales AJ, et al. The association between temperature, rainfall and humidity with common climate-sensitive infectious diseases in Bangladesh. PloS one. 2018 Jun 21;13(6):e0199579.[Article]

26. Endlicher W, Jendritzky G, Fischer J, Redlich JP. Heat waves, urban climate and human health. InUrban ecology 2008 (pp. 269-278). Springer, Boston, MA.[Article]

27. Stefani A, Roux E, Fotsing JM, Carme B. Studying relationships between environment and malaria incidence in Camopi (French Guiana) through the objective selection of buffer-based landscape characterisations. International journal of health geographics. 2011 Dec;10(1):1-3. [Article]

28. Bai L, Woodward A, Liu Q. Temperature and mortality on the roof of the world: a time-series analysis in three Tibetan counties, China. Science of the total environment. 2014 Jul 1;485:41-8.[Article]

29. WHO. Strategic Advisory Group on Malaria Eradication. Malaria eradication: benefits, future scenarios and feasibility. Geneva:, 2019.

30. Ebi KL. Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. Global Health 2008; 4: 1-9.[Article]