Major Health-Related Challenges of Malaria in Nepal

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Malaria is a severe and often life-threatening disease (CDC, 2019; WHO, 2019). Although it is preventable and curable, it continues to be one of the significant causes of mortality worldwide. In 2018, an estimated 228 million malaria cases and 405,000 deaths occurred worldwide (WHO, 2019). Malaria is a vector-borne disease caused by the *Plasmodium* parasite and is transmitted to people through being bitten by infected female *Anopheles* mosquitoes.

Malaria causes illnesses and deaths and affects advances in development in malaria-endemic countries due to the economic burden. There are direct costs at the household level associated with expenses on prevention and treatment and indirect costs associated with the family's loss of productivity due to death or sickness of the family members, including children (Arrow et al., 2004). Children who survive may incur impacts on cognitive development or suffer educational delays by missing school. The adult survivors may have lasting effects on their physical and mental health, affecting their economic potential. At the country level, there are direct costs due to government expenditures on prevention and treatment, as well as indirect costs due to workforce loss. The death of children affects the country's demographic pattern, which might affect the economy long-term. The total costs incurred due to malaria are substantial, even though they are not feasibly quantifiable (Arrow et al., 2004), and the high economic burden eventually affects the development of the country.

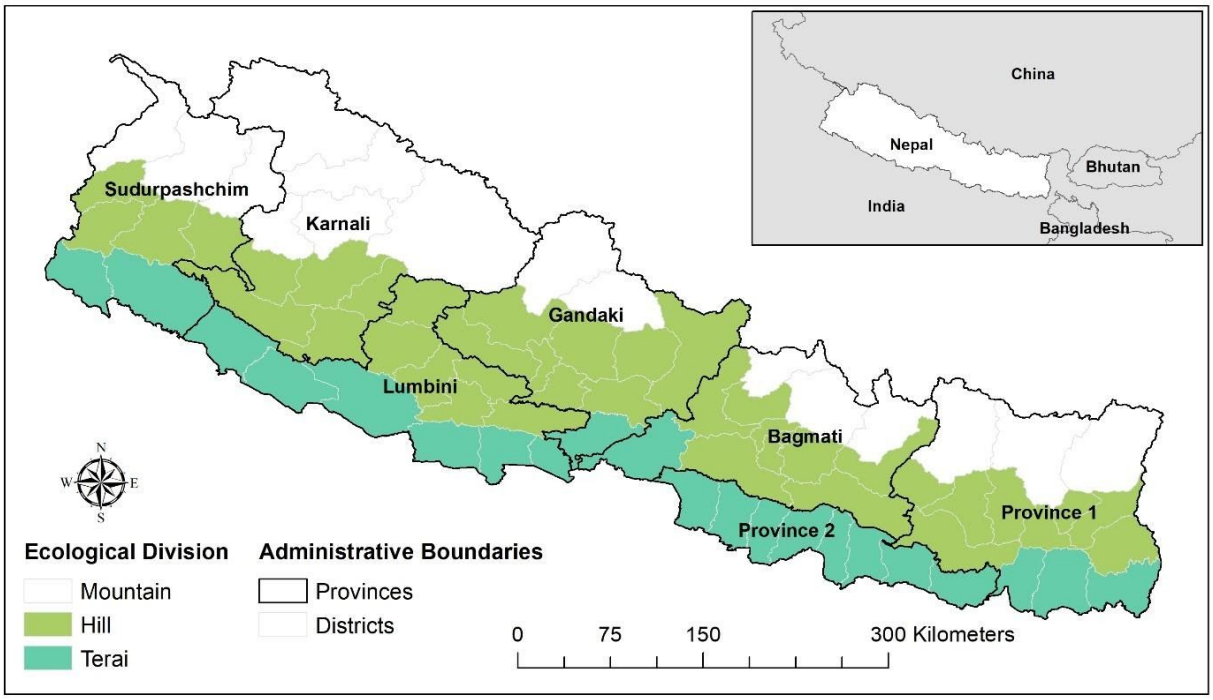
Malaria in Nepal

Nepal is one of the malaria-endemic countries in South Asia. Malaria was the significant cause of morbidity and mortality in Nepal during the early 20th century, with nearly half of the population suffering from the disease and a mortality rate of 10-15% (UCSF, 2015). Malaria was

mostly endemic in the southern region of the country, called Terai. The terai is valued for cultivation potential, and with the presence of malaria into the 20th century in the region, a large part of cultivable land in Nepal was uninhabitable (Sakya, 1981). After the start of anti-malarial operations in the 1950s, several terai areas were freed from this disease by the end of the 1960s (Sakya, 1981). As a result, people began to migrate to the terai and settle in areas previously considered unsafe due to malaria (Sakya, 1981). Now, about 50% of Nepal's population lives in the terai because the land is flat and fertile (CBS, 2014).

Figure 1

Major Ecological and Administrative Division of Nepal



In the early 1950s, the malaria control program using Indoor Residual Spraying (IRS) with DDT (Dichloro-diphenyl-trichloro-ethane) was initiated, and malaria incidence was significantly reduced (Shakya, 1981). In 1958, Nepal launched the "Malaria Eradication Program," using substantial international aid support (DoHS, 2016; WHO, 2011), and the

number of malaria cases in Nepal dropped to 2,500 by 1970 (Shakya, 1981). However, the eradication program then faced financial and technical problems, which resulted in its failure; thus, malaria cases rebounded (Shakya, 1981). Following a renewed global interest in malaria during the 1990s, Nepal began to receive support from the Global Fund in 2004, of which one component was vector control intervention using Long Lasting Insecticidal Nets (LLINs). Malaria transmission once again decreased significantly in Nepal thereafter (Dhimal, 2014a). At present, Nepal is again in the pre-elimination phase and aims to eliminate malaria by 2026.

Malaria Epidemiology in Nepal

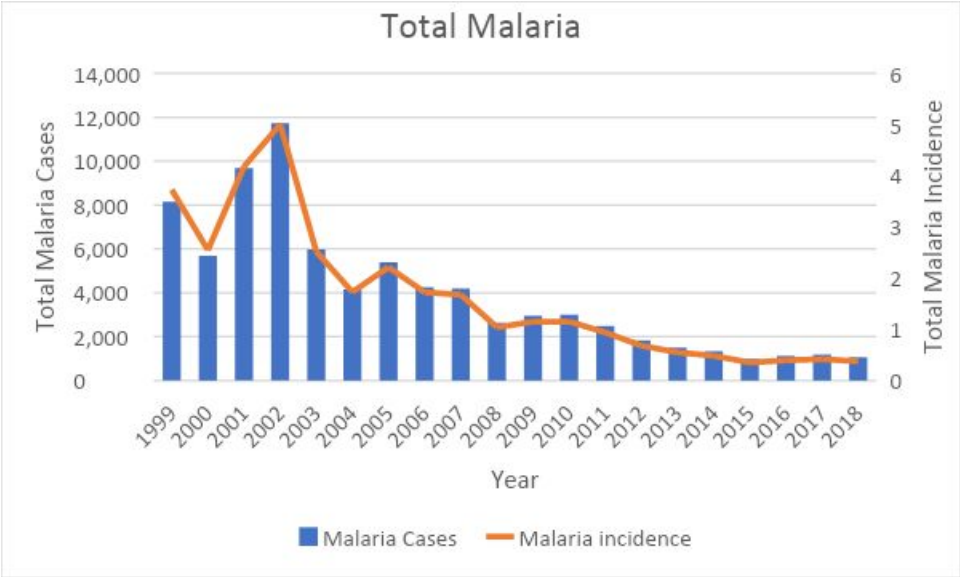
Malaria in Nepal is mainly caused by two species of Plasmodium: *Plasmodium vivax* and *Plasmodium falciparum. Plasmodium vivax* causes about 80-90% of malaria cases whereas *Plasmodium falciparum* is the main cause of outbreaks and deaths (Rijal, 2018; Dhimal, 2014a).

Total Malaria

The total malaria burden has been decreasing in Nepal. There was a peak in cases in 2002 due to an outbreak. Thereafter, cases have been decreasing steadily. The cases were 8,149 in 1999 and 1,064 in 2018. Similarly, the incidence of total malaria has been decreasing too. The incidence was 3.73 per 10,000 population in 1999, and it decreased to 0.38 in 2018.

Figure 2

Total Malaria Cases and Incidence in Nepal between 1999 and 2018

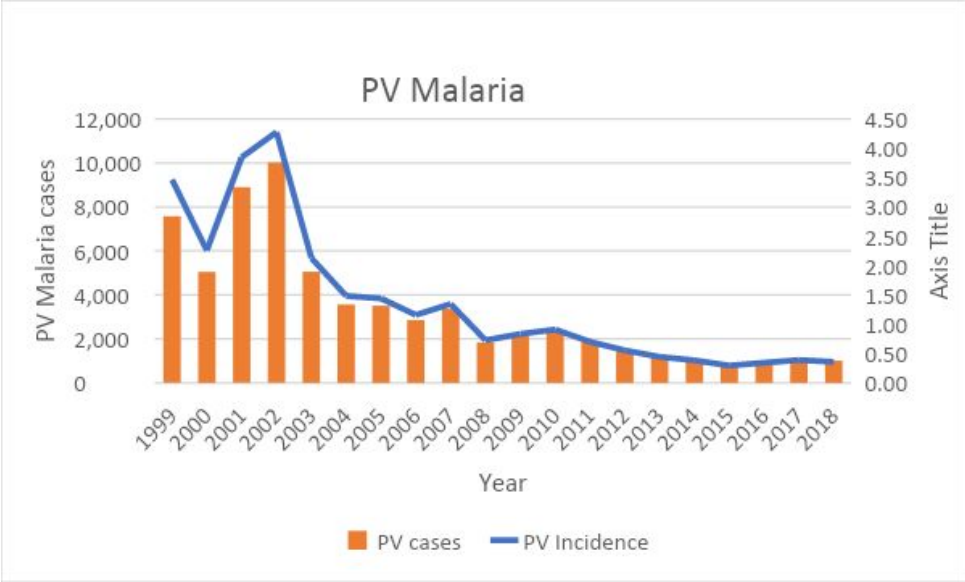


***Plasmodium vivax* (PV) Malaria**

The trend of PV Malaria was similar to that of Total Malaria. The cases and incidence peaked in 2002 and then decreased thereafter. PV cases were 7579 in 1999 and decreased to 1012 in 2018. Similarly, the PV Incidence was 3.47 in 1999 and decreased to 0.36 in 2018.

Figure 3

PV Malaria Cases and Incidence in Nepal Between 1999 and 2018

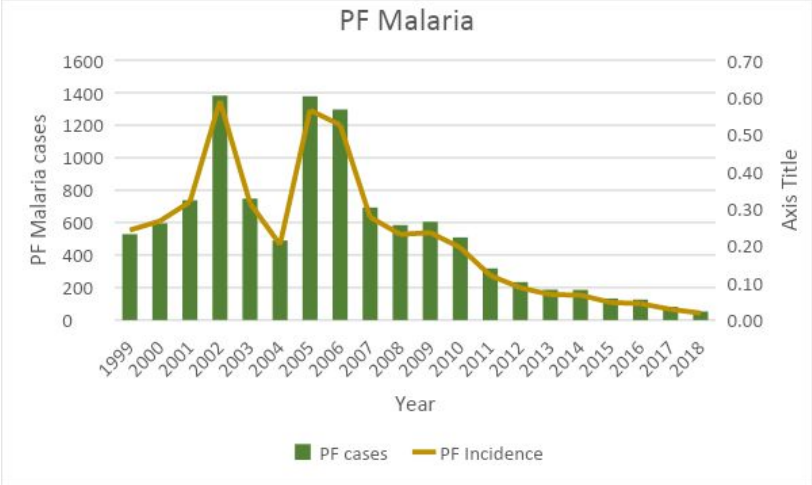


Plasmodium falciparum (PF) Malaria

PF Malaria had a different trend of fluctuation between 1999 and 2018. There were peaks during 2002 and 2005/2006. PF cases were 529 in 1999 and 53 in 2018. Similarly, the incidence has decreased from 0.24 in 1999 to 0.02 in 2018.

Figure 4

PF Malaria cases and incidence in Nepal between 1999 and 2018



Malaria and Migration

A significant number of people from Nepal migrate to foreign countries for work and study. In 2011, the migrant population's ratio increased to 7.4%, double the global average (Shrestha, 2017). The migration of workers in Nepal has become crucial to the national economy. Foreign remittance has become one of the largest national income sources, contributing over a fifth to the national GDP (Table 1) (Shrestha, 2017). The most popular destinations are India, Malaysia, Gulf countries, Qatar, Saudia Arabia, and United Arab Emirates.

Table 1

International Migration and Remittance

Year	Migration / Population			Remittance Income % GDP
	All	India	Non-India	
1961	3.49			
1981	2.68	2.48	0.19	
1991	3.56	3.17	0.37	1.5
2001	3.41	2.61	0.78	2.4
2011	7.43	2.8	4.63	22.4

Note. From Shrestha, M. (2017). *Push and Pull: A Study of International Migration from Nepal.* The World Bank. https://doi.org/10.1596/1813-9450-7965

Migration occurs in Nepal because of scarce economic opportunities, economic inequities, gender and caste discrimination. Many people from the western part of the country travel to India's malaria-endemic states such as Assam, Gujarat, West Bengal, and Maharashtra for work. Most of the time, the migration is seasonal, and the migrant workers return home to celebrate major festivals, which also coincides with the peak malaria season. This is the way of life in the Far West and Mid-West Regions (DoHS, 2016). Due to this migration, a significant number of imported malaria cases are recorded in Nepal.

Imported Malaria

The imported malaria had been decreasing from 928 cases in 1999 to 618 in 2018. However, the rate of change of imported malaria is slower than other malaria indicators. In fact, the proportion of Imported Malaria has been increasing in Nepal.

Figure 5

Imported Malaria cases and incidence in Nepal between 1999 and 2018

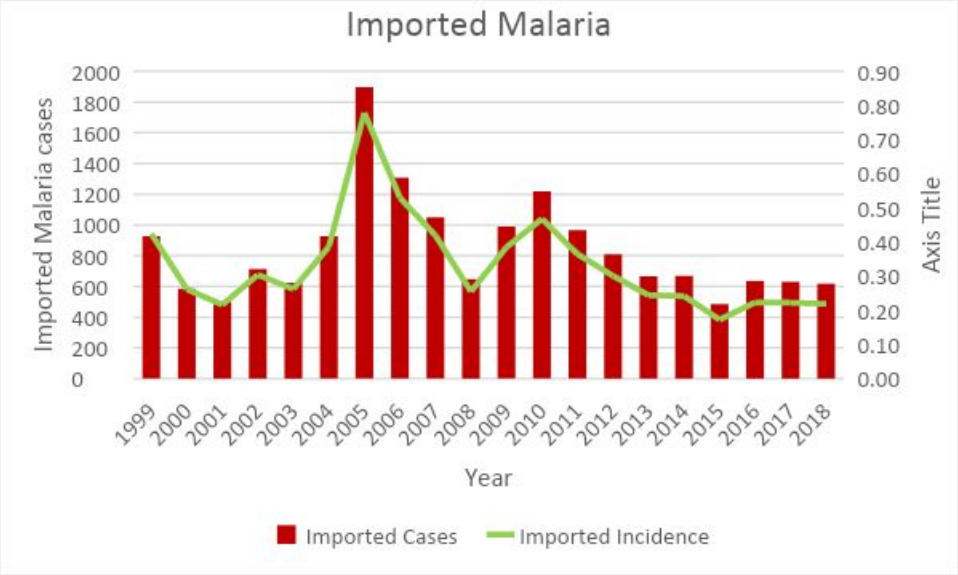
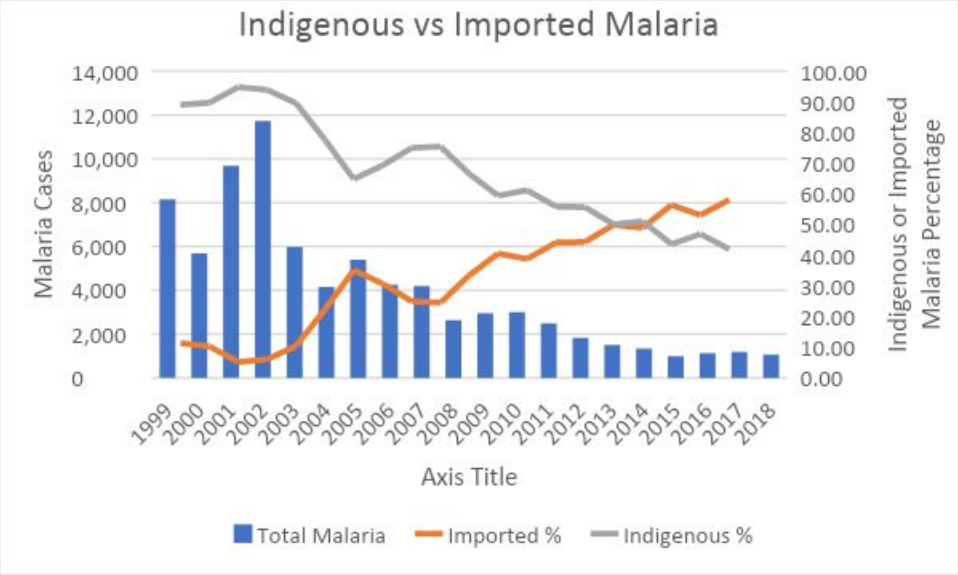


Figure 6

Percentage of Indigenous and Imported Malaria in Nepal between 1999 and 2018



Health Systems and Delivery

Malaria diagnosis, treatment and drugs are free in all public health institutions in Nepal.

Malaria control in Nepal depends on surveillance. Passive surveillance is the predominant form of malaria surveillance in Nepal. It is carried out by different levels of public health facilities. Monthly malaria cases are reported from the community level Sub-Health Post and Health Post to the Primary Health Care center and then to the District (Public) Health Office. All DHOs then report the monthly cases to the Epidemiology and Disease Control Division (EDCD) of the Ministry of Health through the Health Management Information System (HMIS). Besides HMIS, malaria cases are also reported through other mechanisms. There is a weekly early warning reporting system (EWARS) of admitted malaria cases and deaths from hospitals, weekly community sentinel surveillance for outbreaks, a monthly global fund report, a monthly logistics management report, and an annual report of the EDCD (Dhimal et al., 2014a). Malaria is diagnosed by microscopy (where it is available) and Rapid Diagnosis Test (RDT) (where microscopy is not available).

Delivery of Control Interventions

Indoor Residual Spraying (IRS) was the primary focus of vector control interventions in Nepal since the start of the malaria control program in the 1950s. Since 2004, the additional vector control intervention is Long Lasting Insecticidal Nets (LLINS) with the support of Global Fund for AIDS, Tuberculosis, and Malaria, (GFATM). LLINs are distributed in the high malaria risk areas through mass distribution with the rate of one LLIN to every two people in the household. LLINs are also distributed to pregnant women during their antenatal care visit in the health centers in high and moderate risk areas. IRS is sprayed in high risk areas and during outbreaks.

Some of the challenges to eliminating malaria in Nepal are related to the Nepalese government placing a great deal of responsibility on local healthcare delivery systems to address

the burden of malaria and the increasingly high prevalence of non-communicable diseases (Adhikari et al., 2019). However, local healthcare delivery systems cannot provide and manage the delivery of basic, preventive, and diagnostic services due to an insufficient human resource base (Adhikari et al., 2019). Specific challenges include gaps in malaria-elimination initiatives, particularly that of demand and supply challenges. Demand obstacles include malaria control, diagnosis and treatment, and interpersonal and community efforts. Supply challenges include the availability or shortage of medicine, human resource capacity to deliver services, fiscal allocation from the government, and access to health information (Adhikari et al., 2019).

Health Behaviors

Nepali malaria control efforts, which include early diagnosis, prompt treatment, and use of long-lasting insecticidal treated nets (LLINs), have successfully reduced their overall malaria burden (Gautam et al., 2019; Regmi et al., 2016) by addressing the social and environmental determinants which drive individual, community, organizational, and population health behaviors related to malaria risk and transmission. Behavior change communication strategies play a significant role in the adoption, adherence, and return on investment for Nepali malaria control efforts (Koenker et al., 2014; Epidemiology and Disease Control Division, 2016) as they provide tailored health information and education for high-risk populations and providers. In South Asia, the first and second most vulnerable and high-risk populations include children under five and pregnant women, respectively (Regmi et al., 2016). Other high-risk populations include adult male laborers of migrant and mobile populations (MMPs), also known as imported cases, and their MMPs social contacts.

Knowledge and Practice of Health and Health Behaviors

The misperceptions and lack of knowledge about the signs and symptoms, severity,

causes of transmission, treatment, and prevention measures about malaria are still widespread among vulnerable and high-risk populations in Nepal (Awasthi et al., 2018; Joshi & Banjara, 2008). The Nepal Malaria Prevention and Control Program (NMPCP) is one intervention that has aimed to reduce the incidence and burdens of malaria through various strategies, including BCC messages for high-risk populations, LLIN distribution, improving coverage of diagnosis and treatment, along with various other control and prevention efforts. Regarding knowledge about malaria transmission, $p < .001$, the program found that less than half of respondents in both the non-intervention (40.4%) and intervention (49.2%) areas provided correct answers to three or more questions about malaria transmission. The program also assessed behavioral determinants for LLIN usage among the general population and children under five. The assessment revealed that knowledge prevention was best addressed by exposure to interpersonal communication materials and exposure to other BCC channels such as posters, radio, or school-based programs.

Migrant and Mobile Populations. Among imported cases and their social contacts in the lowland Terai region in western Nepal, a 2016 cross-sectional survey conducted by Smith et al. (2019) revealed that more than two-thirds of MMP social contacts (68.8%), $p = .06$, indicated they had 'not heard of malaria' compared to more than half of imported cases (53.8%), $p = .06$. Regarding knowledge of symptoms, the majority of confirmed imported cases (48.3%), $p < .0001$, and their social contacts (75.0%), $p < .0001$, indicated they did not have knowledge of any malaria symptoms. However, confirmed imported cases (45.0%), $p < .0001$, were more likely to have knowledge of four or more symptoms compared to social contacts (15.0%), $p < .0001$. The majority of imported cases (66.7%) and their social contacts (72.5%) indicated they had no knowledge of preventive measures, $p = .22$. Only 28.3% and 21.3% of imported cases and their social contacts, respectively, were aware of insecticide-treated bed nets (ITNs) as a prevention

measure, $p = .33$. Finally, regarding knowledge about free testing and treatment availability, most MMP social contacts (75.0%), $p < .005$, are aware of such services. Less than half of imported cases (46.7%) and MMP social contacts (32.9%), $p < .005$, have knowledge of free testing for malaria.

Use of LLINs and ITNs

Many studies, including the World Health Organization, recommend the regular use of LLINs as a critical approach for effective malaria control and prevention (Ghimire et al., 2020; Regmi et al., 2016). In the Terai regions, Ghimire et al. (2020) indicated that the free distribution of LLINs, more than 90% LLIN coverage via the National Malaria Control Program (Ghimire et al., 2020; Smith et al., 2019), and the adoption of artemisinin-based combination therapy (ACT) between 2003 and 2012 have contributed to the decline in confirmed cases of *P. vivax* malaria. Table 2 shows that during the first round of the NMPCP in 2009, household members and children under five in the intervention coverage area indicated high usage of LLIN or other nets, $p < .001$, as opposed to household members and children under five in the non-intervention area.

However, a high proportion of confirmed imported malaria cases are one of the significant contributing factors driving local malaria transmission (Smith et al., 2019). Among adult male laborers in MMPs, self-reported LLINs usage was infrequent during travel (20%) due to reasons related to limited knowledge about obtaining bed nets, residing in remote areas, or absence during regular home distributions (Smith et al., 2019). In the same study, perceived barriers for low ITN usage while traveling was due to the unavailability and affordability of nets, negative perceptions about the chemicals used to treat nets, and structural limitations of housing preventing bed net setup.

Maternal and Reproductive Health

Since 1997, Nepal has made great efforts to reduce its maternal mortality ratio (MMR) through the implementation of the Safe Motherhood Program (SMP), an initiative aiming to improve maternal and neonatal health outcomes and reducing maternal and neonatal morbidity and mortality (Aryal et al., 2019; Baral and Vashisth, 2014). The SMP in Nepal implemented strategies to expand the accessibility to family planning services and regular antenatal care visits, develop and improve their obstetrician infrastructure, and address predisposing, enabling, and contextual factors that act as barriers to a safe pregnancy for Nepalese women (Aryal et al., 2019). Since 2000, Nepal has reduced its maternal mortality ratio by 66.4 percent, about two-thirds, from 553 to 186 per 100,000 live births in 2017 (WHO, 2019). The Nepal 2011 and 2016 DHS surveys revealed significant increases among the proportion of women completing four or more antenatal care visits (49.5% increase, $p < .001$) and giving birth in a health facility (21% increase, $p < .01$), but only a marginal increase (3.0%) in women completing a postnatal health check within seven days (Aryal et al., 2019).

Malaria and Anemia

Women who are pregnant or are of reproductive age are at an increased risk of having a low concentration of hemoglobin in their red blood cells (Gautam et al., 2019), or anemia, to perform physiological functions effectively. Among Nepalese women of reproductive age, anemia is also attributed to other factors such as residence, nutritional status, decision-making autonomy in their health (Gautam et al., 2019). Further, the double burden of splenic and placental sequestration of malaria-infected erythrocytes among pregnant women places them at higher risks of experiencing maternal morbidities such as microcytic anemia, congestive heart failure, folic acid deficiency, intrauterine neonatal demise (stillbirth), and premature delivery (Schantz-Dunn and Nour, 2009). Anemia during pregnancy can have physiological

intergenerational effects on iron stores in young children.

In Nepal, parasitic infections that cause malaria are often more severe in pregnant women, regardless of previously acquired immunity (Schantz-Dunn and Nour, 2009). Clinically severe malaria among pregnant women can be fatal due to decreased immunity during pregnancy, insufficient iron storage capacity relative to increased iron requirements during pregnancy (Dreyfuss et al., 2000), and increased risk of both splenic and placental sequestration of malaria-infected red blood cells (Schantz-Dunn and Nour, 2009).

Gender, Women's Empowerment, and Conflict

Understanding gender relations and women's empowerment in the context of conflict and fragility is essential to efforts supporting economic and political stability, conflict prevention, peacebuilding, and state-building operations in Nepal – all of which contribute to malaria outcomes as they influence access to and distribution of health information, prevention and control measures, diagnosis, and treatment.

Malaria and Women's Autonomy

The high proportion of adult male laborers in MMPs in Nepal has contributed to the feminization of Nepal's agricultural workforce (OECD, 2017). The male out-migration has allowed women to acquire more autonomy by assuming new economic and decision-making roles (OECD, 2017; Smith et al., 2019). Women's autonomy is an indicator of maternal and child health outcomes, access to wealth, social resources, and material resources (Acharya et al., 2010). Among Nepali women, autonomy over healthcare decision-making increased with age and was higher among women who resided in urban regions, were employed for an income rather than in exchange for subsistence, had three or more living children, and had completed higher education (Acharya et al., 2010).

Despite the increased role of Nepali women in the workforce, the low earning power of Nepalese women, compounded by patriarchal practices regarding household income, hinders the ability of Nepalese women to make important purchases that may help to improve their health outcomes and quality of life (Acharya et al., 2010). Regarding malaria morbidity, such important purchases may include the cost of healthcare services, the cost of travel to a public or private health facility for diagnosis or treatment, the cost of supplies or household items to maintain a physical environment that discourages mosquito breeding sites.

Malaria, Gender, and Conflict

During the Maoist conflict, Nepalese women's economic participation increased, partly due to the overt campaign against gender and caste discrimination practices. However, economic and political instability soon presented infrastructure challenges for the Nepalese government at the local, central, and federal levels (OECD, 2017). Structural instability and inadequacies compound the existing impact of gender inequities and the feminization of poverty among Nepalese women and children (institutional infrastructure), creating increased barriers to accessing support, material resources, and necessary health services (OECD, 2017). For instance, healthcare care services delivery, particularly to women in rural areas, was disrupted as Maoists would aggressively target rural healthcare personnel and their posts, often destroying the health post and pillaging medicines (Bhadra, 2004). Further, traveling to a healthcare post during the Maoist conflict was made difficult for women in rural areas, citing safety and security concerns as well as traveling restrictions imposed by the Maoist insurgents (Bhadra, 2004).

However, post-conflict, there has been a resurgence of discriminatory gender practices and beliefs once predominant during peacetime. Such barriers and practices include gender or caste discrimination (Naujoks et al., 2014), illiteracy, long wait times, and complex and lengthy

administrative claims processes (OECD, 2017). Citizenship registration remains one of the critical post-conflict challenges that intersect gender and conflict. Widows, children, and sexual and gender minorities are likely to face many barriers in acquiring citizenship documentation, which is necessary for receiving relief benefits, owning property, claiming inheritance, accessing necessary health and medical services, and participation in many other civic and personal activities (Naujoks et al., 2014).

Demographic Transition and Non-Communicable Diseases

Since the 1980s, Nepal has experienced a rapid decline in its crude birth rate (CBR) and crude death rate (CDR), an exponential increase in population growth rates, and improved life expectancy (Government of Nepal National Planning Commission, 2017; UNFPA, 2017). Nepal's demographic transition profile occurs outside of the distinct Western four-stage model (GNNPC, 2017); rather than occurring in distinct sequential stages, some demographic transition parameters are co-occurring. Between 2010 through 2015, the total fertility rate (TFR), 2.32 children per woman, in Nepal had decreased by more than half since 1980, 5.62 children per woman (GNNPC, 2017). In the same period and from the same report, Nepal's CDR decreased from 16.9 deaths to 6.5 per 1,000. Although Nepal has significantly improved its CBRs and CDRs, it is still considered a least developed country (LDC) based on the United Nations' development criteria; however, Nepal is expected to graduate from this status in 2022 (GNNPC, 2017).

Health Promoting and Malaria Prevention and Control Initiatives

The reduction of malaria over the last several decades has played a key role in changing Nepal's population structure, mainly through the implementation of various health promotion programs and malaria prevention and control programs. In the late 1950s, Nepal focused its

efforts on malaria eradication (DoHS, 2016; Shakya, 1981; WHO, 2011), but despite some successes in reducing malaria, the program ultimately failed due to lack of financial and stakeholder sustainability (Shakya, 1981). Between the 1980s through 1990s, the combination of renewed interest in malaria prevention and control, rather than eradication, and health promotion programs such as the Safe Motherhood Program (Aryal et al., 2019) and the implementation of the 1991 National Health Policy (Magar, 1970) appear to coincide with changes in the population age structure in Nepal. For instance, as illustrated by Nepal's 1980 population pyramid (Figure 7), taking the shape of an acute triangle, Nepal's population age structure was relatively young as a result of the high fertility rate and a lower proportion of older adults (GNNPC, 2017). In the 1991 population pyramid, the age structure is slightly broadening in the elderly groups, and there is still a high proportion of the young population (Figure 8) (GNNPC).

In 2004, Nepal implemented a National Nutrition Policy followed by the 2012 National Health Communication Policy (Karki, 2018). Partial effects of these policies may be observed in the 2015 population pyramid (Figure 9), where there is a noticeable constriction at the base of the pyramid – indicating a decline in fertility rates – followed by a slight bulge with a noticeable indent in the male population. Projections for 2025 **(**Figure 10) illustrate more constriction at the base of the pyramid and expansion towards the top of the pyramid, indicating an aging population as fertility and mortality continue to decline, and life expectancy improves (GNNPC, 2017).

Non-Communicable Disease (NCDs)

In the last two decades, Nepal has undergone a rapid transition from mortality and morbidity mainly attributable to infectious diseases (IDs), approximately 70% for both, to NCD burdens (Nepal Health Research Council, 2019). The Nepal Burden of Disease (NBoD) 2017

reported that NCDs accounted for two-thirds of deaths (66%), making NCDs the leading causes of all-age mortality in Nepal, followed by 25% attributable to communicable, maternal, neonatal, and nutritional diseases (CMNN), and 9% of deaths attributable to injuries (NHRC, 2019). In 1990, eight out of the top ten leading causes of death (per 100,000) were CMNNs (NHRC, 2019). In the same 2017 report, six out of the top ten leading causes of death were NCDs (per 100,000 population); ischemic heart disease became the leading cause of death, increasing by 60.17% since 1990 to a rate of 100.45, immediately followed by chronic obstructive pulmonary disease (increased by 14.57% to a rate 60.15). Ranked 5th through 7th was intracerebral hemorrhage, ischemic stroke, and asthma, and finally ranked 9th was Alzheimer's disease.

Disability-Adjusted Life Years (DALYs) and Years of Life Lost (YLLs) of Malaria and NCDs. In 2017, neglected tropical diseases (NDT) and malaria was one of the major causes of DALYs and accounted for over 146 thousand DALYs among the Nepalese population (NHRC, 2019). In the same category and year, premature death or years of life lost (YLLs) was less attributed (40.47%) to the overall percentage DALYs than was years lived with a disability (YLDs), which was slightly less than three-fifths (59.53%). YLLs from malaria have decreased from an estimated 94 thousand YLLs in 1990 to 61 thousand YLLs in 2010 (Institute for Health Metrics and Evaluation, 2010), and finally to about 59 thousand in 2017, although the latter estimate is included with other neglected tropical diseases (NHRC, 2019).

Consistent with the earlier discussion of Nepal's top NCD burdens, YLLs attributed to ischemic heart disease increased by 95% from 142 thousand to 277 thousand between 1990 and 2010. In 2017, YLLs from ischemic heart disease substantially increased to over 663 thousand, accounting for 11.34% of total YLLs among major causes of premature death in all ages and sexes in Nepal. Table 3 provides further data among YLLs for select major causes of death

attributable to NCDs between 1990 and 2017.

Although infectious disease burdens have declined, there is a rising issue of addressing the existing infectious disease burden (e.g., HIV/AIDS and tuberculosis), the emergence and re-emergence of infectious diseases (e.g., Dengue fever and Influenza A virus), bacterial drug resistance, and endemic vector-borne infections such as malaria (Rai, 2018). Compounded with the high and increasing NCD burden, the prevalence and incidence of IDs are sufficient to impart a double or triple burden of disease in Nepal, thereby magnifying the risk for opportunistic infections and potentially increasing the total DALYs among the Nepalese population.

Land Use, Climate Change, and Malaria

Land use and land cover (LULC) are one of the important environmental factors known to influence malaria incidence and transmission (e.g., Lindblade *et al*., 2000; Ijumba and Lindsay, 2001; Yasuoka and Levins, 2007). LULC variables such as forests, water bodies, and agricultural practices such as rice cultivation have been associated with malaria in several studies (Prothero, 1999; Bharati and Ganguly; Ripert and Raccurt, 1987; Khaemba *et al*., 1994; Koudou *et al*., 2005; Sarkar *et al*., 2012). Such research is negligible in Nepal. A recent study by Bhattarai *et al.* (in press) found that the malaria incidence rate (MIR) in 2001, 2002, and 2003 had a significantly positive relationship with water bodies and rice paddies; however, the relationship disappeared during 2011, 2012, and 2013. The relationship between LULC and MIR changed over time. The possible explanation for this changing relationship is that due to the vector control intervention, the malaria burden has decreased significantly, and thus the relationship between LULC and MIR is not visible recently. However, although forests and forest fringes are associated with malaria in Nepal and other Southeast Asian countries by several studies (Prothero, 1999; Bharati and Ganguly, 2013), such a relationship was not found

in this study.

According to the IPCC (2007), climate change has mixed effects on malaria: the geographical range of malaria will contract in some places while the range will expand in others, and the transmission season may be changed as well. In Rwanda, there was a large increase in malaria cases country-wide, but the rate of increase was greater at high elevations than at medium and low elevations (Loevinsohn, 1994). A study examining future malaria risk over West Africa using simulations shows a decreased risk of malaria (Caminade and Jones, 2016). In Nepal, a 1°C increase in minimum temperature increased malaria incidence by 27% in a study done in Dhangadi and Morang districts (Dhimal et al., 2014b). Another study in Nepal showed that malaria cases increased with a minimal increase in temperature and a considerable decrease in total rainfall in the Jhapa district (Bhandari et al., 2013).

In addition, due to temperature increases, malaria is migrating to new areas along the borders of the existing endemic areas and into highland regions. Malaria cases occurred at a higher elevation in the highlands of Ethiopia and Colombia during warmer years in 1997 and 2002, followed by El Nino events (Siraj et al.,. 2014). In Rwanda, malaria migrated to new areas in the late 1980s, to places where it was previously rare or absent due to a record high temperatures and heavy rains in 1987, followed by the El Nino event in 1988 (Loevinsohn, 1994). In Nepal, malaria hotspots have shifted to new VDCs (Village Development Committee) within the Morang district (Dhimal, *et al* 2014b). Additionally, another study done in Nepal showed that malaria incidence increased in recent years, particularly in the hills and mountains of Nepal, which indicates that malaria is migrating to new locations that traditionally were considered malaria-free (Badu, 2012).

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Tables and Figures

Table 2

Behavior and Use Indicators of LLINs in 2009

Behavior or Use	Non-Intervention Area *N=2375*	Intervention Area *N=1600*
	% (*n)*	% (*n)*
Every individual household member slept under a treated or untreated net the previous night.	78.9 (13306)	96 (9019)
Every individual household member slept under a LLIN the previous night.	25.2 (13306)	86.6 (9019)
Children under five sleeping under a treated or untreated net the previous night.	81.7 (1480)	96.7 (1008)
Children under five sleeping under a LLIN the previous night.	33.3 (1480)	91.5 (1008)

Note. P-value for all indicators shown $p < .001$. Data from PSI Research Division. (2009). *Nepal (2009): Malaria TRaC study evaluating LLIN use among general population and children under 5 years of age in 13 high-risk districts 1st round.* Population Services International.

Table 3

Years of Life Lost Among Major Causes of Death from NCDs and Malaria

Cause of Death	1990		2010		2017	
	% YLL	(n) YLL in thousands	% YLL	(n) YLL in thousands	% YLL [a]	(n) YLL in thousands [a]
Ischemic heart disease	1.2	142	3.8	277	11.34	663
COPD	2.4	287	3.5	249	5.51	322
Intracerebral hemorrhage	0.96[a]	562			2.7	158
Ischemic stroke	1	126	2.9	212		
Malaria	0.8	94			40.47 [b]	59 [b]

Note. From the IHME (2010) GBD profile report on Nepal.

[a] From the Ministry of Health (2019) Nepal Burden of Disease (NBoD) report.

[b] Derived from the Ministry of Health (2019) NBoD report. Malaria was aggregated with neglected tropical disease.

Figure 7

1980 Nepal Population Pyramid

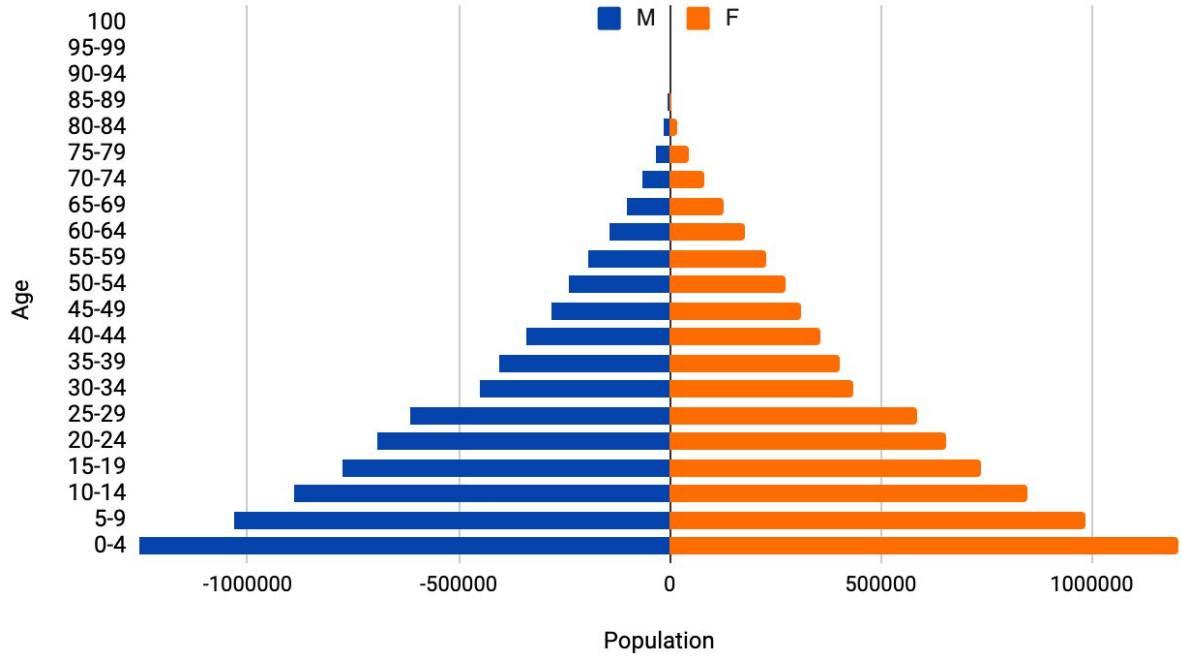


Figure 8

1991 Nepal Population Pyramid

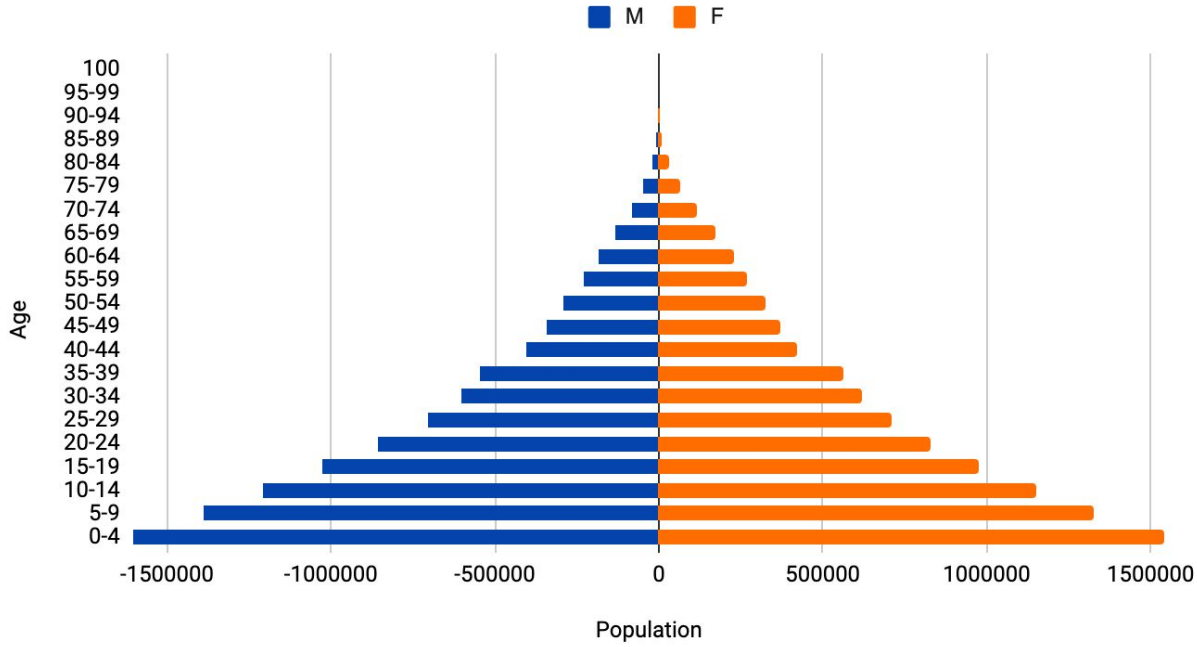


Figure 9

2015 Population Pyramid

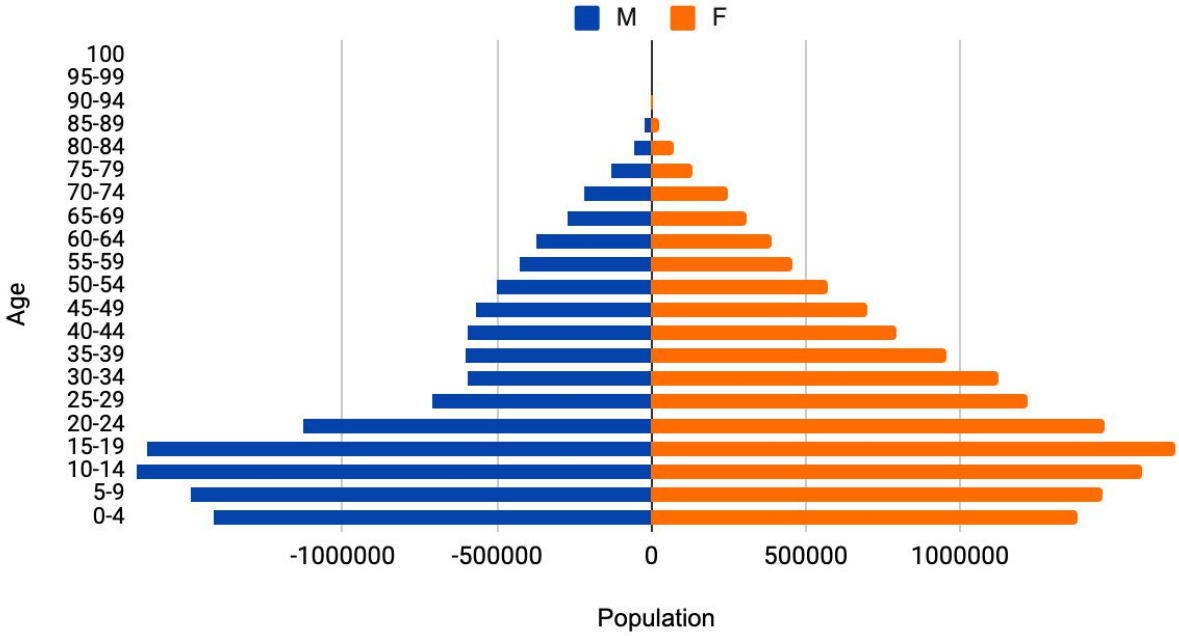
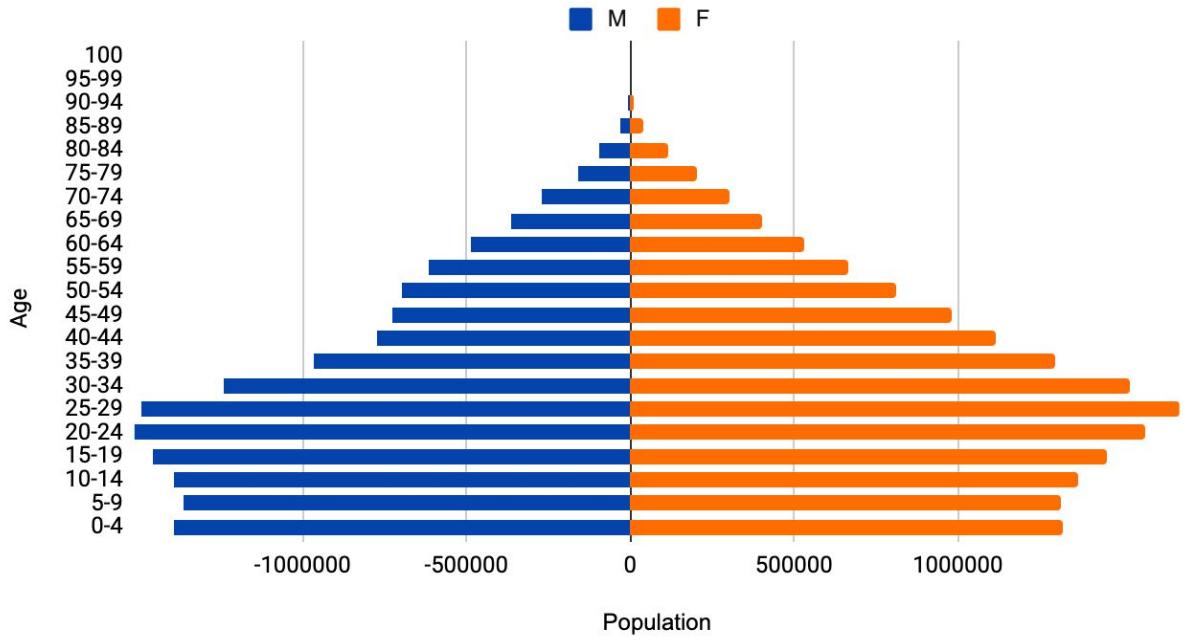


Figure 10

2025 Nepal Population Pyramid



Annex

Data

Malaria Data

The available online record of annual malaria cases for the years 1999 to 2016 were obtained from the annual reports of the Department of Health Services of the Government of Nepal (DoHS, 1999-2016). Annual malaria cases for years 2017 and 2018 were obtained from a report 'Dengue, Kalazaar and Malaria trend update 2020' (EDCD, 2020). All of these reports were downloaded from the website of the Epidemiology and Disease Control Division (EDCD) of the Department of Health Services, Government of Nepal (http://www.edcd.gov.np/). There was a change in administrative boundaries in Nepal in 2015: two districts were split to make two each, and now there are 77 districts instead of 75. i.e., Nawalparasi has been split into Nawalpur and Parasi, and Rukum has been split to Rukum East and Rukum West. For this study, since the majority of the data are for 75 districts, the analysis was done for 75 districts by adding up the cases of split districts into one.

Census Data

Population data for census years 2001 and 2011 were obtained for each district from the Central Bureau of Statistics (CBS), Nepal (CBS, 2014). The population for non-census years between 1999 to 2018 was extrapolated based on the population growth rate of the census years.

Geographic Boundary Data

The shapefile of polygon data of district boundaries and Province boundaries of Nepal were obtained from the ICIMOD (International Center for Integrated Mountain Development) website **(**https://rds.icimod.org/home/datadetail?metadataid=1669).

Malaria Incidence Calculation

The incidence of malaria was calculated using the following formula:

$$Malaria\ Incidence = \frac{Malaria\ case}{Population} * 10,000$$