Chapter 9

Impact of Cold Wave on Vulnerable People of Tarai Region, Nepal

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Additional information is available at the end of the chapter

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Abstract

Climate extremity phenomena are increasing with the global climate change. Cold wave is one of these climate extremities affecting the health of people, especially vulnerable groups. Nepal is also experiencing the impacts of global warming on its temperature patterns. The climate data of more than four decades have shown an increasing trend of annual temperatures across Nepal. However, the change in temperatures is found varying greatly among its three broad physiographic regions: Tarai, hill, and mountains, as well as among four distinct seasons: winter, pre-monsoon, monsoon, and post-monsoon during a year. Further, since the last two decades Nepal has experienced climatic extremities such as heat wave, cold wave, precipitation concentration, prolonged dryness affecting livelihood of the people and demographic features like mortality, morbidity, etc. This study intends to deal with the impact of cold extremity on the death of vulnerable people such as children and elderly in the Tarai region. It draws on meteorological data for four decades since 1974. The magnitude of mortality rate of those vulnerable people is analyzed from 1974 to 2013, and prediction of mortality rate is made with respect to decrease in temperature or intensity of cold wave.

Keywords: cold wave, temperature change, vulnerable people, number of death, Tarai region, Nepal

1. Introduction

The evidences of impacts of climate change across the world are that there has been an increase in climate extremity phenomena such as cold wave, heat wave, extreme

depressions, intense precipitation, rising number of warm days and nights, and decreasing number of cold days and nights. AR4 and AR5 IPCC have predicted an increase in frequency and intensity of warm spells or heat waves in the end of twenty-first century, affecting to increase vector-borne diseases, water-borne diseases, reduce cold-related mortality, and diminish food production and labor productivity at different levels over most land areas of the earth [1, 2]. As a matter of fact, there is large number of studies on health effects of heat waves [3, 4]. Some of the studies argue that the contribution of rising in minimum temperatures has decreased in number of deaths associated with cold spells [5, 6]. On the other hand, there are few studies dealing with cold spells and health impacts. For instance, some studies indicated that the effects of extreme cold temperatures are generally more prolonged than heat wave without mortality displacement [3, 7]. However, most of the existing studies on health effects of cold spells are found to be associated with the temperate climate regions in developed countries, while there are very few such studies carried out in tropical or subtropical regions of developing countries [3, 8–11].

Nepal has experienced global warming and its impacts on forming climate extremities, ill-health of the people, change in agricultural production patterns, etc. over the past recent decades. Cold wave is one of the climate extremities due to global warming in Nepal. The studies of National Agriculture Research Council (NARC) have indicated negative impacts of cold wave on agricultural productivity in Nepal [12]. Other studies have shown the health of the inhabitants being affected due to cold wave in the Tarai region of Nepal in the last two decades [13–16]. The present chapter intends to analyze the climate change patterns and the climate extremities such as cold wave and its impacts on the vulnerable populations in the Tarai region of Nepal.

2. Methodology

The vulnerable population is defined in terms of age group such as children below 5 years of age, pregnant women, and elderly population above 65 years of age [17]. The three subsets of under-five children, such as neonates <1 months, infant <1 year and <5 years, of which neonates is the most vulnerable and it is followed by other subsets [18].

The climate prevailing in Nepal can be divided into four seasons, based on rainfall and temperature conditions. They are rainy summer or Monsoon (June–September with rainy, hot, and humid weather), winter (December–February with coldest and driest weather), pre-monsoon (March–May with hot weather and thunderstorms) and post-monsoon (October–November with cool and pleasant weather). The climate data including monthly minimum and maximum temperatures for all individual years from 1974 to 2014 by the physiographic regions, such as mountain, hill, and Tarai have been acquired from all 67 weather stations from the Department of Hydrology and Meteorology, Kathmandu, and Nepal [19]. These data have been used for describing climate change patterns for all

physiographic regions across the country in general and for analyzing seasonal trends of climate and climatic extremities for the Tarai region in particular. The prediction of trends of temperatures by year has been carried out for two distinct slots: 1974–2014 and 2000–2014.

Data on daily death of the vulnerable population groups due to cold wave during the winter season from 1974 to 2013 for all districts of the Tarai region were obtained from available sources [18–22]. The contribution of seasonal temperature change, mainly, cold wave to the deaths of the vulnerable groups, and the mortality rate have been analyzed by using multiple regression analysis.

The multiple linear regression analysis has been used to develop a model for predicting mortality from the climatic variables at different time lags. This relationship is given by the equation [23]:

$$Y = \beta o + \beta 1X1 + \beta 2X2 \ldots\ldots \beta kXk + \varepsilon \quad (1)$$

where β_k is coefficients, X_i is the predictor, Y is mortality (predicted), β_o is a constant and ε is random error.

The perception about the death due to cold spell or wave and status of vulnerable population groups were carried out by informal talking among 25 respondents selected randomly: 5 each from different walks of life such as the local communities, government personnel, public health personnel, female community health volunteers and school teachers.

3. Findings

3.1. Brief introduction to physiography, climate, and population of Nepal

3.1.1. Physiography

Geographically, Nepal can be divided into three broad physiographic regions, namely mountain, hill, and Tarai from north to south (**Figure 1**). The altitudes of these three regions range from 8848 m above sea level (masl) in the north to 60 masl in the south over an average north-south span of 193 km [24]. Tarai refers to plain topography in Nepal.

The Tarai is the smallest physiographic region, sharing 23% of the country's total area, but it has the largest population with over 50% of the nation's total population of 26.6 million (**Table 1**). Population has increased consistently in this region during the past decades. In 1971, the Tarai's population had shared nearly 38% of the country's total population that increased to over 50% in 2011 [17]. The rapid growth of the Tarai population is considered due to natural cause and other causes including internal migration of population from the hills and international migration from adjoining Indian states [17, 21].

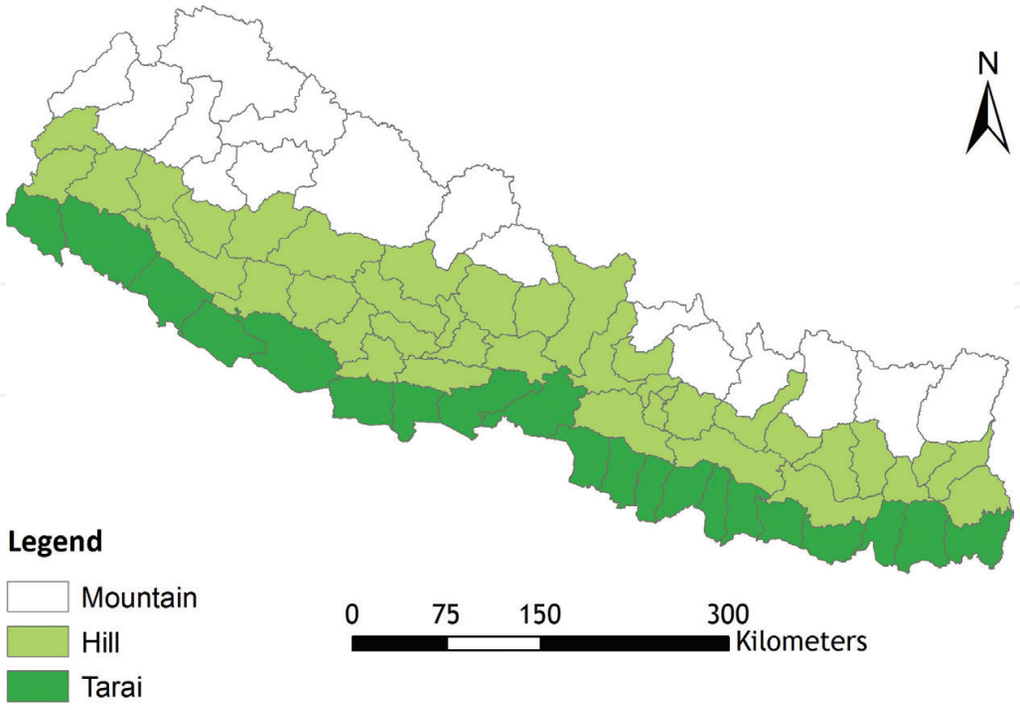

Figure 1. Physiographic regions of Nepal.

Ecological regions	Approximate elevation (m)	Area		Number of districts	Population (2011)	
		km²	%		In million	%
Mountain	>4870	51,817	35.2	16	1.78	6.7
Hill	300–4870	61,345	41.7	39	11.39	43.0
Tarai	<300	34,019	23.1	20	13.32	50.3
Total		147,181	100	75	26.49	100

Source: [17].

Table 1. Broad physiographic regions and their features.

Table 2 exhibits that the combined populations of the vulnerable groups (under-five children, pregnant women, and elderly) account for about 17% of the Tarai's total population. For Nepal, the life expectancy at birth of Nepalese population is 66.51 years, whereas the death rate is 6.75 deaths/1000 population and infant mortality rate is 32 deaths/1000 live births [18].

3.1.2. Climate

Nepal lies within the subtropical climatic zone over the globe [19]. The climate is largely influenced by the Monsoon system, but there is also an influence of the cyclonic system originating from the Mediterranean Sea during the winter season. Owing to rise of altitude of mountains considerably from the south to the north, Nepal possesses diverse climate types ranging from

Vulnerable groups	Total population	% of vulnerable population
Under-five population	1,380,169	10.3
Expected pregnancies	350,497	2.6
Elderly population	534,018	4.0
Total	2,264,684	16.9

Source: [17, 21].

Table 2. Distribution of population of vulnerable groups in Tarai region, Nepal.

sub-tropical in the Tarai region to the arctic in the high Himalayas. Likewise, the annual precipitation also ranges from over 5000 mm in the Western and Eastern midland mountains to below 150 mm in the northern areas beyond high Himalayas, with an annual mean precipitation of 1858 mm [19, 25].

In Nepal, the annual trends of temperature patterns vary remarkably among four different seasons: summer monsoon, post-monsoon, winter and pre-monsoon, and those three physiographic regions (**Table 3**). The annual maximum and minimum temperature trends for the country as a whole are 0.056 and 0.002°C/year, respectively [19]. **Table 3** shows a negative trend of maximum temperature in contrast to the positive trend of minimum temperature during the winter season in the Tarai region [19].

The mean annual maximum temperature for the Tarai region is 30.4 at 95% confidence interval (CI) of 36–30 and mean annual minimum temperature is 18.3 at 95% CI of 16–25. During the winter season, the mean minimum temperature in the Tarai region remains at 9.8°C with 95% CI of 9.5–10.1°C and mean maximum temperature is 23.2 with 95% CI of 22.7–23.7°C. While analysis of temperature trends by year is performed, a conspicuous distinction is found between two slots of years, such as 1974–2014 and 2000–2014 (**Table 4**). During the second slot of years: 2000–2014, negative trends are found in the annual mean minimum temperature, as well as in both mean maximum and minimum temperatures in the winter season in the Tarai region, but found a positive trend in the annual mean maximum temperature in this slot of years. Conversely, positive trends are found in all three temperature conditions during the first slot of years: 1974–2014 except in the winter maximum temperature, which shows negative trend. Thus, the analysis of two slots of periods of years shows a decreasing temperature scenario, particularly during the winter season in the Tarai region.

3.2. Cold wave impacts on Tarai people

Cold waves generally occur in the Tarai region from mid-November to mid-February. On average, the duration of cold waves is found to be 8 days. In 2003, the duration of cold waves remained to be up to 60 days. However, the duration of cold waves prevailing in the Tarai has risen since 2004, compared to that in 2000 (**Figure 2**).

Record of hourly average temperature data shows that the peak cold temperature appears to remain from December to January, where minimum temperature goes below 5°C for few hours during night (**Figure 3**).

Physiographic regions	Temperature trends °C per year (1974–2014)				
	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
Maximum temperature					
Tarai	−0.004	0.018	0.036	0.028	0.021
Hill	0.046	0.049	0.055	0.052	0.052
Mountain	0.101	0.076	0.072	0.085	0.086
Minimum temperature					
Tarai	0.025	0.015	0.015	0.013	0.018
Hill	0.004	0.004	0.014	0.006	0.010
Mountain	−0.056	−0.021	0.013	−0.025	−0.015

Table 3. Seasonal temperature trends by physiographic regions, Nepal.

Temperature conditions (°C/year)	1974–2014	2000–2014
Annual maximum	0.021	0.031
Annual minimum	0.018	−0.040
Winter maximum	−0.016	−0.062
Winter minimum	0.024	−0,024

Source: [19].

Table 4. Trends of maximum and minimum temperature trends in the Tarai region.

There are altogether 30 different types of disaster events being recorded in Nepal [20]. Of these events so far recorded, cold wave is the most crucial one. It is as large and serious as damage of crops due to disaster (**Table 5**). The effect of the cold wave is found across the country (see also **Figure 7**), or primarily in the high mountain region, where there is cold in most of the year, which is, however, not so significant because there exists very thinly scattered population, which mostly have been adapted to the cold climate. But it is crucially very significant in the Tarai region of Nepal, as it possesses largest population size and its poverty level is comparably large [17].

Figure 4 exhibits yearly trend of deaths of people due to cold wave, which is found to be increased exponentially at 13% per year. It is found that the number of deaths due to cold wave has speedily increased, particularly from the year 2000 onwards.

The magnitude of deaths of people due to cold wave in the Tarai is comparably large in the country, as shown in **Figure 5**. The total deaths from cold wave from 1974 to 2013 were recorded at 822. Of these total deaths, 89% took place in the Tarai region, followed by 9 and 2% in the Hill and the Mountain regions, respectively [20, 22].

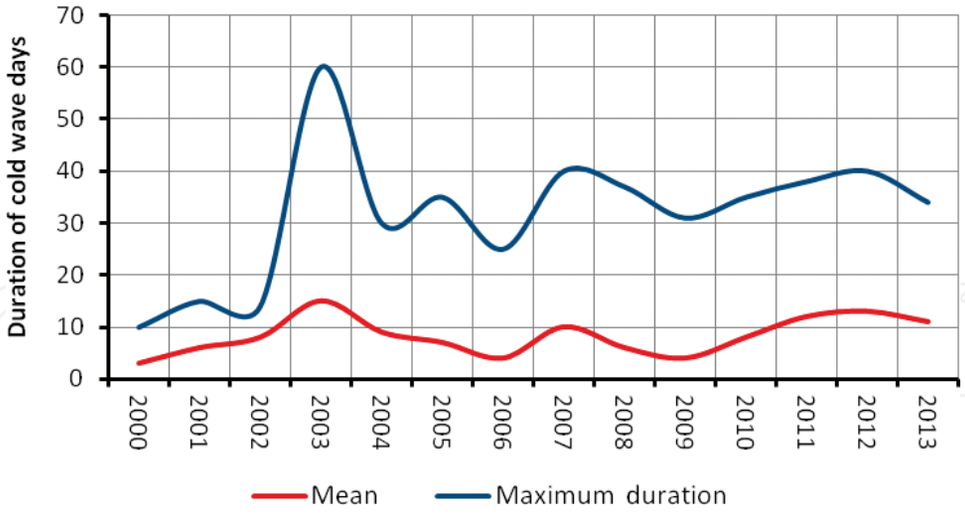

Figure 2. Trend of duration of cold waves in Tarai region, 2000–2013.

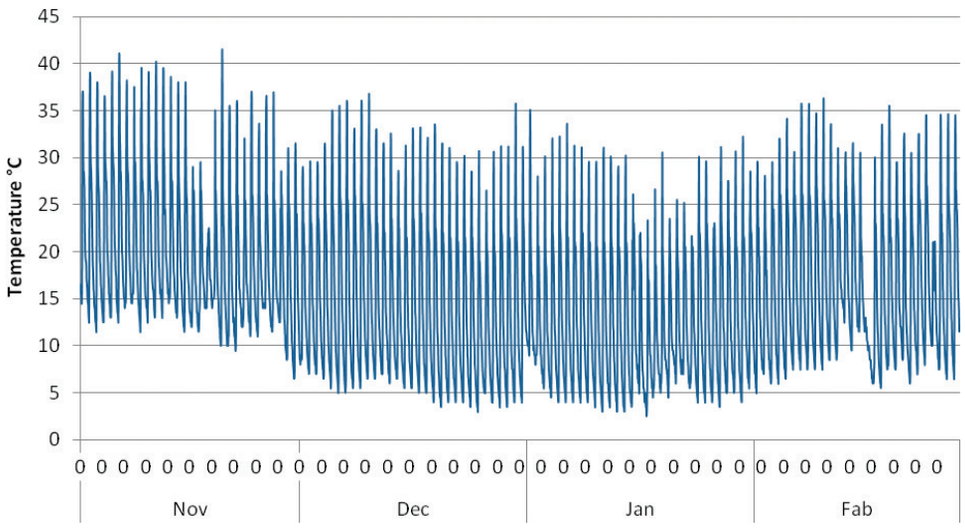

Figure 3. Distribution of average hourly temperature by winter months, Tarai region.

The distribution of average number of deaths due to cold wave by district across the country is found to be varied remarkably. **Figure 5** shows that the number of deaths due to cold wave in the Tarai region were higher in its central and eastern districts than other parts [20].

Further, the deaths of people due to cold wave in the Tarai region are found to have taken place in 4 months (**Figure 6**). The distribution of the deaths is that: it has reached peak in January, with 71.5% and followed it by December (22.0%), February (3.8%), and November (2.4%).

Figure 7 shows 2 years, 2004 and 2013, having the largest number of deaths due to cold wave in the Tarai. Though there is a fluctuation in the number of deaths due to cold wave, gradual rising of number of deaths is found since the year 2000 and more elevated trend of number of deaths since 2009.

Description	Cold wave	% of cold wave among the total impacts due to disaster
Deaths of human beings	822	2.5
Injured due to cold wave	83	0.1
Indirectly affected—morbidity	2405	0.0
Economic losses (US$)	834,650,000	2.1
Damages of crops (Ha)	26906.5	2.6
Death of cattle	732	0.1

Source: [20].

Table 5. Impacts of cold wave in Tarai region (1974–2014).

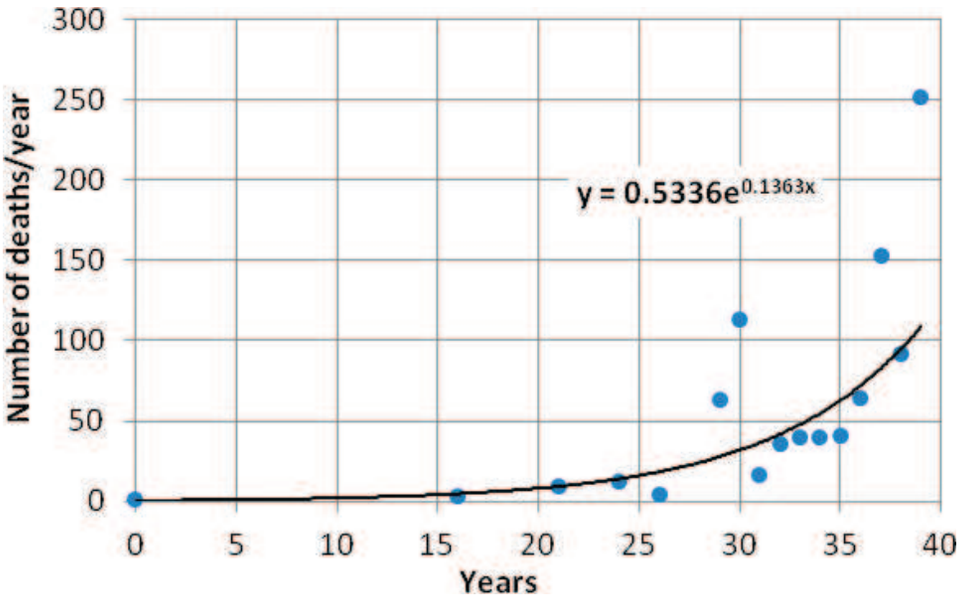

Figure 4. Death trend due to cold wave during the years 1974–2013.

3.3. Age-specific vulnerable people

The number of deaths due to cold wave is found varied remarkably among the age groups of vulnerable people. Of the total deaths, about 60% were children below the age of 5 years, while the 35% elderly population occupied 35% and others the rest 5%.

3.4. Perception of the people

3.4.1. Cause of death

The perception survey indicated that the deaths of the people in the Tarai were mainly due to severe cold, as poor people (children and elderly) with inadequate living conditions (lack of warm cloths and poor house-huts) could not combat with the impacts of severe cold wave. The deaths are found due to diseases like pneumonia, ARI, influenza, COPD, asthma, fever, and hypothermia.

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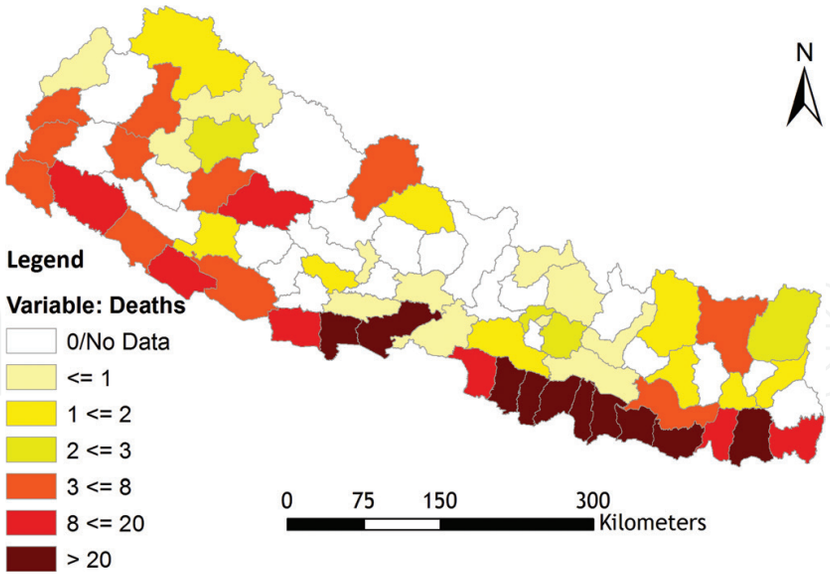

Figure 5. Spatial distribution of deaths due to cold wave by district in Nepal (1974–2013).

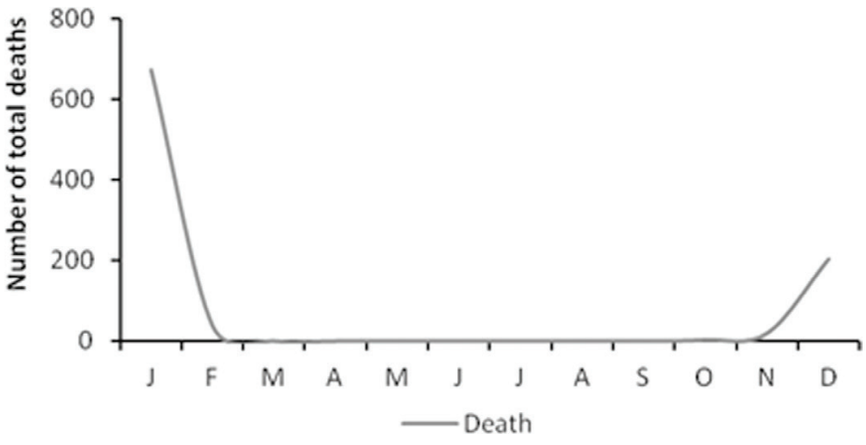

Figure 6. Total number of deaths in Tarai region from 1974 to 2013.

3.4.2. Adaptation

Undoubtedly, impact of cold wave is severe among the local communities, whose economic status is poor, and also daily wage laborers are affected the most, as their wage works are hindered due to cold wave. Normally, they use fuelwood to combat the cold wave but that is not adequate to manipulate the room temperature to bring to the normal standard. In response to this, the Government of Nepal is found distributing fire wood to the local inhabitants of certain pocket areas, and warm clothes to the new born baby and mother in the hospital during delivery.

3.5. Mortality prediction

The prediction of number of deaths of people due to cold wave has been carried out by using multiple linear regression, based on the data of three variables such as minimum temperature,

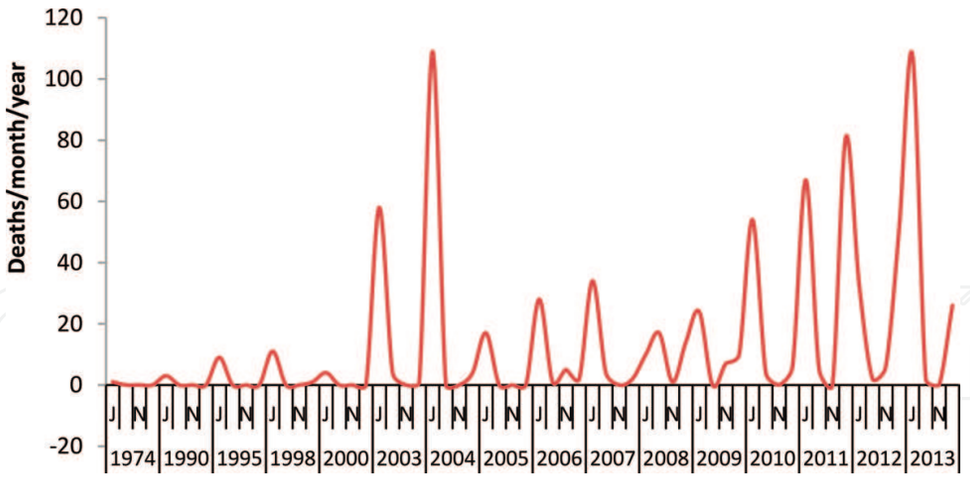

Figure 7. Mortality per month/year due to cold wave in Tarai region.

maximum temperature and rainfall from 1974 to 2014. A significant regression equation was found at [$F(3, 38) = 4.258$, $p < 0.05$)], with an R^2 of 0.252. The prediction of the number of deaths by employing the multiple linear regression is found equal to 814.84 + 20.07 (minimum temperature) − 40.70 (maximum temperature) − 0.561 (rainfall), where minimum temperature and maximum temperature are measured with degree centigrade (°C) and rainfall in millimeter (mm). Number of deaths of people is found to be decreased by 20 with an increase of 1° minimum temperature. On the other hand, the number of deaths is calculated at 54 people with a decrease of 1°C of temperature and 0.56 deaths with each millimeter decrease in rainfall.

The multiple regression tool has been used to predict the number of deaths from 2000 to 2013 considering the same three variables and the significant regression equation was found [$F[3, 11] = 1.483$, $p < 0.05$)], with an R^2 of 0.29. Prediction of the number of deaths based on the multiple linear regression is equal to 980.45 − 32.442 (minimum temperature) − 25.695 (maximum temperature) − 0.066 (ml), where temperature conditions are measured with degree centigrade (°C) and rainfall is measured in millimeter (mm). The number of deaths is calculated to increase at 32, with a decrease of each degree in minimum temperature. Similarly, 26 people are expected to die with decrease of 1° temperature and 0.066 deaths will occur with a decrease of each millimeter of rainfall.

4. Discussions

As other countries across the world, Nepal has also experienced increasing trend in average annual temperature as well as in minimum and maximum temperature conditions [26]. But however, since the last two decades, Nepal's Tarai region has got a decreasing trend of minimum temperature in winter season, unlike other regions [19]. While attempts have been made to analyze the temperature trend, two slots of year duration such as 1974–2014 and 2000–2014 were found as distinctive. In contrast to the trend of temperature conditions during

1974–2014, the analysis shows negative trends of minimum and maximum temperature conditions in the winter season during 2000–2014 years, indicating increase in the number of cold days in the Tarai. Globally, the annual numbers of warm nights and cold nights have increased and decreased by about 25 and 20 days, respectively, since 1951 [27]. In Nepal, the annual numbers of cool days and cool nights have decreased by about 5 and 9 days, respectively from 1971 to 2006, but however, during the same time period, the warm days have increased by about 16 days and warm nights have increased by only about 7 days [28]. It is interesting to note here that the decreasing trend of cool days and increasing trend of warm days are clearly seen at higher elevations in Nepal [28].

Death of people due to cold wave is increasing in the Tarai due to increasing duration of cold wave. Tarai region also suffers death of people from heat wave, as it is the hottest region of Nepal. However, the number of deaths due to cold wave is larger than that due to hot wave in the Tarai. The study of MoHA found that the number of deaths in the Tarai due to heat wave from May to August was 45 during the years 1974–2013, which was, however, quite low as compared to the 822 deaths due to cold wave from November to February during the same year duration [20]. The impact of heat wave was mostly on the elderly people, while that of cold wave was on children.

Death of people in the Tarai is found not only due to cold wave but also because of lack of facilities in living places or public hospitals [19, 26, 29]. For instance, during the severe cold months, the average indoor room temperature was found so low than the normal standard [13, 15]. Even in the hospitals, there was seldom provision of room heating system, resulted into death of neonatal and under-five children due to hypothermia and acute respiratory problem [15]. Further, there has been an increasing trend of mortality and morbidity due to respiratory diseases like ARI, COPD and cardiovascular diseases as a result of decreased temperature or cold wave in the Tarai region of Nepal [16]. The same study has predicted that there will be decrease in number of death of people by 2.68% due to ARI as per 1°C rise in minimum temperature. A study carried out in Sarlahi district of Tarai region found out that about 92% of new born babies born in winter suffered from the hypothermia [30]. Overall, only 10.7% of neonates have received optimum thermal care as per the WHO guidelines [15].

In addition to the deaths of people, there are other adverse impacts of cold wave in the Tarai region. Running schools and daily life and livelihoods of people usually are severely interrupted by the cold waves, especially, the vulnerable people like children, elderly and pregnant with low-income groups, and homeless people and daily waged people are affected the most. It is found that cold wave is a risk factor for diseases like respiratory, cardiovascular, viral influenza and Rotavirus infection [16]. Further, during the onset of cold wave, there would be poor visibility leading to increasing trend of road injuries and interruptions in aviation industry, which ultimately hinder livelihood. Outbreaks of avian influenza have a highly seasonal pattern, with nearly all outbreaks occurring in January and February [31]. In mid-winter, especially, the Tarai region can experience cold waves, which often cause crop damage that may lead to famine [20, 32].

Undoubtedly, impact of cold wave is severe on the community, whose economic status is poor, and daily wage laborers are also affected the most, as their activities are hindered due

to cold wave. As they are poor, they burn locally available fuelwood or straw, which are also available in small quantity, to combat the cold wave, but this is found not adequate to manipulate the room temperature to bring to the normal standard. Government's effort in this case is very crucial. The government agencies used to distribute fire wood in some pocket areas and warm clothes to the new born baby and delivered mother in the hospitals. Until now, these mere efforts so far undertaken by the government to address the adverse impacts of cold wave seem inadequate. As health is directly and indirectly affected by climate change via various pathways, there should be a priority focus on health in national adaptation sustainable plans for the medium- and long-term needs of all sectors, such as multisectoral preparedness plans [25, 26].

5. Conclusion and recommendation

It is evident that the average minimum temperature trend during the winter months is declining in the Tarai region of Nepal. The predictions of minimum and maximum temperature trend with regard to number of deaths have been made with different scenarios, that is, increasing or decreasing of 1°C affecting the change in number of death of people by using the modest model of multiple linear regression. Number of deaths due to cold wave in the Tarai has increased over the past two decades due to increasing duration of cold waves in the winter months. Adverse impacts are seen more on vulnerable groups of population such as under-five children and elderly. These are no doubt, the impacts due to global or regional warming, change in land uses, rapid urbanization, etc. It is urgently essential that the adaptation strategy and plans should be designed and implemented to address the increasing trend of cold wave in the Tarai region and other regions based on the findings and recommendations of the rigorous studies.

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