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Strategic Framework for Implementation of Heat Wave Early Warning System

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***Abstract*—Southern Nepal (Terai region) experiences very hot summer every year and is more vulnerable to heat waves with climate change and increasing population. Heat wave hazard is overlooked in Nepal by government and scientific community as it lacks spectacular and sudden violence like other hazards and the country is trying to mitigate other major hazards like epidemic, floods, landslides, fires and earthquake. Through literature review, case studies and study of meteorological and demographic data of Bara district, this thesis presents outline of trend and impacts of heat wave describing current level of preparedness and adaptation. It proposes a heat wave definition for southern Nepal which requires value of T_{max} to exceed 39.5 °C or THI_{max} to exceed 33.1°C for 3 consecutive days. It proposes heat wave early warning system from national to local level for Terai region of Nepal with three warning levels which will remain active from April to July along with response plans.**

Early Warning System Model designed using Android-based mobile technology, with the aim of warning to the continuity. An early warning system will send text messages based Web Services via mobile devices such as smart phones. The results of this study are models of early warning systems designed to help and provide an information through text messages. Waterfall and in the development of system design using integrated modeling language namely Unified Modeling Language (UML).

I. INTRODUCTION

The climate change has increased frequency and intensity of extreme weather events such as droughts, hurricanes and Heat Waves. Heat Wave is period of generally days with uncomfortable heat and humidity which can cause cramps, fainting, heat exhaustion, heatstroke, dehydration, disease exacerbations, combined effect of medications on thermoregulation and ultimately mortality [1]. 2015 was the hottest year on record and this contributed to a major loss of life from heatwaves, including a combined total of 7346 deaths: in France (3,275), India (2,248) and Pakistan (1,229) and 1.2 million people were affected by extreme temperatures [2].

The physical nature of a heat wave itself is not unambiguous but international meteorological societies have different definitions of heat wave [3] ; [4], defines heat wave as a period of three consecutive days during which the maximum temperature is above the threshold of 32.2°C, but it is also defined more generally as "a period of abnormally and uncomfortably hot and usually humid weather". According to French meteorologists, a heat wave is simply a period during which the maximum temperature goes beyond 30°C, while acknowledging that humidity, air motion, and radiant energy also influence the heat stress upon human health that is observed during a heat wave [5].

Hence heat waves can be understood as periods of unusually hot and dry or hot and humid weather that have a subtle onset and cessation, a duration of at least two–three days, usually with a discernible impact on human and natural systems. Because there is no absolute universal value, such as a given temperature that defines what is extreme heat, heat waves are relative to a location's climate: the same meteorological conditions can constitute a heatwave in one place but not in another [6]. Official definition of heat wave cannot be found to the context of Nepal. Heat wave is generally understood as "Loo" meaning hot winds and "Ghaam Laagnu" meaning getting affected by heat of Sun in southern Nepal. As Nepal has vast climatic and physiographic variations, definitions of heat wave are to be prepared according to the climatic and physiographic divisions.

Thermal indices are single scale which combines effect of various climatic parameters to describe the complex conditions of heat exchange between the human body and its thermal environment. Different thermal indices are developed as air temperature alone doesn't give good indication of the human thermal environment [6].

II. LITERATURE REVIEW

Heat wave incident occurs across the world every year taking thousands of lives. Documentation of and study about heat wave incidents in South Asia is difficult to find. No study or documentation of heat wave can be found in context of Nepal except for few newspaper articles. Every year newspaper reports about people's lives being affected by heat waves in Terai region (especially western Terai) but it hasn't acquired attention of government or private institutions. The nature of heat wave being the silent killer of socially deprived people [7] and non-occurrence of huge number of mortalities by it may be the reason why heat wave isn't considered as major hazard in Nepal. The DesInventar [8] data presents record of 45 casualties and 380 families affected by heat wave since 1972.

Early Warning Systems (EWS) as “the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss”. According to UNISDR, a people-centered or community based EWS comprises four key elements which are Risk Knowledge, Monitoring and Warning Information and Dissemination and Response Capacity.

Heat wave is different than other hazards as its main impact is human health. Thus, heat wave EWS can be defined as a weather-based alert component of a wider Health Action Plan. Heat wave EWS includes weather forecasting, determination of a threshold temperature or bio meteorological index for action trigger and the issuance of warning messages to stakeholders in the heat–health field. Other activities like the identification of vulnerable population groups, interaction with stakeholders, the design and operationalization of heat-intervention strategies, the implementation of longer-term heat-mitigation and evaluation of effectiveness of heat wave EWS are component of wider heat wave health action plan. The first heat wave EWS was implemented in Philadelphia, USA, in 1995 [6] [9].

Flash floods face forecast and detection challenges because they are not always caused simply by meteorological phenomena. Flash floods result when specific meteorological and hydrological conditions exist together.

Flash floods may also be triggered by dam or levee failures, rapid snow melt, ice jam and rainfall over recently burned or deforested watersheds. There are mainly two types of early warning system in the world. The first called as a Local Flood Warning System (LFWS) which is made up of manual and/or automatic hydro meteorological gauges plus some method for collecting and processing their reading at a central location. The second method is based on the guidance of Flash Flood Guidance (FFG), employed be the U.S National Weather Service and several other countries around the world. This process compares the rain-fall and runoff relationship to determine the threat of a flash flood, given the soil moisture and degree of saturation. [10]

With the knowledge of hydro-metrological hazards and disaster triggering mechanisms, there are different types of Early Warning Systems (EWS) established in case of floods and landslides. EWS has been defined as “the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and act appropriately and in sufficient time to reduce the possibility of harms or loss” [11] This definition is also upheld by IPCC 2012, which states that these systems are developed in such a way that they are cost effective, easy to operate and maintain and such systems are referred to as Community Based Early Warning Systems (CBEWS). [12]

Until recently, Natural Calamity Relief Act 1982 was the only legal document for disaster management sector which focused solely on relief activities. [13] The parliament has recently approved Disaster Risk Reduction and Management Act, 2074 which is not yet implemented. Amongst the responsibility given by this new act to its executive committee, the responsibility number 15 is “to develop and operate national EWS”. One of the responsibilities of envisioned National Disaster Risk Reduction Authority is to study about EWS and select best system. The District Disaster Management Committee’s (District DMC) responsibility is more focused towards post disaster management works of rescue, relief, emergency shelters, reporting incident, etc. while the Local DMC’s responsibility is more focused in pre-disaster works of preparedness, training, awareness and mitigation. According to the new act of the Province DMC has responsibility “to develop and operate state level disaster management information system and EWS” and the Local DMC has responsibility “to develop and operate local level disaster management information system and EWS”. The Local DMC has responsibility to form ward level or community level Disaster Preparedness and Response Committee to ensure community participation. The Local Government Operation Act, 2074 which has empowered municipalities and rural municipalities also gives responsibility of disaster risk management to local government.

III. RESEARCH METHODOLOGY

A. Study Area

Bara district has been selected as study area as it is one of the representing districts of Terai region with mean maximum temperature at over 30°C and the district with maximum casualties from heat wave according to the DesInventar [8] data as shown in Fig. 2.

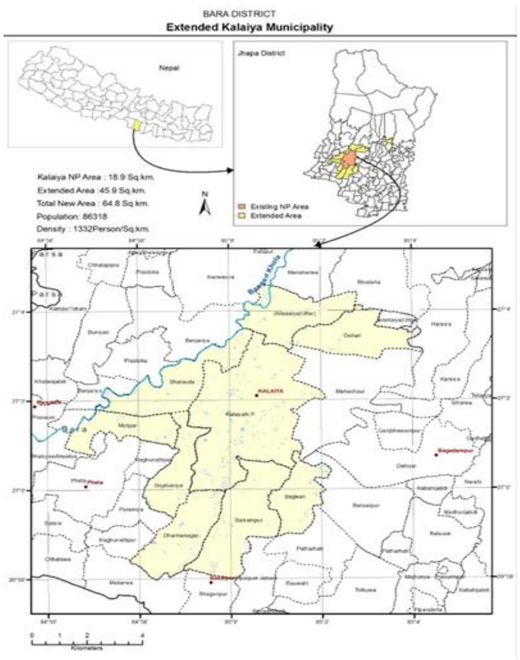

Fig. 1. Bara District [15]

Bara District is situated in Madhesh Province (No. 2). The district, with Kalaiya as its headquarters and the biggest city, covers an area of 1,190 sq. km. and has a population of 687,708 - highest in the district as of 2011. The main languages spoken in Bara are Bhojpuri, Bajjika, Maithili and Nepali. According to recent restructuring of local bodies by

Nepal Government, Bara district has now 2 sub metropolitan cites, 5 municipalities and 9 rural municipalities [14].

The study has been done in Kalaiya Sub-metropolitan city through discussion with officials from District Health Office (DHO), District Coordinate Office (DCO), District Administration Office (DAO) and local people.

The summary of demographic distribution of Bara district is shown in **Error! Reference source not found.**.

TABLE I. DEMOGRAPHY OF BARA [16]

Parameter	Bara District	Kalaiya Sub Metropolitan City
Population	687,708	100,234
Population density	578	818
Percentage of population over 75 years (Both)	1.08%	1.33 %
No of household	108,600	16285
Average household size	6.33	6.01
Literacy rate	52.00%	62.48%
Household with toilet	26.6%	43.8%

The main reason of selecting this district as the study area is that (as shown by **Error! Reference source not found.**) t he southern part of Bara District has higher temperature than northern part; and was easily accessible from the district headquarter.

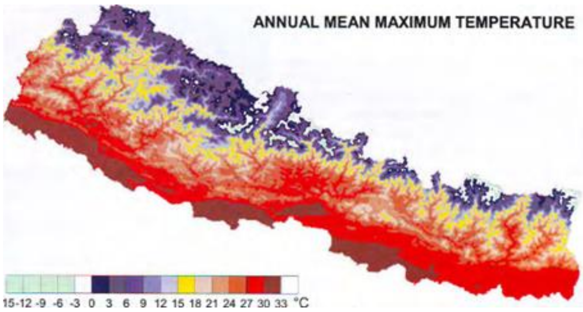

Fig. 2. Map of Nepal showing annual mean max temp

Bara lies in Sub-tropical climatic region according to Shrestha's classification while it lies in zone with warm climate with dry winters and hot summers (Cwa) according to Global Koeppen-Geiger climate classification [41]. The climate is divided into four distinct seasons; pre-monsoon/Spring (March-May), monsoon (June-September), post-monsoon/autumn (October-November) and winter (December-February). Winter season has lowest temperature and occasional rainfall due to western air movements. Temperature starts to increase as spring season advances due to increase inn solar insolation with occasional pre-monsoon shower thunder. The arrival of monsoon rain from Bay of Bengal with around 80% of total rainfall checks the increase in temperature making generally May or early June the hottest months. The temperature starts decreasing as autumn advances.

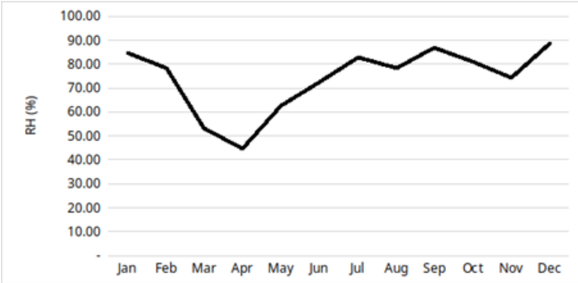

Fig. 3. Seasonal cycle of monthly average temperature in 2016

Average seasonal cycle of temperature and RH for the year 2016 of Bara is shown in Figure 3.6 and Figure 3.7. The daytime temperatures (T_{max}) reach their highest values (close to 36.9°C on average) in May, decreasing with the start of the monsoon season in early June, increasing slightly towards end of monsoon at September and decreasing as the cold season starts (Figure 3.6).

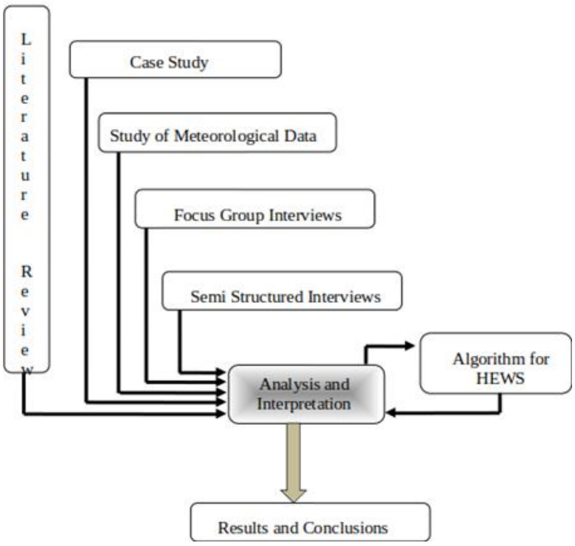

Fig. 4. Flow chart of research methodology

Nighttime temperatures (T_{min}) follow slightly different path as it reaches its highest value at middle of monsoon season at July (Figure 3.6). The RH has its peak value (around 90%) in winter at January and decreases rapidly to around 57% during pre-monsoon when the temperature is highest. The RH value increases as the monsoon begins in June all the way to January (Figure 3.7).

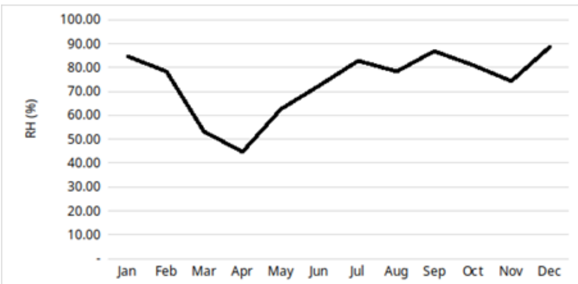

Fig. 5. Seasonal cycle of mothly average RH in 2016

The mean average temperature of 2016 for Kalaiya was 24.6°C with mean maximum temperature at 30.4°C and mean minimum temperature at 18.8°C. The mean relative humidity of same year at Kalaiya was 77 % while the annual precipitation was 1398mm.

B. Research Design

The research is based on constructivist paradigm seeking to construct local and specific realities through interactive, transactional and subjective findings which are correlated to each other. The research uses qualitative approach with interpretive and analytical strategy. Through brief study of existing scenario about heat waves in Nepal and around the world, problem statement is formulated. After the formulation of the problem, a detail study on the heat wave was done to select study area and formulate research question and objectives. The research design is represented in **Error! Reference source not found.**.

1) Data Collection

The research required both qualitative and quantitative data which were collected using different sources as shown in **Error! Reference source not found.**.

Primary data collection is done by interviewing / questioning different types of respondents. The respondents are divided into four categories – (1) community people (FGD), (2) health professionals, (3) government officials, and (4) meteorologists. At first, respondents were interacted to understand their knowledge about heat wave EWS and then asked about the type of EWS that would be suitable in their locality and their willingness to participate in preparation and operation of that system. Different checklists for discussion are used for separate groups of respondents.

For the research to be carried out, secondary data are also collected. Different literature about heat wave, their modelling procedure and heat wave EWS are collected and studied. Case study of heat wave events and EWS are also analyzed. For this, India and Europe are selected with intention of learning from both regional experience of India and advanced system of Europe. Nepal's existing policies related to disaster preparedness and District Preparedness and Response Plan (DPRP) of Bara are also collected and thoroughly studied.

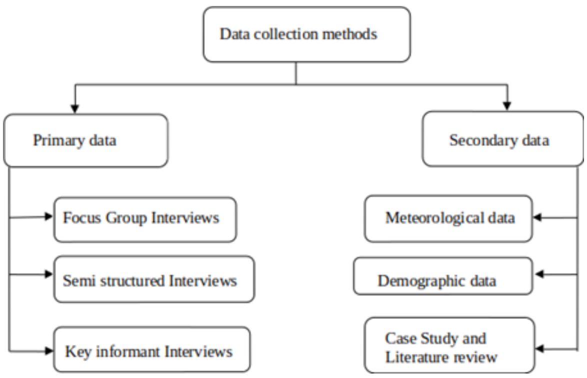

Fig. 6. Data collection methods

The historical meteorological data of Bara district from 1977 to 2017 has been obtained from Department of Hydrology and Meteorology. The data collected was from the only available climatological station (Index no 911) located at just outside Kalaiya Sub-Metropolitan City at an elevation of 115 m above mean sea level. The station was located at the Prawanipur Rural Municipality 15 km north-west from the Kalaiya Sub-Metropolitan City. The collected data included temperature (daily maximum and minimum), relative humidity (at 8:45 and 17:45) and precipitation.

Also, demographic data of the census data of 2011 are used for the study. Different data like population, number of households, literacy rate, water supply, cooking fuel and household facilities which could be useful to study impact of heat waves and design EWS were obtained for Kalaiya Sub-Metropolitan City.

2) Analysis of primary and secondary data

Primary data are collected from (1) FGD and semi-structured interviews and (2) key informant interviews. The data thus collected are recorded using Microsoft Word and Microsoft Excel and then reduced to manageable chunks for comparison between similar interviews. After that, data are divided into number of categories for further analysis. The categories, in case of FGD and semi-structured interviews are – (i) understanding about heat wave, (ii) effects of heat wave, (iii) information and communication of heat wave, (iv) preparation and adaptation to heat wave, (v) health facilities, (vi) government help and expectations, (vii) NGO's and (viii) understanding of EWS. Whereas the categories of key informants' interviews are - (i) the scope of work of MFD, (ii) current monitoring and warning system, (iii) incorporating my findings with available forecast to issue heat wave warnings and (iv) involving community in monitoring and issuing warning. After categorization, the data are studied according to objectives, differentiating them in urban and rural context. Finally, these data are then analyzed and interpreted to obtain findings.

As the secondary data, the collected literature reviews and demographic data are studied and inference are taken to assist in developing heat wave EWS. Among the meteorological data, the years which has more than 10% data unavailable are discarded during analysis [35]. In the cases where less than 10% data were missing, average of previous and next 3 years are done to produce the data.

PET was calculated for few days using RayMan model to find human discomfort through heat budget model. A male of age 35 years, height of 1.65 meter and 65 kg was used for reference. The value of T_{max} is used for air temperature (T_a) and average RH of that day is used for RH from the DHM data. The PET for a day when T_{max} is 30 ºC and average RH of 60% is found over 41 ºC. According to classification (Table 2.2), values greater than 41 ºC is considered to be very hot with extreme physiological stress. Most of the summer days in Terai region has temperature above 30 ºC and RH around 60% or more. Hence, PET isn't used for further study as all the days which exceeded 95th percentile of T_{max} and THI_{max} would automatically fall in extreme category.

Maximum temperature (T_{max}) and Thermo-hygrometric index calculated using maximum temperature (THI_{max}) are studied. As data of maximum temperature and RH is available, THI is selected over other simple bio meteorological indices because it uses these two parameters (i.e. temperature and humidity) to find human thermal comfort level as shown in Eq. (4). Maximum temperature is used as it provides the highest level of thermal stress which will give better understanding about extreme discomfort. The percentile classification of all data of THI_{max} and T_{max} from 1977 to 2017 is done for further analysis to define trigger for heat wave, find trend and distribution of heat wave. Yearly highest value of T_{max} and THI_{max} are plotted to see their trends and distribution over months. Microsoft Excel is used to analyze the data and prepare charts.

3) Early Warning System Modeling

A new approach for Heat Wave Early Warning Systems (HWEWS) is presented that uses wireless, self-organizing temperature sensor networks. To develop the prototype of such IT-infrastructures, a model-driven system development paradigm is followed. Structure and behaviour models of network topologies in specific geographic regions are coupled with wave signal analyzing algorithms, alarming protocols, convenient visualizations and temperature data bases to form the basis for various simulation experiments ahead of system implementation and installation.

The general objective of these studies is to test the functionality of an HWEWS and to optimize it under the real-time, reliability and cost-depended requirements of potential end-users. For modelling a technology mix of SDL/ASN.1/UML, C++ is used to generate the code for different kind of simulators, and for the target platform (several node types). This approach is used for realizing a prototype-HWEWS developed [17]

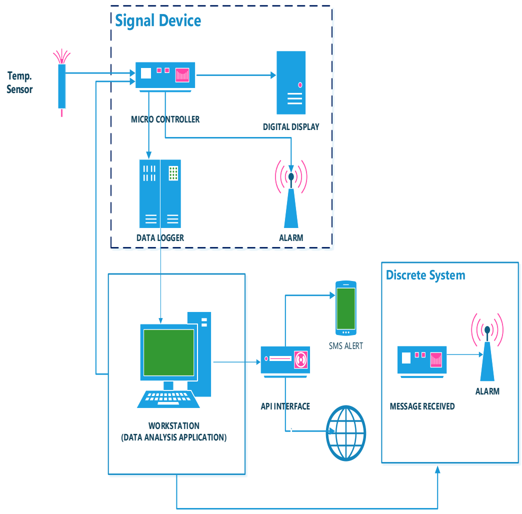

Fig. 7. Block Diagram of Early Warning System

IV. RESULT AND DISCUSSION

A. Definition of Heat Wave

Locals in Bara understood heat wave as an event when a person's health is affected by the heat of the Sun. There is no official definition of heat wave in Nepal hence a definition of heat wave for Terai region of Nepal is proposed in the following section;

B. Indicators of Heat Wave

T_{max} and THI_{max} are used as indicator to define heat wave. Night time temperature (T_{min}) wasn't used for study as through interviews it was found that people felt heat stress during the day and nights were relatively cooler. The average difference between T_{max} and T_{min} for summer months was 12 ºC indicating comparatively cooler weather at night. Most of the precipitation during monsoon in southern Nepal occurs at night (DHM, 2016). Also, Indian Meteorological Department's definition of heat wave doesn't involve T_{min}. [18]

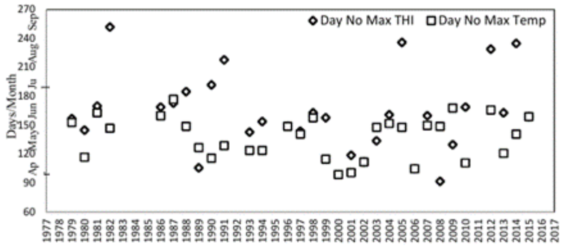

Fig. 8. Distribution of days of max THI and max temp

T_{max} gives us the maximum thermal stress for a person in a day while THI_{max} gives maximum human thermal discomfort in a particular day [21]; [19]. Through analysis of data it was found that the highest value of T_{max} was around April, May and early parts of June while highest values of THI_{max} was also found during July, August and September when humidity has its peak value although the temperature is slightly less as shown in Fig. 7.

As there was no mortality data to support use of either indicator hence both indicators were used to define and study heat wave.

C. Threshold and Trigger for Heat Wave

Categories of THI couldn't be used in context of Bara as over 25% of the days in a year had value corresponding to highest value, > +30 ºC referring to torrid category. The highest value of T_{max} found for Bara is 45 ºC and that of THI_{max} is 41.86 ºC. States that for places where health and mortality data are not available, developers of EWS assume that 95th to 99th percentile values of thermal stress index will be extreme to generate health response and use such value to define threshold. Hence, the values over 95th percentile were taken as threshold for extreme days or heat wave days considering the top 5 percentile values from 1979 to 2015 as proposed in Bangladesh, Spain and Belgium [1]; [20]. The 95th percentile value for T_{max} is 39.5 ºC and 95th percentile value for THI_{max} is 33.1 ºC.

Heat wave is understood as period of hot (dry or humid) weather lasting for at least two to three days with distinguished impacts to human health and natural system. Most of the countries with heat wave EWS consider 2 to 6 days of extreme weather to trigger alert [1]. Trigger is defined through study of T_{max} and THI_{max} data over threshold level and also on the basis of case studies and literature review as there is no mortality data to support. There were many days which exceeded threshold level but many of them lasted only for a day or two and returned to lower values. Hence the trigger for heat wave would be activated only on the third consecutive day on which either T_{max} or THI_{max} exceeds its threshold.

Hence, a heat wave is declared on third consecutive day on which either T_{max} > 39.5 ºC or THI_{max} > 33.1 ºC.

A minimum of 3 consecutive days with exceedance of threshold is required to trigger heat wave but it doesn't distinguish between events of longer duration; for example, 4 consecutive days of exceeding threshold will count as 2 heat wave days as the conditions are met on 3rd and 4th day. A day which meets criteria of definition is a heat wave day. A heat wave which can last for different length of time may have different number of consecutive heat wave days and two heat waves must be separated from each other by at least one day below the threshold.

In Bara, from 1977 to 2017 there were 109 heat waves, 443 heat wave days and 967 days exceeding threshold. Although there are 967 days which exceeded threshold there were only 443 heat wave days as remaining 524 days failed to meet the criteria of definition which means either they were scattered in group of less than 3 or were the first 2 days of a with before heat wave is declared. These 443 heat wave days occur as part of 109 heat waves. The heat wave events lasted for different lengths of time.

This definition developed based on climatic data of Bara can be used across the Terai belt of Nepal as reference to prepare and respond for heat wave. Study of climatic data from all available station of Terai region is required to make it fully acceptable. There is no global heat wave definition as each country or city (region) is developing their own indicators and threshold according to their local climate. The proposed definition is consistent with the definitions elsewhere in many aspects but differ in certain aspects according to local climatic condition and availability of data. In France and Belgium, heat wave is declared after daily minimum and maximum temperature is high for 3 days and in France the threshold is determined according to local mortality [1]. In India the definition of heat wave only considers maximum temperature and is declared after the threshold is exceeded for a single day (Azhar et al., 2014 [46]; Chaudhury et al., 2000) [10].

D. Trend of Heat Wave

According to people of Bara, there is no significant difference between heat stress in past and present but they feel it is increasing due to pollution and deforestation. As per the definition, 109 heat waves had occurred on 40 years studied from 1977 to 2017 on average of 3.4 heat wave per year. 2007 had highest number of heat wave with 9 events while three years didn't have a single event of heat wave. The trend line shows slight increase in number of heat wave over the years (Figure 4.21). The trend line of Tmax also shows slight increase but there is slight decrease in trend of THImax (Figure 4.22). The years with more heat wave events than average have mostly occurred in group of 2 or more which coincide with years of peak value of Tmax and THImax.

The trend and distribution of number of heat wave over the years can be generalized in context of Terai region of Nepal as it is consistent with the Des Inventar data (Figure 2-4) which indicate high impact on mortality by heat waves across Nepal in the year 1997, 2004, 2007 and 2009 which are the years with more than 4 heat wave events.

E. Distribution of Heat Wave

Local people experience hot weather from mid-March until mid- September, mainly from May until the monsoon arrives (July). Most of this period is stressful unless there is rainfall. Among them, some of the days in summer are highly stressful.

All the heat waves occurred from March to October spanning over duration of 8 months (Figure 4.23). Most of the heat wave events occurred from April to July. Events of heat wave were rare in month of March and October with only 3 separate heat wave events consisting of total 11 heat wave days while there were less number of heat waves in August and September too. May and June consisted highest number of heat waves and heat wave days with 38 heat waves occurring in May consisting of 147 heat wave days and 30 heat waves occurring in June consisting 151 days. On average each heat wave event consisted around 4 heat wave days in April and May but it consisted of 5 heat wave days in June meaning heat waves in June persisted for longer duration.

Most of the heat waves in months of April, May and June are triggered due to value of Tmax exceeding threshold than THImax exceeding threshold. Sometimes, both indicators exceeded threshold for same day in these months. In months of March, August, September, October and late July, although the value of T_{max} is in between 36-39 ºC which is not the above the threshold but due to the value of RH being around 90%, value of THI_{max} had exceeded above the threshold level triggering heat wave events in these months.

As Terai region lies in same climatic zone, distribution pattern of heat waves is likely to be similar across the country. As the monsoon rainfall enters the country from eastern region in June, number of heat waves will be less in eastern Terai compared to western Terai. Heat waves are distributed in different time of year according to climatic condition of a country or a region. In Ahmedabad they are distributed from March to October [46].

F. Impact of Heat Wave

There is direct impact on human health, agriculture and economy but very low cases of mortality. The observed impact of heat wave is described under following headings;

G. Impact on human health

Heat wave had caused many health-related problems but loss of life only from heat stress is rare. Sickness, burning sense in body, loss of appetite, fainting, vomiting headache, fever and diarrhea were most common health problems caused by heat wave.

H. Impact on daily life and economy

Daily routine of people is severely affected because working under sunlight is extremely difficult. People manage all of their works in morning and evening. Due to the extreme heat less jobs are available affecting the economy of people who involved in daily labor. Income of farmers and laborers is badly affected while income of business persons in city area is increased due to sale of cold drinks, summer clothes, fans, umbrellas, coolers, etc.

I. Impact on livestock and agriculture

Livestock and agriculture are also affected by heat wave. Livestock mostly remain in shades and there will be less water in ponds for them to drink and cool off. Many ponds will dry off. Although there is not much agricultural works in that period (pre monsoon) working in farms for off season vegetables and other works is extremely difficult.

J. Impact on water and energy consumption

Water and energy consumption increases highly during heat waves. Many tube wells and hand pumps which is the major source of water supply especially in rural area, dry during that period. People, therefore have to walk far to fetch water which makes them more vulnerable to heat wave. In rural areas there is no regular supply of electricity so people maximize use of electricity when available. In urban areas the supply of electricity is more regular and more people have appliances like fan, cooler, refrigerator, etc. resulting in higher consumption of electricity.

The impact of heat waves over Terai region is likely to be similar due to similar climatic as well as social, economic and cultural conditions. Larger cities could have more impact due to concentration of population and Urban Heat Island (UHI) effect. In Europe and India heat wave has caused large number of mortality but not in Nepal. This may be due to the adaptation of people of Terai to hot summer unlike in Europe and temperature of Terai consistently not reaching as high (around 45 ºC) as in India [46] [47].

K. *Adaptation of Locals to Heat Waves*

There is no special preparation done by local people and none by health institution and government bodies for heat waves. In urban areas, people who can afford buy appliances like fan, cooler, refrigerator, etc. as preparation to incoming summer. People have been adapting to extreme heat and heat waves in summer for centuries by changing their daily routine, eating and working habits. Neither government offices nor NGO's have been providing any assistance for locals to cope and adapt to heat waves. The health post and hospitals don't have any program focused for heat waves. They provide basic treatment and advice to people who come for treatment. Some of the adaptation techniques used by locals in Bara during heat waves are listed in coming section.

- They sit in tree shades or inside house and avoid contact with Sun.
- They work in morning and evening, resting during noon and afternoon.
- They bath twice a day.
- They drink plenty of water, even when they aren't thirsty.
- They wear light clothes and use a piece of cloth or cap to cover head.
- They eat easily digestible food which have more water contents like onion and lemon.
- They eat more vegetables and don't eat meat and fish.
- They believe that eating onion and boiled cover of mango will cure them from effects of heat wave.

Similar adaptation techniques are likely to be used across Terai belt due to similar social, economic, cultural and behavioral habits.

V. CONCLUSION AND FURTHER WORK

This thesis presents outline of trend and impacts of heat wave describing current level of preparedness and adaptation while proposing heat wave EWS from national to local level for Terai region of Nepal through case study of Bara district.

Further research should be carried on automated and radar systems to forecast heat wave alerts with ample lead time. Studies should also be done using data from all climatic stations of Terai region to see the similarities and difference with current proposed thresholds. Research should be done on soil moisture through remote sensing and other technologies to predict heat waves.

Finally, the proposed heat wave EWS should be updated and modified with experience from future heat wave events and changes in capacity of MFD, local government and health institutions.

Develop framework for Community Based EWS for Heat Waves in Bara which can be later used to design EWS in other parts of the county to help lives of people residing in Southern Nepal.

Further research is required to determine the site-specific temperature threshold to trigger heat wave Further update on the model is required to upload the data on the server, create basic documents and System Model for further research on Heat Waves in Nepal.

Validation of the model is important to know the functional status and performance of the presented model. Validation can be done with other existing models if any. However, the validation of the presented model with existing other models has not been possible. This is because no such models to demonstrate the EWS of heat wave have been presented in literature. This is probably due to less attention paid on heat wave by researchers and managers. In the context of Nepal, EWS has been highly prioritized for flood risk reduction and has been being prioritized for landslide risk reduction but not for other hazards like heat wave and cold wave.

Validation of presented model can also be undertaken with the data collected and results presented in the current research. Since the model is recently developed, it is to be installed in the study area preferably at the office premises of the municipality. The data collected during hot months (i.e. March and April) can be used to validate the model. It is better to see the data of more than two years to further verify the data. The collected data of more than two years of dry months are to be used for the proper validation of the model. Therefore, further work and research is required to validate the model in the context of Nepal.

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