Causes and Management of Damaging Flood Incidences in Rapidly Urbanizing Areas of Kathmandu Valley: A Case Study of Flood Event in Bhaktapur District, Nepal

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Abstract The ever-growing incidences of urban flooding that were previously anomalous have now started affecting many parts of Kathmandu Valley on a yearly basis. This study aims to understand the causes of urban floods and the adaptation/mitigation interventions being implemented through a case study of recurrent urban flooding in Bhaktapur District, Nepal. A Land Use Land Cover Change (LULCC) map to trace the local LULCC of the flood-affected area and precipitation data of Bhaktapur city was analysed to examine its contribution to the flood. Household surveys, FGD and key informant interviews were conducted to understand the mitigation and adaptation practices at household, community and national levels. The research revealed that the flooding impact has been increasingly severe in recent years, mostly due to poor mitigation efforts. Poor storm water management aggravated by disorganized human settlements in the right of way of the river contributes to scale up the infrequent overflows to overt flooding. Therefore, it is important to expand our understanding regarding causes and consequences of flooding events to inform urban planning. Considering current and potential adaptation strategies, this research makes suggestions for effective adaptive measures and adds to a global conversation about the future of sustainable cities.

Keywords Urban Flooding · LULCC · Climate Change · Storm water · Drainage

1 Introduction

The annual flood brought by heavy monsoon precipitation results in enormous damage to lives and properties, making regions of southern Asia vulnerable to floods (Mirza 2011). In addition, population growth and changes in land use have also increased human vulnerability to floods (Dewan 2015). The changes in land use not only bring changes in the geomorphology but also change the infiltration capacity of soils, which leads to increase in the amount of overland water flow causing floods

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downstream. In addition, the changes in natural drainage and increased burden on existing drainage system, as a result of population growth, increase the likelihood of the system being overwhelmed (Salike and Pokharel 2017). With extreme rainfall events having more recurrent trends in the recent years (IPCC 2014), incidences of both pluvial and riverine flooding have been exacerbated.

Flooding has become a major problem in Kathmandu Valley, Nepal in recent years. Rapid urbanization and subsequent human led changes in the urban landscape has increased the imperviousness exacerbating the flood frequency. The flood incidences over the last one decade have increased in areas with no flooding events in the past, that also includes areas with relatively low precipitation in the catchment. In Hanumante River of Bhaktapur district, there have been two flood events within the four years producing widespread damages—the first one occurring on August 27, 2015 and the second on July 12, 2018 (Prajapati et al. 2018). This study mainly focuses on the flood incidence of July 12, 2018.

While incidences of urban flooding are on the rise all over Nepal, it remains one of the least explored areas in the field of disaster management (NWCF 2009). The challenges to flood hazard mitigation are essentially about instituting good governance (Rijal et al. 2018). The policy, as it exists, does not allow the government to impose necessary restrictions on private property, thus proving ineffective in preventing the unsustainable expansion of urban sprawl.

This research analyses the factors and processes accumulating in the urban areas responsible for the genesis of the flood event of July 12, 2018 in Hanumante River of Bhaktapur, Nepal. It also analyses the strings of adaptation and mitigation efforts implemented by the community and different levels of government. It also aims to draw key gaps in the policies, regulations and practices leaving the urban flooding unaddressed in the rapidly changing urbanscape and urban development plans.

2 Methodology

2.1 Study Area

The study area (Fig. 1) of this research lies in Madhyapur Thimi Municipality (MTM) in Bhaktapur District. Geographically, MTM lies at 27°40′00″ to 27°42′00″ N latitudes and 81°22′30″ to 85°25′00″ E longitudes, at an average elevation of 1320 m from the mean sea level. Much of the landscape of the municipality is plateau-like, located between Manohara and Hanumante Rivers, which includes conspicuous upland and lowland areas.

Hanumante River flows from north-east to south-west of Bhaktapur District with an average width ranging from minimum of 10 m in the dense urban sprawls to maximum of 20 m in peri-urban and rural areas. The catchment of the river is 143 km^2 stretching across 23.5 km (Sada 2012). The river includes numerous tributaries and among them Ghatte Khola, Kasan Khola, Kalighat Khola and Kaalcha khola are

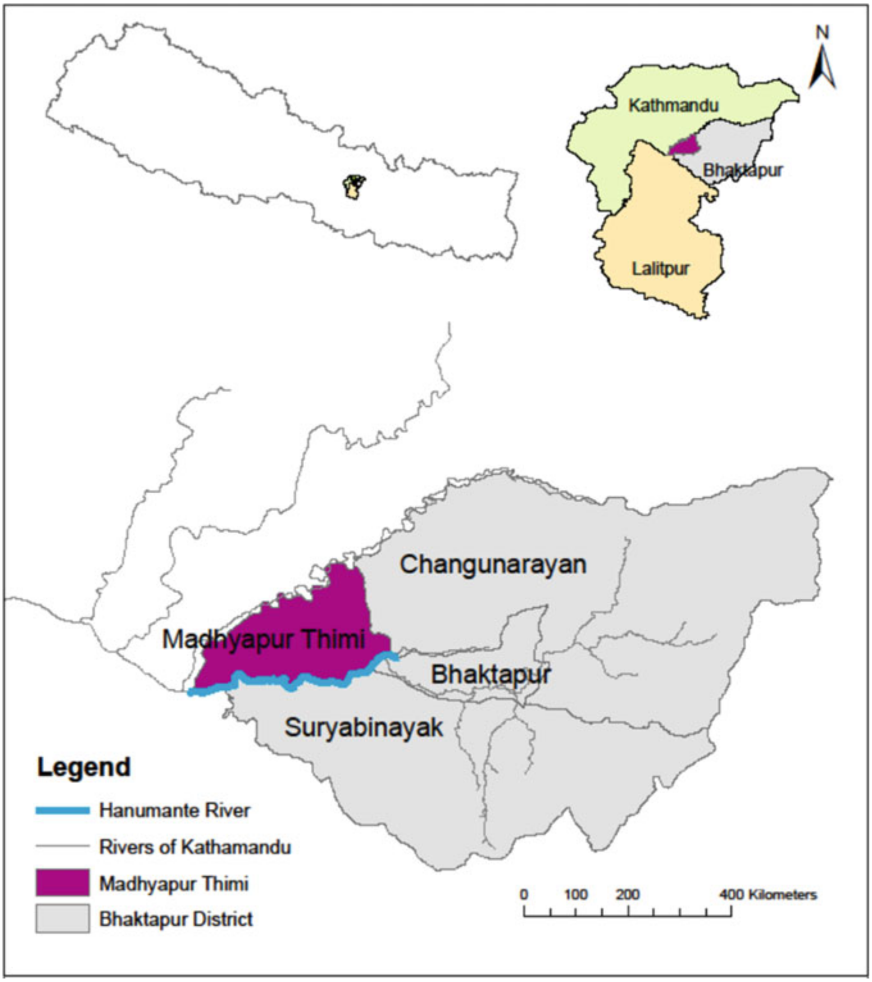

Fig. 1 Study area

important tributaries which join the river at different stretches. Specifically, the low land areas were in the focus of the study because these were the areas inundated in the flood event of July 12, 2018.

This research has used a case study approach and multi-perspective analysis: geographic, geomorphic, meteorological and socio-economic in unpacking the flood incidence of July 12, 2018 in Hanumante River that inundated Madhyapur Thimi Municipality. The following methodological tools were used.

2.2 Reconstruction and Mapping of the Studied Flood Event

The flood event of July 12, 2018 was reconstructed using secondary data collected from different published/unpublished sources and primary information was collected through the questionnaire survey with thirty-five people who faced the event. The primary information was also received from those associated to different social and humanitarian organizations and local governments who were involved in rolling rescue/relief operations following the event and mitigation efforts in the aftermath of the event. The information collected was validated with the recorded information of local government, civil society organizations, red-cross and district administration.

2.3 Reconstruction of Historical Events

Hanumante watershed is ungauged therefore longer-term hydrological data and records of flood history was not available. The Disaster Risk Reduction portal of the Ministry of Home Affairs which is responsible for maintaining records of the disaster event across the country did not have any record of flood events in Madhyapur Thimi and/or Hanumante. Similarly, Municipal Office, Department of Hydrology and Meteorology (DHM), Department of Irrigation and Water Resources (DIWR), Water and Energy Commission Secretariat (WECS), District Administration Office, Nepal Red Cross Society, Bhaktapur and District Police office had no archived information regarding historical flood events. In the absence of hydrological stations at any of its reach in the Hanumante River and unavailability of water flood records, hydrological analysis could not be done, so, the records of flood history were developed using information from the memory of the people.

2.4 Meteorological Data Analysis

The study used rainfall data maintained by the DHM to analyse the rainfall trend in the areas. For this purpose, daily rainfall data of the time period 1971–2018 of the nearest meteorological station (Nagarkot index no. 1043, Bhaktapur index no. 1052, and Changunarayan index no. 1059) were analysed using RCLIMDEX software (Zhanag and Yang 2004). These stations were selected by drawing Thiessen Polygon to establish possible contributions in Hanumante catchment. Out of three rainfall stations closer to Hanumante basin, the data of Bhaktapur station were only found to be homogeneous while conducting RH test and hence was only used for rainfall analysis.

RClimDex is a software package which is useful in calculating the climate extremes indices, required to monitor and detect climate change (Zhanag and Yang 2004). RClimDexuses R platform was used to perform and check the data quality before computing the indices (Zhanag and Yang 2004). This study uses selected precipitation indices for the rainfall analysis and conducts quality control which checks the data input errors which also includes missing data as well. The RHtest software was applied for homogeneity testing of the rainfall data as it does not require any reference series and is available freely (Wang and Feng 2013).

2.5 Map Analysis

The study has analysed the changes in land use and land cover around Hanumante River in Madhyapur Thimi Municipality (MTM) where time series analysis was done from the late seventies to look into the decadal change. Due to limitation of the high-resolution images for detailed LULCC analysis in the small area along Hanumante River, this study uses aerial photographs of 1979 and 1992 which were available with the Department of Survey, Government of Nepal and the Google earth images of 2005 and 2018 which were downloaded and refined for the year 2005 and 2018. These images were used to develop the LULCC map for the lowlands of Madhyapur Thimi and Suryabinayak Municipality, that lies within 500 m width from the Hanumante River for the stretch of 7.13 km covering 7.34 km^2, to know the increase in built-up area along the Hanumante River, which is prone to flooding.

After georeferencing the aerial photographs in ArcGIS, digitization of the photograph was done using four classifications to look into the changes in the land use and land cover: (i) vegetation, (ii) water body, (iii) settlements and (iv) farmland and open space. Similarly, digitization of the Google earth image was done using the same classification and decadal land use and land cover changes were assessed.

2.6 Focus Group Discussion

Experiences and perceptions of the flood event, the changing rainfall pattern, causes and impacts of the flood events were collected from the urban poor, slum and squatter settlers, old inhabitants and recent migrants with their dwellings close to the river course through FGDs, with the following two groups having ten people in each of the groups. Series of questions were asked and documented.

i. Old habitants living in the upland of MTM but having farms in low land and
ii. Old and new migrants living in the lowland of MTM who at least experienced the flood incidence of July 12, 2018.

2.7 Key Informants' Interviews (KII)

Fourteen KIIs were conducted to collect information pertinent to plans, policies and strategies of the government; social, economic, infrastructural and environmental changes in the area and planned and autonomous adaptation practices rolled at different levels. The key informants included personnel working in KVDA, DHM, DOI (WRRDC), Smart Panni, HPCIDBC, MTM, Bhaktapur Municipality and Red Cross Society, including independent professionals and academicians and researchers.

2.8 Physical Observation of the Study Area

The land use pattern and the corridor development work in progress implemented by the High-Power Commission on Integrated Development of Bagmati Civilization (HPCIDBC) were observed as part of the study. At some sections the original width of the river was narrowed as a result of development of the road corridor, which was indicative of the encroachment in the river even by the government supported development programmes.

3 Results

3.1 Historical Flood Events in Hanumante River

The focus group discussion, household interviews and key informants' surveys showed that the lowland areas of MTM have had a past history of getting flooded intermittently at an interval of a few years but the magnitude of damage produced by the recent floods including on July 12, 2018 was unprecedented. In the past, there were no disturbances on the passage of flood and therefore the water level in the river receded within a few hours to few days' time. But the floodwater on July 12, 2018 stood in the area for more than 24 hours showing significant change in the recession of flood flow.

3.2 Analysis of Climatic Causes of the Flood

In order to analyse if the variability in rainfall has been responsible for the flood event, rainfall records of Bhaktapur meteorological stations were analysed using RCLIMDEX software. The catchment of the Hanumante River is 143 km^2 and almost all of the surface water of Bhaktapur is drained through this river. Therefore, when it rains covering the entire catchment the volume of the water in the river rises, producing potential risk of flooding and inundation in the downstream areas.

3.2.1 Rainfall Frequency Analysis

Daily rainfall records of Bhaktapur Station for the period 1971–2018 were subjected to frequency analysis using Gumbel's Type I Extreme Distribution Function to estimate the return period of rainfall of different magnitude (Table 1).

The stations at Bhaktapur, Changunarayan and Nagarkot recorded 24-h rainfall of 129.6, 30, and 117 mm, respectively, on July 12, 2018. As the Bhaktapur station is considered representative to the study area and therefore contributor to the genesis of the flood event on the day, the return period of the event is calculated to be 8.4 years. This shows that the likelihood of recurrence of the flood event of the magnitude of July 12, 2018 is once in 8.4 years (Fig. 2).

Table 1 Estimated 24-hours rainfall for different return periods

S. No.	Return Period (years)	Rainfall (mm)
1	2	73.3
2	5	110.99
3	10	135.95
4	50	190.87
5	100	214.08

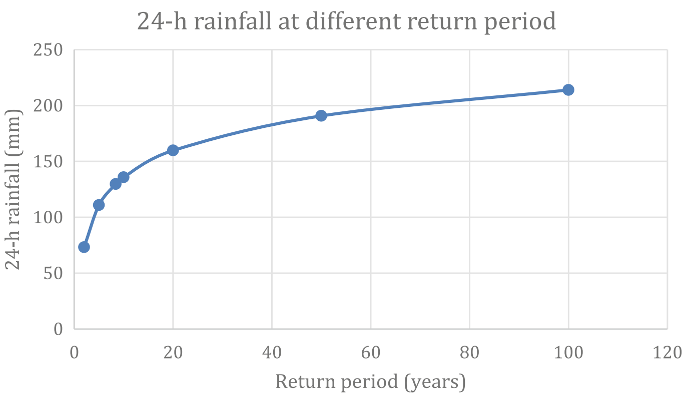

Fig. 2 Likely 24 hours rainfall at different return periods in Bhaktapur

3.2.2 Analysis of Rainfall Trend

This study maintained that one of the causes for the flooding event was extreme rainfall event. The five indices used in the study provide opportunity to look into antecedent rainfall conditions and persistence in the event, both proving bases to logically unpack the extremity of the event.

i. Trend of Annual Total Rainfall

   The annual total rainfall analysis revealed a decreasing trend, but the trend was found non-significant as the *p*-value is 0.075 (i.e. non-significant at 5% level of significance). The decreasing trend in annual total rainfall would mean lower possibility flooding occurrences in the study area in future. However, relying on this observation to make any assessment of flooding trends in the study area would be grossly unrealistic for the fact that flood events are often results of extreme events and the runoff producing potential of the catchment and not necessarily the contribution of total annual rainfall in the catchment.

ii. Trend of Extreme Values

   In order to analyse the likely contribution of extreme values responsible for the genesis of the flood event of the day, the highest daily rainfall amount (RX1day) and highest 5-days consecutive rainfall amount (RX5day) of Bhaktapur Station were subjected to trend analysis. The analysis revealed an increasing trend ($p = 0.521$) of highest daily rainfall while decreasing trend ($p = 0.719$) in 5-days consecutive rainfall total. However, this trend cannot be relied upon as both of the observed trends are very weak and non-significant.

iii. Trend of Consecutive Wet Days (CWD)

   The observed trend in maximum consecutive wet days was noted to be decreasing significantly ($p = 0.041$) in the study area. This trend signals lowering of persistence in rainfall in future times, even in the monsoon. Lower CWD in the area even if there is not much change in the total amount of rainfall would mean lower runoff concentration to produce peak flow because runoff yield from catchment depends on antecedent moisture condition in the catchment besides the amount of the rainfall. Similar observations have been observed of the people living in the study area for a longer time, who revealed that monsoon rainfall in the area is no longer persistent. Number of days without rainfall in between two successive rainfall events has increased, unlike in the past.

iv. Simple daily intensity index (SDII)

   In order to look into the trend of SDII in the study area, the SDII values of each year over the past 47 years (1971–2018) were plotted and it revealed a decreasing trend in the study area, which was non-significant ($p = 0.087$). This trend of SDII in the study area revealed decreasing rainfall amounts on the wet days to produce concentrated runoff causing flooding in the study area.

All the rainfall trend plots are shown in Fig. 3.

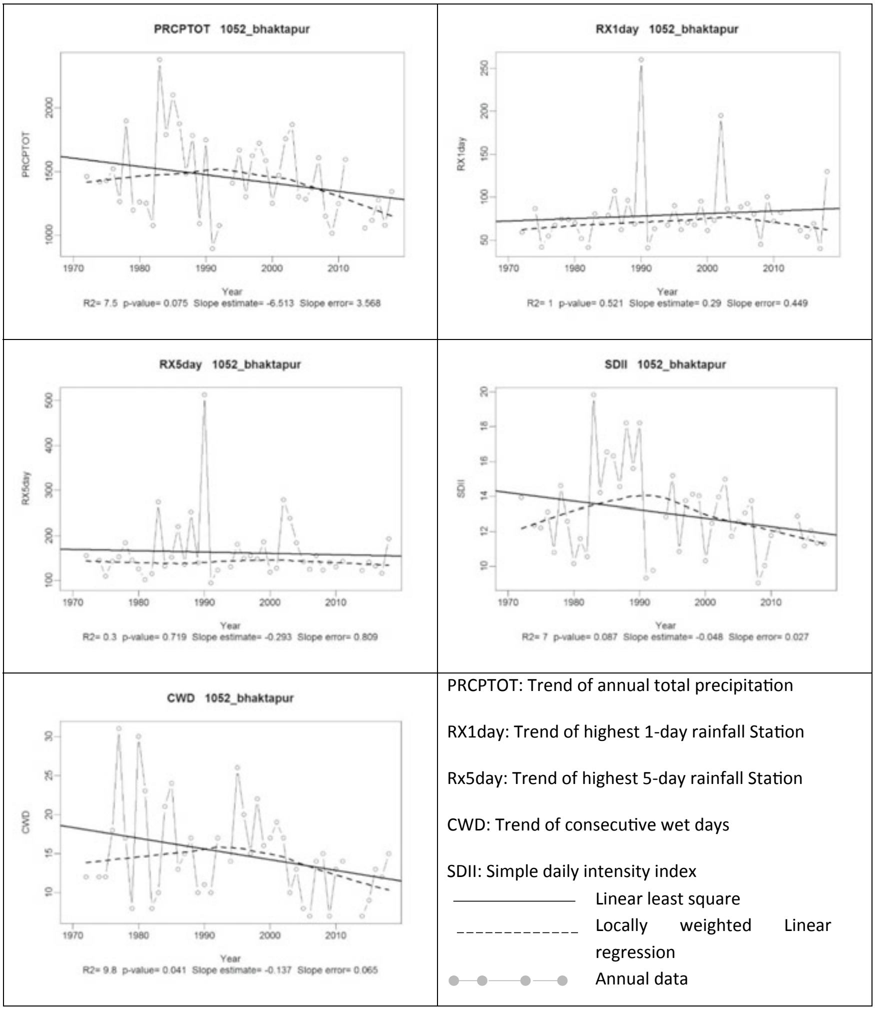

Fig. 3 Trend of rainfall analysis

3.2.3 People's Perception on Climatic Trend

People in the area recall significant shifts in the pattern of rainfall and seasonality indicating that the past moderate and persistent monsoon rainfall had mostly been of short duration with high intensity. Increased occurrence of high intensity rainfall event in the monsoon was attributed by most people to the cause of flooding in Hanumante River and inundation in the surrounding areas, however out of 35 local people who were interviewed, only a small number of people (less than 20%) pointed the rainfall to be the only cause of the flooding. They rather attributed changes in the land use, particularly changes brought in the natural drainage pattern as a result of rapid infrastructure development to be the additional cause. This attribution signifies that they do distinguish rainfall amount and the surface water flow that the given amount of rainfall produces. This perception of rainfall excess clearly signifies people's knowledge of the changes occurring in the landscape and hydrological processes as a result of population growth and densification of human built infrastructures.

3.3 Analysis of LULCC

The study attempted to relate LULCC as a possible causal factor combining with rainfall for producing the flood event of July 12, 2018 in Hanumante River. The LULC maps of the area for different time periods covering a stretch of 500 m width on both sides of the river in Madhyapur Thimi Municipality were prepared. In addition, LULCC map of Kathmandu Valley was also prepared to relate the urbanization trend and related LULCC in the study area with the general trend in Kathmandu Valley.

3.3.1 LULCC of Kathmandu Valley

Land use map of Kathmandu Valley was prepared in Google Earth Engine (Gorelick et al. 2017) for the year 1988, 1998, 2009 and 2018 to assess the general trend of urbanization in the valley and to compare the resulting changes with the changes in the study area (Fig. 4). This was needed because LULCC in the study area cannot be looked at in isolation.

The LULCC analysis of the Kathmandu Valley shows that between 1988 and 2018, the size of the -developed area increased by 625% (Table 2). Much of this growth was found concentrated in three major urban centres: Kathmandu Metropolitan City, Lalitpur Metropolitan City and Bhaktapur Municipality. Human settlements were also found to be rapidly expanding in the peripheral areas, radiating to all directions, from the urban core mostly after the late nineties with 165.60% growth in the developed area from 1998 to 2009. This clearly reveals significant growth in the developed area in Kathmandu Valley over the last three decades.

3.3.2 LULCC of Study Area

In order to assess the land use change in the lowlands of Madhyapur Thimi that was engulfed into recurrent flooding and inundation on July 12, 2019, 7.34 km^2 of area that extended 500 m on either side of the Hanumante River for a stretch of 7.13 km, one side in Madhyapur Thimi and on the other side Suryabinayak Municipality, was analysed (Fig. 5). The periods selected for analysis included 1979, 1992, 2005 and 2018, to cover a time span of four decades (Fig. 6) and maps were prepared in ArcGIS. There has been significant expansion in the built-up area over the period 0f 2005–2018 (Table 3), it increased from 84.9 to 389.330 ha. On the other hand, there

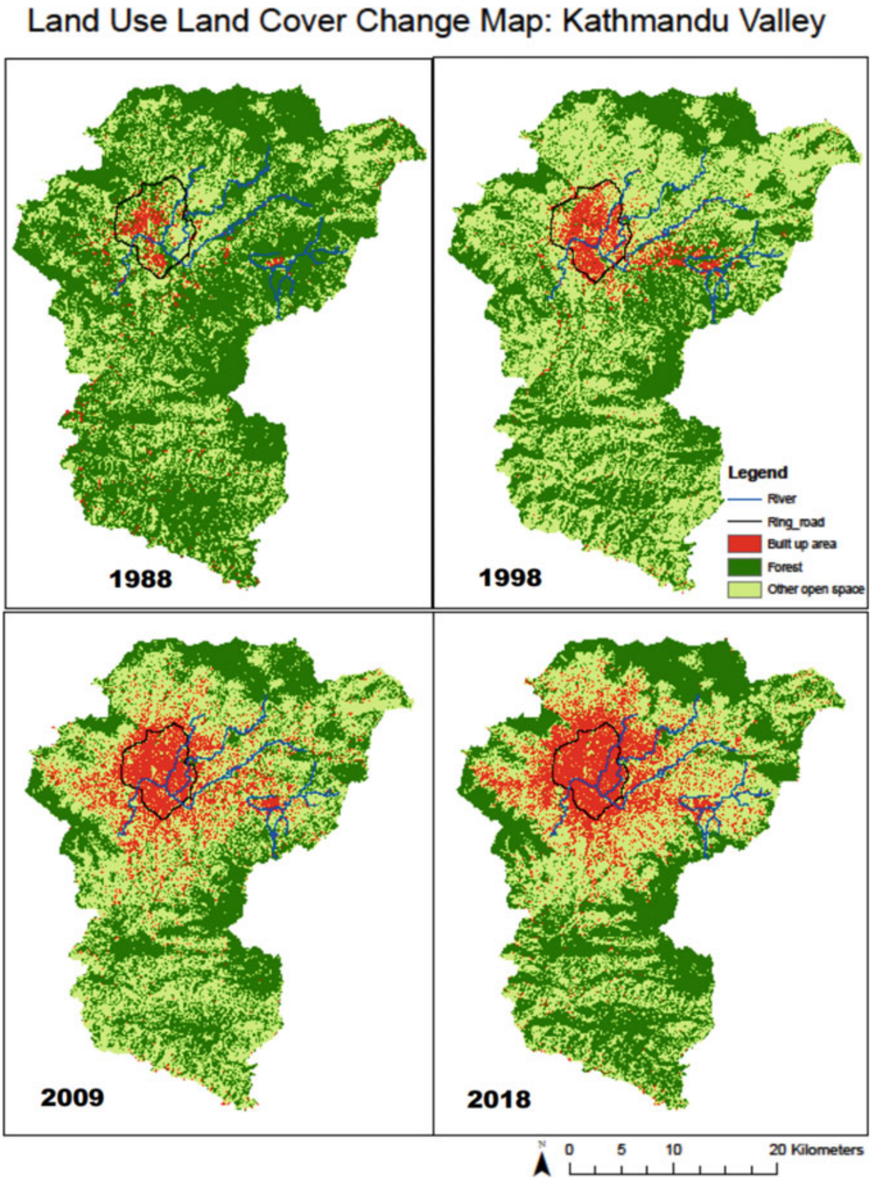

Fig. 4 Land Use Land Cover Change map of Kathmandu valley

Table 2 Land Use Changes in Kathmandu Valley (1988–2018)

	Area (ha)		
Year/Categories	Built-up area	Forest	Other (Agriculture, barren, open space)
1988	2023.74	61,379.73	29,336.76
1998	4212.81	43,420.77	45,106.65
2009	11,189.34	35,886.87	45,664.02
2018	14,678.71	39,475.98	38,586.84

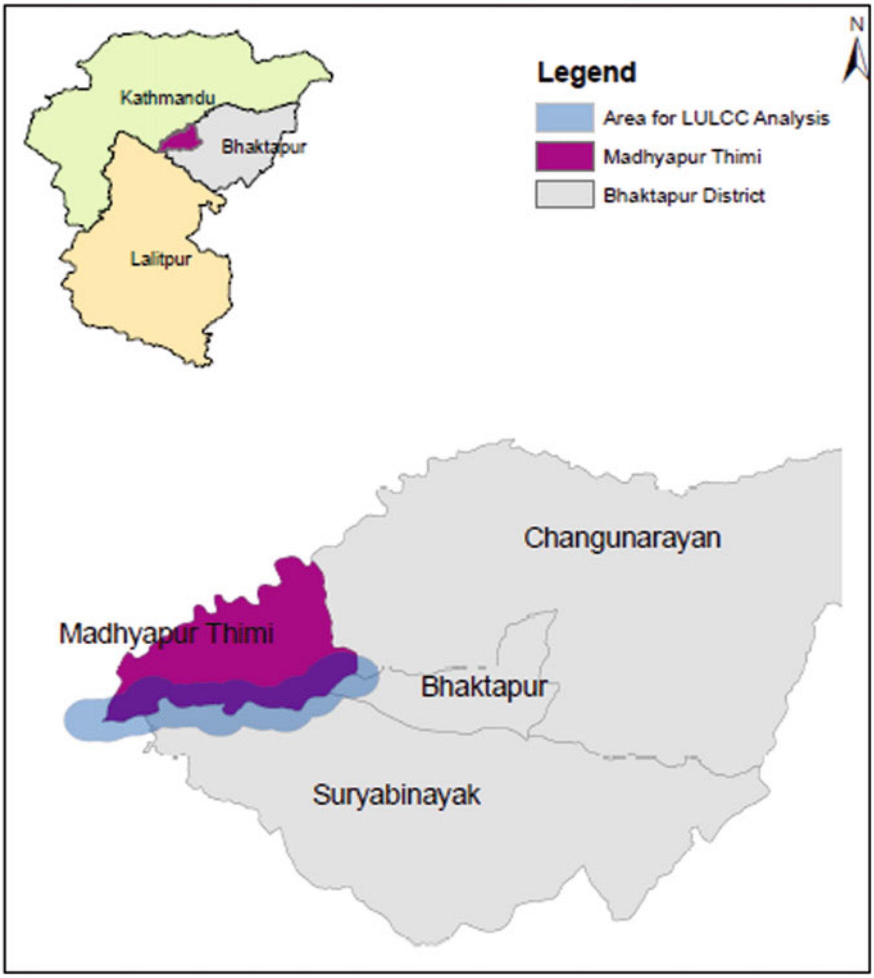

Fig. 5 The site location for LULCC in MTM

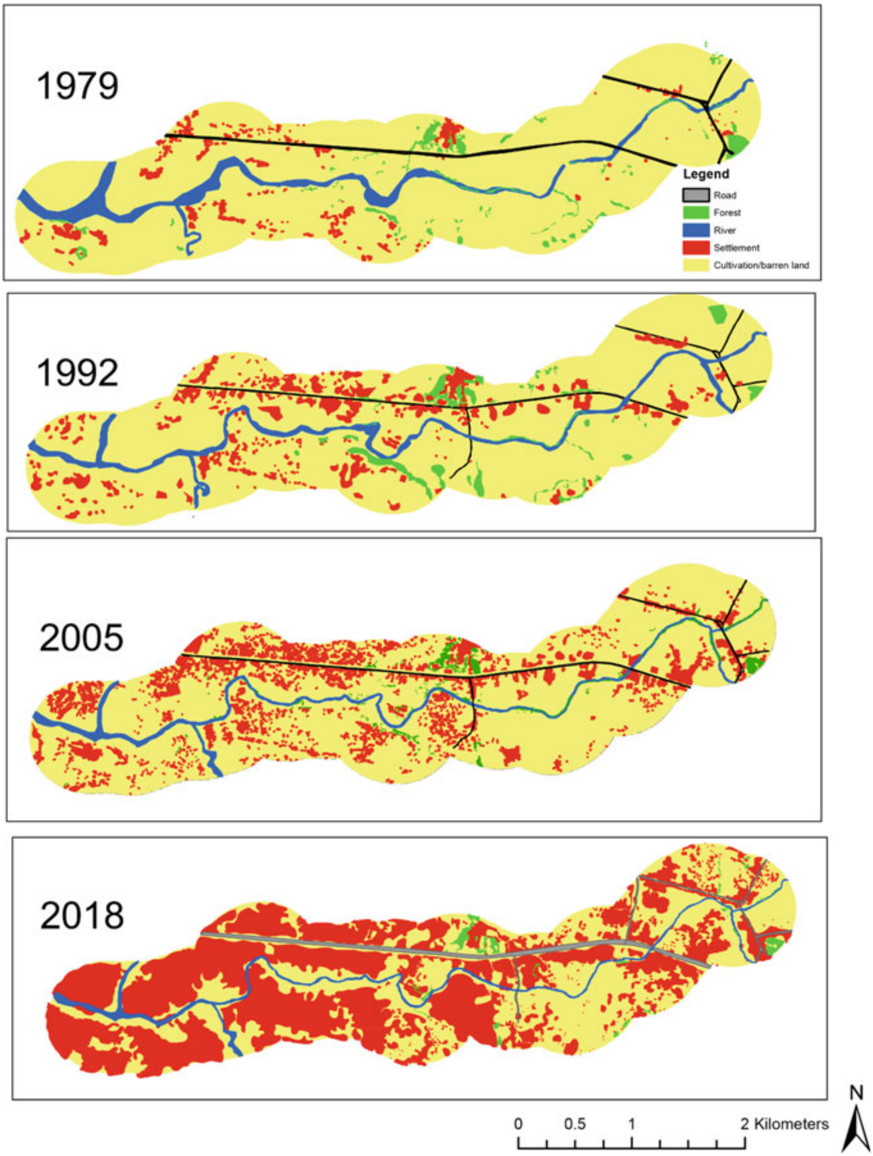

Fig. 6 LULCC map around Hanumante River

has been reduction in the area under agricultural use, water bodies and forest. This resonates with the information provided by the people that the extent of damages faced by the people in the flood event of July 12, 2018 was essentially due to growth in human settlement in close proximity of the river and not by the magnitude of the flood itself.

Table 3 Land use changes in the study area over 1979–2018

	Area (ha)				
Year/Categories	Settlement	Forest	River	Road	Cultivation/barren land
1979	19.00	23.73	41.33	6.24	643.34
1992	54.64	19.48	30.72	6.31	622.49
2005	84.96	14.69	15.32	6.31	612.36
2018	389.33	8.81	11.90	17.27	306.34

3.3.3 People's Observation on Urbanization vis-à-vis Trend of Flooding

This section presents the observation of the people living in the study area regarding the pattern of flooding and inundation in relation to urbanization and changes in the landscape along Hanumante River.

i. Growth in the Population and Human Settlements

   The high rate of migration, development of roadways and conversion of agricultural land have developed physical barriers for surface water flowing back into the river during heavy rainfall. This has resulted in inundation for prolonged duration in the human settlements on both sides of the river. Nearly 67% of the respondents blamed the government for not having strict policies to regulate the land near the rivers.

ii. Encroachment into the Flood Plain

   The key informants identified significant encroachment on the right of way of the river. The area adjoining the river was previously a farmland that had always been the flood plain of Hanumante River, but, at present, the entire area is covered by new settlements and commercial establishments. Unregulated conversion of the farmlands into settlements led it to emerge close to the river's waterway. Also, the natural barriers of endemic vegetation were gradually removed that resulted in floodplain and the riverbanks becoming weak, causing significant erosion due to bank cutting and sloughing. The sediments entered into the river and were deposited on the bed, causing the river bed to rise. The problem was aggravated when riverbank was used for dumping solid wastes by the municipal authorities of Bhaktapur and Madhyapur Thimi.

iii. Poor Storm water Management Practices

   People attributed the problem of flooding and inundation to their inability to evacuate the excess water from the rainstorms quickly. With the reduction in the open spaces and porous land surface, the existing drainage system gets overwhelmed even with rainfall of moderate intensity. The overland flow from paved areas and human settlements, which generated suddenly following the rainfall event, when added to the river flow at lower reaches, aggravates flooding.

iv. Infrastructures Development without Drainage Considerations

   Construction of new roads and other human built infrastructures brought changes in the natural drainage system and the routes for the flow of excess water in the study area. There are several bridges along the Hanumante River and at these bridge crossings, the river section has been narrowed which blocks the natural flow of the river.

v. Erosion of Traditional Systems and Practices of Water Management

The respondents revealed that in the past, there were a number of ponds, natural drains, canals and open areas that buffered the flood water reducing damage. Drainage and excess water from the stone spouts went to the ponds downstream and during rainfall the ponds acted as a storage that was used in the pre-monsoon period for agriculture (Molden and McMahon 2019). In addition to this, surface runoff was also channelled into these ponds. These traditional systems and water management practices are now on the verge of extinction and the pace of development of new infrastructures hardly respects their existence and accrue importance.

vi. Landscape Level Changes Caused by Land Development

Local governments allow land developers to extract sand from hillocks on the river terraces in the valley, which is also common in Madhyapur Thimi. The damage caused to landscape and the environmental damage resulting from such practice of land development, which is rampant at present, is difficult to reverse. The sandy hillocks in the landscape have an important role in sustaining local hydrology for their ability to store water during and after rainfall. Highly permeable sand formation retains the water which would regulate runoff. The loss of the sandy hillocks in the landscape has been one of the reasons for urban flooding, particularly in the catchment of Hanumante River in Bhaktapur. With the loss of more porous sub-surface sandy formation rainwater moves out quickly to produce floods and inundation on the downstream.

3.4 Management of Flood

Management of flood involves minimizing the negative impacts, but they are difficult to eliminate altogether (Khanal 2018). Therefore, resilient adaptive strategy and mitigation efforts rolled at various levels is a cornerstone for minimizing loss and damage. In addition, it is imperative to explore sustainable solutions with regard to management techniques.

3.4.1 Adaptation and Mitigation Efforts Rolled at Household and Community Level

As stated in the preceding sections, the study area had been experiencing incidences of recurrent flooding in the past. Therefore, the case flood incidence was not new but the intensity and duration of flooding and inundation caused by it and the losses and damages suffered were alarming. The event has made people more cautious of repetition of events of similar or larger magnitude in the future.

People revealed that the magnitude of flooding and inundation, at least those that had occurred in the recent past including the event of July 12, 2018, has been so large and sudden, that this leaves very little scope at their end to cope with or adapt to them. People think this would require larger efforts and investment which would be beyond their reach and they foresee the importance of collective efforts and investment made by local governments. Nonetheless, some of the measures that they have started rolling at their end following the event to develop their adaptive capacity include:

- Shifting to other areas or at least shifting to live on the 1st and 2nd floor of the house.
- Raising the plinth level of new houses to ensure that the floodwater would not enter the house.
- Investing to develop raised masonry boundaries, to function as flood walls.

3.4.2 Adaptation and Mitigation Rolled at Local Government Level

Some of the initiatives that have started at the local level following the event have been: (i) removal of silt and cleaning of the river bed and banks annually with the aim of maintaining the river cross-section to allow the floodwater to pass the river channel quickly, and (ii) strengthening riverbanks by developing masonry and vegetated revetment at critical sections and strengthening the ghats and (iii) development of the road corridor, under the funding of the High-Power Commission on Integrated Development of Bagmati Civilization (HPCIDBC) which involves the development of a 20 m wide river followed by 20 m wide road on both sides, and construction of flood wall and retaining wall to strengthen the bank.

The hydrological report of this project reveals that the hydraulic calculation for flood is carried out for the 2- and 5-year return periods at the cross-section and bridge locations along the reaches of all rivers. Though the actual impact of the project is yet to be seen, the real risk is the infrastructure development under the project producing large and irreversible changes in the river environment. When inquired, 83% of the respondents opined that the corridor project development will address the problem while 17% of them maintained that the river width will be further narrowed, thus limiting the capacity of the river to dispose-off the runoff that often produces from extreme rainfall events. One obvious consequence that can be thought of is the disconnection between surface water and groundwater in the river environment as a result of creation of a physical barrier on the riverbank.

3.4.3 Adaptation and Mitigation Rolled at the Central Government Level

The past flood events and the one of July 12, 2018 does not seem to have produced enough concern at the level of central government agencies, those entrusted with the responsibility of decision making and issue policy directives, that urban flooding and inundation is an impending hazard risk in the urban areas and the consequences could be grave if it remains unaddressed. Their focus continues to be on designing and rolling infrastructure solutions to the problem. One such example which is currently underway in the area is urban drainage development involving construction of trunk sewer lines on both sides of the river collecting sewage disposal of the household. The project is part of the urban water system improvement project of Kathmandu Upatyaka Khanepani Limited (KUKL), implemented through a Project Implementation Directorate (PID). The design of the project does not involve any focus on collection and management of storm water, which is the cause of flooding and inundation in the area.

4 Discussion

The flood event of July 12, 2018 was the result of several factors and processes, all combining to produce the flood event of the day. The rainfall trend analysis demonstrated an increase in the high intensity short duration rainfall events which also corroborated with the people's perception. With the increase in urbanization, the events of flooding are seen to be more deleterious and detrimental to the inhabitants in the floodplain. The analysis also shows that the likelihood of recurrence of the flood event of the magnitude of July 12, 2018 once in only 8.4 years. Given the fact that Bhaktapur station has historically witnessed the highest daily rainfall amount of 260 mm recorded in 1990, occurrence of rainfall events of this magnitude could produce even worse floods in the future if not addressed timely. This observation must draw the attention of local governments and the agencies responsible for the development and management of urban infrastructures and services. The Weather Forecast Division of Nepal (DHM) agrees that events of urban flooding, such as the one that occurred on July 12, 2018, are not solely the result of weather-related causes. Most of the time the genesis of urban flooding lies on poorly developed urban infrastructures and services.

The scope of mitigation and adaptation at the household level is much limited as the recurrent urban flood events require larger scale efforts, involving a multi-pronged approach of storm water management, improvement of drainage systems and regulation of infrastructure growth in the urban areas. Contrarily, the local government in the existing arrangement bears responsibility to roll preparedness but does not seem to have any organized and coordinated preparedness measures. Development of river corridors along Hanumante River undertaken by HPCIDBC was identified as the only major activity in the floodplain, although the primary objective of this was to develop road corridors and not for flood control.

The issues of disaster risk reduction and management (DRRM) remained outside the scope of urban development policies until the proclamation of Hyogo Framework (2005–2015) and Sendai Framework of Action (2015–2030). But, the attention has been only on the high intensity and episodic disasters, small yet recurrent disasters, such as urban flooding and inundation, continue to remain outside the radar of DRRM especially in context of Nepal. One of the hard facts projected by the study is the lack of attention and priority for urban flooding and inundation in the existing regulatory codes and practices of Nepal. Nepal's Urban Development Policy (2007) and Urban Development Strategy (2017) considers 'resilience' as the guiding principle of urban development and emphasizes on sensible urban development, and these policy directives do set conceptual clarity for sustainable urban development. However, they do not provide for an operational mechanism to translate the policies into action on the ground. The land use zonation (LUZ) maps which are basic instruments to regulate the land use in the urban and rural areas have not been developed at the level of most municipalities. Even in Kathmandu Valley where these maps have been developed, it is yet to be implemented effectively. This is mainly due to the fair amount of ambiguity in the existing regulatory laws to impose restrictions on the development and uses of private land other than those for designated purposes.

4.1 Sustainable Solutions to Mitigate Urban Flooding

Kathmandu was once a city of culturally and religiously significant ponds that enabled urban development. These traditional systems are rapidly decreasing as the new development did not respect their existence, to add on, the new development did not care for the development of additional drainage facilities to compensate for this loss. This has certainly produced a regime of increased flooding and inundation in urban areas. The local knowledge that informed these ancient structures can be adapted to a modern context by improving drainage systems, groundwater recharge and rainwater storage. The use of traditional water storage systems in new development plans can have the potential of adapting local knowledge systems to solve this modern problem. Also, the dissipation of rainwater, especially its use to recharge groundwater, should be part of the mitigation plan for urban flooding problems.

There is no doubt that the change in local hydrology due to urbanization has contributed to an increase in the frequency of damaging flood incidences in Hanumante River and the damage suffered by the people. This change in the local hydrology is also exacerbated by other changes in land use such as the switch from rice to vegetable cultivation and the practice of increasingly leaving land fallow, as land without a cover crop does not hold water, it acts like a pavement during the deluges of the monsoon and disrupts the recharge cycle (Wrobley 2020). Therefore, planting rice could also be one of the solutions to hold the water.

For enabling resilient urban living, urban flooding and inundation should both be included in the urban development policy and programming. One of the major clauses to be included is the river waterway demarcation in order to avoid further encroachment along the river as well as maintenance of natural drainage in the urban areas. Planning and regulatory capacity of agencies, including local government, to regulate haphazard urbanization should be developed to restrict urban areas from turning into disaster hotspots.

5 Conclusion

The study intended to look into the factors and processes that were responsible for the onset of the flooding event of July 12, 2018. This involved a multi-perspective analysis involving analysis of rainfall data and LULCC in the catchment and flood plain of the river to establish their relationship with the incidence of flooding and inundation on the stated day. Alongside, the perception of the local people was collected to validate the finding.

While climatic factors control the inputs that set the processes for genesis of urban flooding, the physical changes in the urban landscape particularly those relating to land use and drainage system largely modulate the flow and flow rates to produce flooding damages resulting from the flood events caused to livelihoods of urban dwellers. The responsibility of mitigation and adaptation falls in the domain of local and central government. Infrastructure solutions that are developed to mitigate the impacts of the flood have negative consequences on the environment. As seen in most of the cases, in an attempt to develop permanent solutions, the river environment is changed. For example, solutions like building flood walls and developing road corridors along the river changes the flow regime by decreasing the river's right of way. The major problem of urban areas is the increasingly impervious surface, so the most important aspect of urban flood management is to look into rainwater management which is not sufficiently addressed and the worst part is that the storm water management does not even come in the purview of urban development in Nepal.

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