Situation Analysis Gorakhpur, India: Climate Change, Flooding and Vulnerability

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INTRODUCTION

Gorakhpur city lies in eastern India in the mid-Gangetic plains between the Rapti and Rohin river basins. The 2011 population of Gorakhpur is close to 700,000 and the city is spread in a geographical area of about 147 sq km and divided into 70 administrative wards. Ironically, one of the most fertile areas in the country/region is also the one where poverty is very high. Gorakhpur city is bowl shaped with a low-to-flat gradient and high groundwater tables. Historically, there were 103 water bodies that served as natural drainage to the city. With urbanization, less than a third of the water bodies remain (Wajih, 2010). Historical records date back to the early 1800's and show regular flooding throughout the last two centuries. However, recent floods have become more severe; the impacts of the 1998 flood were unprecedented and had significant influence on how locals prepare and react to floods. Recently, however, floods and inundation are occurring even at moderate rainfall levels. Housing practices are changing in Gorakhpur with a slow shift from traditional (Kutcha) to a modern concrete (pucca) housing construction. Despite more modern housing construction, many of these are built without design considerations or regulation, resulting in houses that remain vulnerable to floods. Though shifts have been made in reaction to the 1998 flood, there is still a lot to be done in reducing vulnerability to floods at the household level. According to the "Vulnerability Atlas of India," developed by Building Material Technology Promotion Council (BMTPC, Government of India), about 21% of houses in the Gorakhpur district are highly susceptible to floods (BMTPC, 2006). The majority of these vulnerable houses are in rural areas. Vulnerability to flooding extends beyond the household level and is changing due to several anthropogenic factors. While meteorological and morphologic factors persist, poor urban planning, unregulated development, failed embankments, drainage

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congestion, and other development related factors have exacerbated vulnerability. Furthermore, a large part of the city elevation is below the river, and this has resulted in water-logging of lands and periodic flooding. The bulk of the water-logging problem—affecting about 40% of the city—is to the south and west. However, the drainage system for the entire city is impacted. Water-logging has worsened in recent years in Gorakhpur, partly due to changes in rainfall, and aggravated by the degradation of water bodies and unplanned development (e.g. land encroachment).

Climate change brings a new dimension to the problem as more intense and untimely rainfalls add to the flooding regime changes. In recent years, floods have occurred earlier than normal and catching people off-guard, causing more damage than usual. Climate change is likely to increase the intensity of rain events around Gorakhpur over the next 50 years. Rainfall intensity is a measurement of the total rainfall (mm) per year over the total rainfall per each storm in mm/hour (see Figure 1). It is projected that by the 2050s, small intensity rain events might see a 10%–20% increase. Of those more severe events, climate change might increase rainfall intensity by 2%–25%. Overall, climate change will impact rainfall amounts, resulting in continued and potentially worsened flooding scenarios (ISET-International, 2013).

HISTORIC FLOOD EVENTS AND DAMAGES

Flooding and inundation are century-old problems in Gorakhpur. Historical records date back to 1823 when a sudden rise in the Ghaghra River blocked the waters of the Rapti and Ami rivers, where the resulting floodwaters turned the city of Gorakhpur into an island. Additional floods of significant magnitude occurred in 1839, 1873, 1889 and 1892 (Nevill, 1909). During the 20th century, the number of recorded significant flooding events increased in the decades listed below.

- 1900s: 1903, 1906, 1910
- 1920s: 1922, 1924, 1925, 1927, 1928, 1929
- 1930s: 1930, 1932

TABLE 1: DAMAGES OF MAJOR FLOODS IN GORAKHPUR CITY

	1993	1998	1999	2000	2001	2007	2008
Total affected villages	921	1598	373	679	928	610	721
Total population affected	831695	1414790	218876	465179	715010	453100	506505
Area inundated by flood (hectare)	102525	267416	NA*	500032	98861	25248	292009
Marooned villages	436	1145	107	323	569	266	323
House damaged (fully)	317	16275	NA*	19	NA*	NA*	384
Houses damaged (partially)	1123	45000	18	55	NA*	NA*	4269
Human loss	26	127	2	23	40	38	23

Source: District Disaster Management and Mitigation Plan (DDMP),2012-13,District Disaster Management Authority, Gorakhpur

*Data is not available

- 1950s: 1953–1960 yearly
- 1960s:1961, 1967, 1968
- 1970s: 1970, 1971, 1973, 1974

The 1974 flood was the most severe since 1889, however, the floods in the 1990s were even more severe in terms of total damages caused. A flash flood of the Rapti and Rohini rivers exceeded 83 meters above sea level. The flood in 1998 had unprecedented damages, when the Ghaghra and Rapti rivers, along with their numerous tributaries, exceeded their danger levels and caused exceptional damage. The subsequent embankment failures and drainage congestion disrupted normal life for more than 90 days. In the decade to follow, there were frequent floods of medium to high intensity, even when rainfall levels were average. Table 1 (previous page) outlines the damages of major floods of the previous two decades.

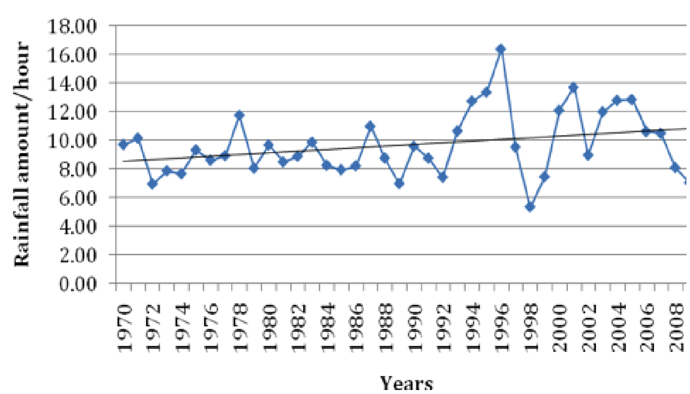
CAUSES OF FLOODS

Gorakhpur faces frequent floods and inundation due to heavy rainfall during the monsoon. Because the monsoon season is associated with intense and wide spread rainfall, it is natural that the south west monsoon season happens to be the flood season in the Rapti river basin. Over the last 10 decades, the ferocity and frequency of floods in the region has considerably increased, recurring every 3–4 years. In some places this has even become a regular, annual occurrence, and has greatly impacted the livelihoods of locals. There are three main characteristics that factor into the magnitude of damage a flood causes:

- Hydro-Meteorological: rainfall patterns;
- Morphological: channel patterns and topography of the region; and
- Anthropogenic: channel alteration, drainage management, surface sealing, and embankment construction are some of the factors that exacerbate flooding impacts, inundation and water-logging.

Geographically, the region comprises part of the Himalaya and the north Gangetic plains (a mountainous to low-lying area). Therefore, a huge volume of water travels quickly (the time lag is only 17–24 hours) to the plains of eastern Uttar Pradesh, inundating a very large area. Though heavy rainfall is the prime initiator of floods, the flooding may occur due to a combination of rainfall intensity, duration, area and location relative to drainage networks (Jones, 2002). Srivastava (1975) observed that the Rapti river basin is subject to frequent floods and serious inundation. This is due to heavy rainfall and an enormous quantity of silt and water brought by numerous tributaries on the lower reaches. Almost 80%–85% of the total annual rainfall is concentrated during three months of the year, from June 15th to September 15th.

FIGURE 1: RAINFALL INTENSITY IN GORAKHPUR 1970–2008



Source: Indian Meteorological Department, 2012

* Total rainfall (mm) per year/total rainfall hours = rainfall intensity

Water-logging in Gorakhpur © GEAG, 2013

EFFECTS OF THE BASIN AND MORPHOLOGY

The uniform speed of runoff in the different parts of the Rapti basin can be critical in creating a flood. The upper part of the Rapti basin runs through the foot-hills of the Shivalik, an area characterized by homogenous aggradational plains of older and newer alluvium deposits. Numerous small tributaries (about one kilometer apart and covering 13000 km^2 of catchment) drop vertically down into the Rapti river from the Shivalik (Rana, 2005). Furthermore, a large, elongated catchment area in the upper basin, as well as a peculiar drainage composition and greatly reduced slope gradient in the lower basin, contribute to the creation of floods in the lower reaches. Additionally, the presence of terai soils in the upper catchment area and high water table generate floods more readily. Steep gradient and high drainage capacity contributes to high runoff speeds.

DEFORESTATION

Removal of natural vegetation cover and canopy tends to reduce evapo-transpiration losses and infiltration capacity. Thus, the net result of deforestation is an enormous increase in the quantity of water available for runoff and reduction in the time lag, both of which increase the flood risk. In earlier days, a large part of the Gorakhpur and the Rapti basin were covered with forest, but in the last century, almost the entire tree cover has disappeared. Only a few patches of old woodlands are found in the northern area.

ENCROACHMENT OF NATURAL RESERVOIRS

There are stagnant water bodies such as lakes (oxbow and others), ponds and other depressions (locally known as tals), which were important features of the inland drainage system of the area. These natural reservoirs played a vital role in the minimisation of floods. They not only collected the excess water, but also acted as a detention basin for the flood water. In the recent years of rising urbanisation, many of the smaller reservoirs have been reclaimed while many large ones are facing problems of encroachment, thereby decreasing water retaining capacity. The encroachment of these water bodies is due to increasing demand of space for waste disposal, expansion of land for residential purposes and paddy and vegetable cultivation. In addition to this, sedimentation and growth of a number of surface and submerged weeds further decreases water-holding capacity. The famous Ramgarh lake presently covers 700 acres, while in 1916-1917 it covered 1,980 acres (GEAG, 2008). Thus, within 30 years the lake has been reduced by 12%. However, encroachment and waste dumping also cover 0.84% and 0.51% area, respectively.

ANTHROPOGENIC FACTORS

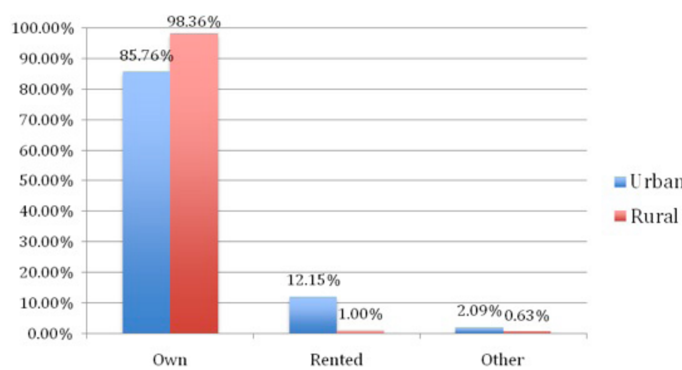
Since the 1970s, embankments (totaling over 113 km in length), roads and some spurs have been constructed for flood control. In reality, the embankments not only provided a false sense of security, thereby promoting development on the vulnerable areas, but also severely altered the basin morphology. Due to poor maintenance, these embankments have been frequently breached, causing more damage than if they had not been built. Embankments have also caused the river bed to rise, decreasing the river's carrying capacity and increasing chances of flooding. Water-logging occurs because of drainage congestion and is caused mainly by embankments and other construction (roads, railways, canals, urbanization, etc.). Thus, as a result of a combination of the above factors, the nature of flooding has changed. During the previous 10 years, waterlogged areas have increased by 65%–95% (Gupta & Wajih, 2013). Locals have responded that past floods caused less impact, but now the flooding regime causes immense damage to life and property. The citizens of Gorakhpur live with annual flooding.

However, the recent flooding damages, such as those in the 1998 flood, changed building construction practices and habits significantly. The evolution of this change is discussed in the following section.

HOUSING AND CONSTRUCTION PRACTICES

The housing scenario in Gorakhpur is similar to most of the Tier 2 cities in the country. Gorakhpur is a small city and a majority of households own the residential units where they live, though there are also households that rent. This is quite true of any small cities in the country, and is quite opposite to the situation in large metropolitan cities like Delhi or Mumbai, where a majority of the households live in rented accommodations. The distribution of housing units as per ownership is given in the figure below.

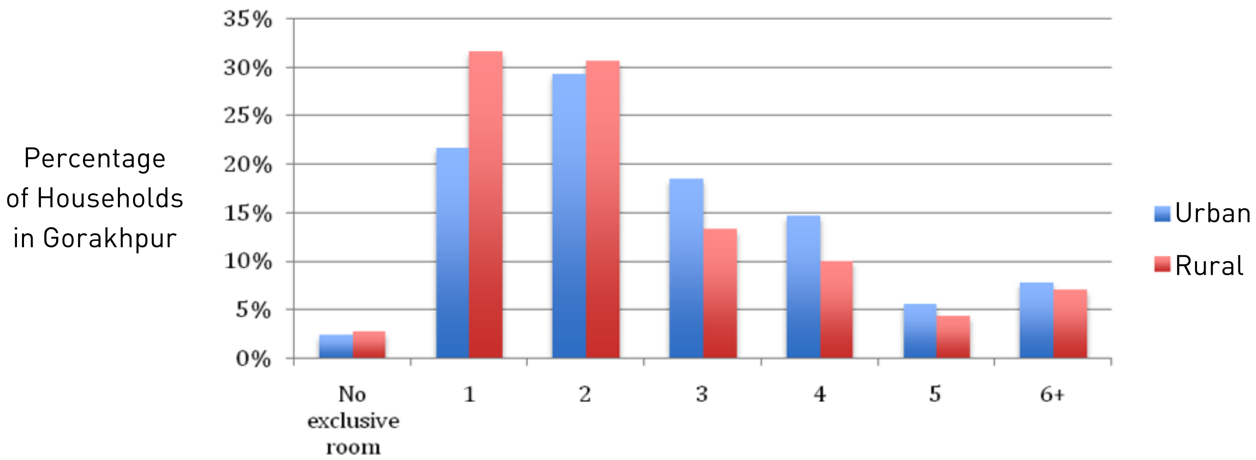
FIGURE 2: DISTRIBUTION OF OWNERSHIP



Source: Government of India Census, 2011

In the last decade, the housing scenario in rural and peri-urban areas of Gorakhpur has altered very rapidly. From census analysis and field observation of peri-urban and rural areas of Gorakhpur, it is observed that 73.93% of houses have pucca (permanent) walls and roofs while 23.47% of houses have kuccha (semi or non-permanent) walls and roofs. The housing units in rural areas of Gorakhpur have predominantly one or two rooms; more than 62% of houses fall in these two categories. In urban areas of Gorakhpur about 50% of housing units have one or two rooms per housing unit. The distribution of housing units by number of rooms in urban and rural areas is shown in the figure below.

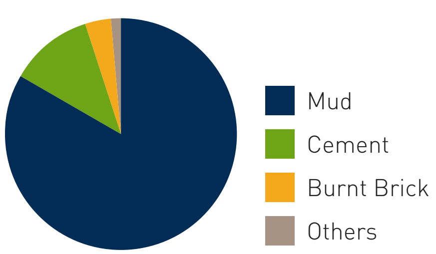
FIGURE 3: NUMBER OF ROOMS BY LOCATION



Source: Government of India Census, 2011

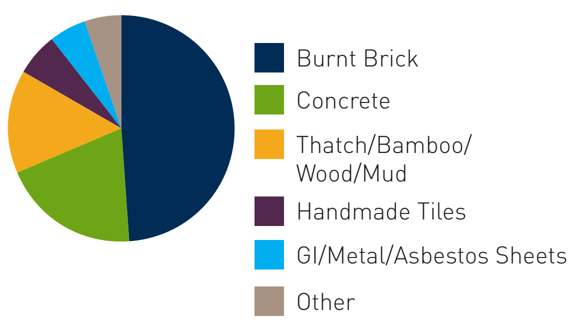
Though most houses in urban Gorakhpur have brick and cement walls and flooring and reinforced cement concrete roofs, the situation in peri-urban and rural areas is different. The predominant material for flooring here is mud. This makes such housing particularly vulnerable to floods when water enters the homes. The figure below gives the proportion of households in rural areas of Gorakhpur by material used for flooring. Similarly, material used for roofing in rural areas is predominantly burnt bricks, thatch, bamboo, wood, and mud (Census, 2011).

FIGURE 4: MATERIALS USED FOR RURAL FLOORS



Source: Government of India Census, 2011

FIGURE 5: MATERIAL USED FOR RURAL ROOFS



Source: Government of India Census, 2011

The recurrent flood situation has also changed the mindset of people regarding housing design. The shared learning dialogues conducted in the three villages of Gorakhpur clearly indicate that the 1998 flood played a catalytic role in changing housing designs in peri-urban parts of Gorakhpur. People have responded that all kutcha houses were ruined in the 1998 flood. Consequently, most people, poor and rich, have shifted from kutcha to pucca house construction. (Shared learning dialogues conducted with villagers in Uttarasoth, Domarghatand Semra Devi Prasad, 2012). Despite the shift to "modern" housing construction methods in Gorakhpur, vulnerability to flooding and water-logging still remains and is being compounded by changing climate, rising temperatures and variable precipitation patterns.

VULNERABILITY

Rising populations and improper construction practices have significantly enhanced the vulnerability of houses and livelihoods. According to locals during the community consultations, the pattern of flooding and water-logging has significantly altered in the last couple of decades due to changes in land-use patterns and other anthropogenic activities. Poor drainage system and low water retention causes water stagnation in agricultural land and sometimes even in homes. Water-logging can occur for more than 20–30 days during the monsoon period, which causes heavy losses to agriculture, shelter, indoor assets, and education/working days of poor and vulnerable people. As per the official records from Tehsil and District Disaster Management Authority (DDMA), on an average, the floods impact more than 600 hundred villages and 0.5 1 million people annually (see Table 1). The data collected from the DDMA indicates that about 20%–25% of the area in peri-urban villages is marooned on a regular basis. As stated earlier, the 1998 flood was a landmark flood in the history of Gorakhpur and it has left a deep imprint on the housing scenario in peri-urban villages.

HOUSING VULNERABILITY

Most of the peri-urban and rural houses designed in the area are constructed with the advice of local masons and called for easily available materials. Many houses have been constructed incrementally over a period of time. Many factors have led to poor quality housing, making them vulnerable to disasters. Factors include those listed below:

- income levels of home owners;
- unregulated, poorly designed and constructed houses (both traditional and modern);
- constraints in the availability of local materials;
- changing occupational patterns; and
- limited technical capacity and minimal design regulations in rural areas.

The poor housing stock has always led to devastating consequences during floods and other risks. In the last decade, the housing scenario in rural and peri-urban areas of Gorakhpur has changed rapidly. Although these new buildings are constructed using modern materials, the design and construction is based more on experience rather than engineering design as per building codes. As a result, even modern housing types are still vulnerable to floods. Vulnerability of various housing types/construction materials in Gorakhpur district is shown in the table below.

TABLE 2: DISTRIBUTION OF HOUSES BY DOMINANT ROOF AND WALL MATERIALS AND THEIR ASSOCIATED RISK LEVELS

WALLS				
TYPE OF WALL	CENSUS HOUSES			
	Category	No of houses	% of houses	Level of Risk
Mud	Rural	148675	20.2%	
Unburned brick wall (A1)	Urban	12525	1.7%	
	Total	**161200**	**21.9%**	**Very high**
Stone wall (A2)	Rural	455	0.1%	
	Urban	283	0.0%	
	Total	**738**	**0.1%**	**Very high**
Total of Category A		**161938**	**22.0%**	
Burnt brick wall (B1)	Rural	389136	52.9%	
	Urban	124538	16.9%	
Total of Category B		**513674**	**69.9%**	**High / moderate**
Concrete wall (C1)	Rural	401	0.1%	
	Urban	642	0.1%	
	Total	**1043**	**0.1%**	**Low / very low**
Wood wall (C2)	Rural	2408	0.3%	
	Urban	548	0.1%	
	Total	**2956**	**0.4%**	**High**
Total of Category C		**3999**	**0.5%**	
Other material (X)	Rural	52179	7.1%	
	Urban	3541	0.5%	
Total of Category X		**55720**	**7.6%**	**Very high**
TOTAL BUILDINGS		**735331**		
Flood Prone Area in District Gorakhpur in %			**53.40%**	

ROOFS				
Type of Roof	Category	No of houses	% of houses	Damage risk as per that for the wall supporting it
Light weight sloping roof (R1)	Rural	105662	14.4	
	Urban	12470	1.7	
	Total	**118132**	**16.1**	**Very high**
Heavy weight sloping roof (R2)	Rural	159019	21.6	
	Urban	15461	2.1	
	Total	**174480**	**23.7**	**High**
Flat roof (R3)	Rural	328573	44.7	
	Urban	114146	15.5	
	Total	**442719**	**60.2**	
TOTAL BUILDING		**735331**		
Flood Prone Area in District Gorakhpur in %			**53.40%**	

Housing category:
A: Building in field stone, rural structure, unburned brick houses; B: Ordinary brick building, building of large block; C: Reinforced building
Source: Vulnerability Atlas of India' developed by Building Material Technology Promotion Council (GoI), 2006

IMPACTS

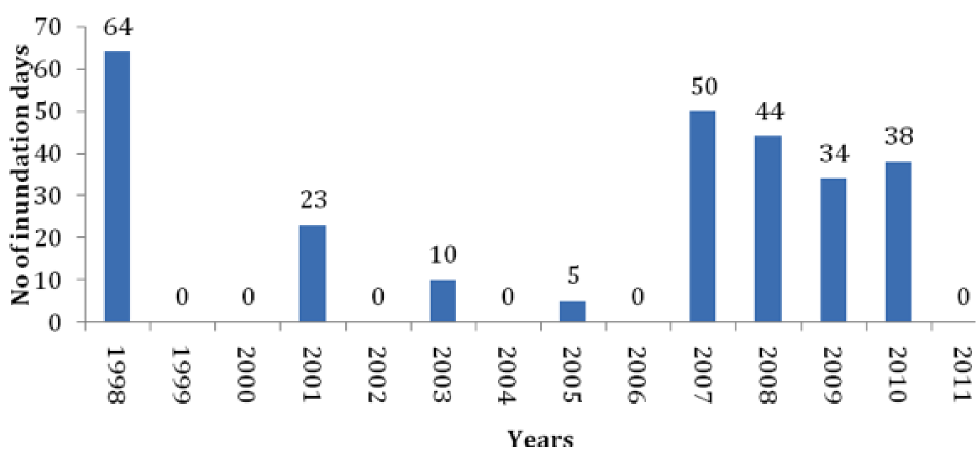
Based on the vulnerability assessment of the region, the main impacts of flooding and water-logging on houses are:

- the soil that supports the foundation is washed away;
- kutcha houses made of mud or unburned brick are most vulnerable and susceptible to continuous rain and prolonged water-logging;
- walls that are made of earth and exposed to water for long periods of time collapse;
- during heavy rains, the exposed walls situated on the side or the top (due to roof damage) often collapse; and
- scouring of soil around the house may cause uneven settlement of the foundation and walls, causing severe structural damage.

The importance of the location of the house, the type of soil, material degradation due to frequent floods, weaker joints and the plinth height, etc., were also identified as deciding factors for determining the vulnerability of houses in the region. As stated earlier, Goarkhpur city has less than a third of its water bodies remaining, resulting in reduced capacity to retain water and, thus, increasing the duration of water-logging and stagnation (see figure 6). The continued flooding and water-logging causes many issues and directly affects the livelihood of the majority of people, resulting in long-term impacts. Impacts of the flood include:

- loss of human life;
- loss of livestock;
- destruction of field crops;
- sedimentation/silting on inhabited land;
- loss of stored grains due to floodwater;
- loss of fodder for livestock;
- loss of infrastructures and communication;
- loss of livelihoods;
- destruction of shelter;

FIGURE 6: NUMBER OF INUNDATION DAYS

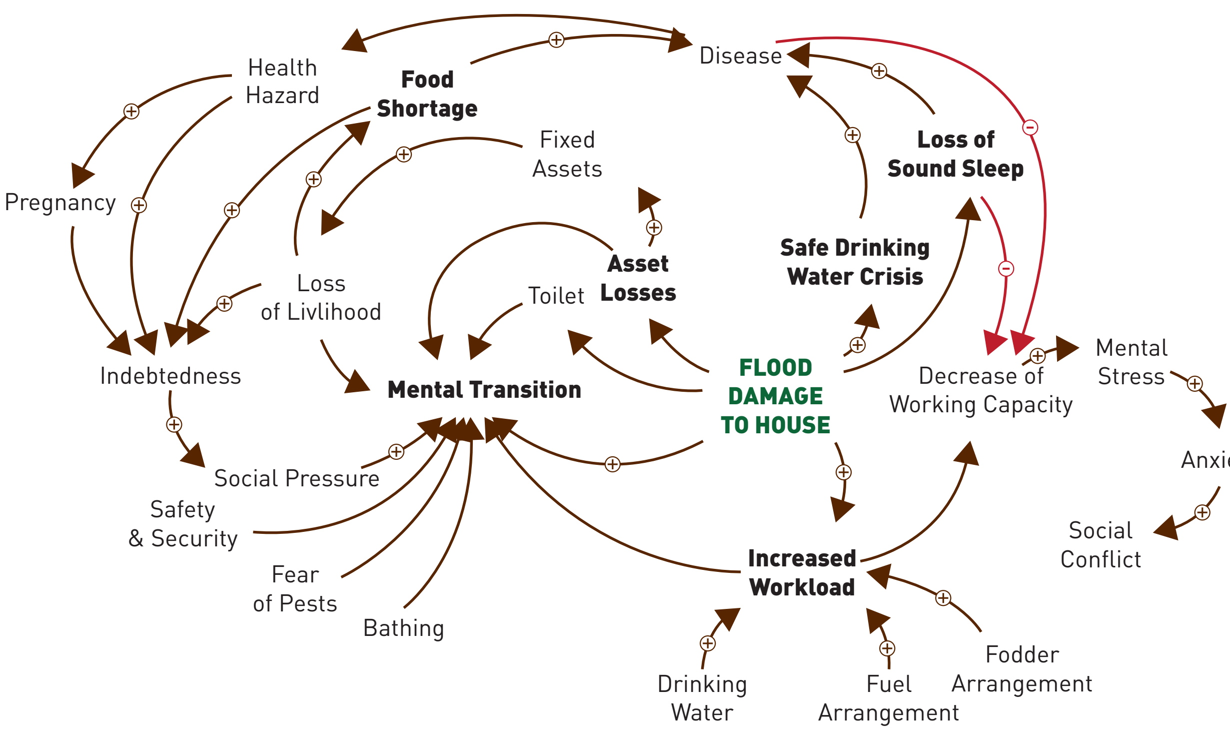


Source: Flood Division of Gorakhpur, 2012

- adverse impacts on health;
- adverse impact on education;
- sanitation problems; and
- problems with safe drinking water.

Vulnerability in Gorakhpur has multiple facets that have been exacerbated by anthropogenic causes including poorly planned urbanization and poorly designed and constructed buildings. However, with the onset of climate change (specifically, changing rainfall and temperature patterns) the characteristics of impacts of floods are changing (and increasing) over time. The following causal loop diagram, constructed during a participatory appraisal of flooding and its impacts in Paneli village in 2012, explains that floods impact various facts of life and the overall cumulative effect traps the poor communities in a poverty cycle. This type of representation of information also examines the causes of any specific issue and inter-linkages between cause and effect. A positive sign on the linkage indicates a re-enforcing effect and vice-versa. A causal loop diagram (CLD) is a causal diagram that aids in visualizing how different variables in a system are interrelated. The diagram consists of a set of nodes and edges. Nodes represent the variables and edges are the links that represent a connection or a relation between the two variables. A link marked positive indicates a positive relation and a link marked negative indicates a negative relation. A positive causal link means the two nodes change in the same direction, i.e. if the node in which the link starts decreases, the other node also decreases. Similarly, if the node in which the link starts increases, the other node increases as well. A negative causal link means the two nodes change in opposite directions, i.e. if the node in which the link starts increases, the other node decreases and vice versa.

FIGURE 7: CASUAL LOOP DIAGRAM FOR DAMAGES TO HOUSING FROM FLOODS AND WATER-LOGGING



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CONCLUSIONS

The communities inhabiting the flood-affected regions attribute the worsening flood impacts to climate change. Climate change is likely to increase the intensity of rain events around Gorakhpur over the next 50 years. It is projected that by the 2050s, small intensity rain events might see a 10%–20% increase. Of those more severe events, climate change might increase intensity by 2%–25%. Overall, climate change will impact rainfall amounts resulting in continued and potentially worsened flooding scenarios (ISET-International, 2013). This has likely contributed to and will result in more frequent water-logging, as shown in the previous section. Floods and water-logging create a recurring problem in Gorakhpur. Climate change is likely to make this problem worse. The problem has already been exacerbated by unplanned and unregulated development, but higher temperatures and more variable, unpredictable and intense precipitation pose an additional threat. The changing climate has given new dimensions to the problem and further extends the risk of floods and damages. Future climate impacts with more intense rainfall and changes in rainfall patterns could be significantly more severe and need to be considered in urban planning for the future.

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