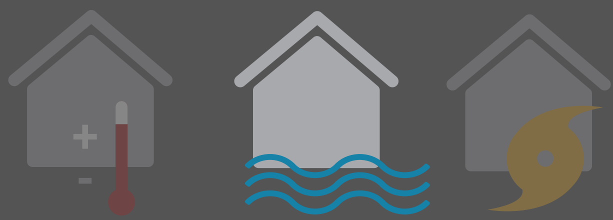


SHELTERING FROM A GATHERING STORM

FLOOD RESILIENCE IN INDIA

Sheltering From a Gathering Storm: Flood Resilience in India

Authors: Dilip Singh, ISET-International; Dr. Bijay Singh, Gorakhpur Environmental Action Group; Kate Hawley, ISET-International

March 2014

Published by: Published by ISET–International and Gorakhpur Environmental Action Group.

For a downloadable PDF of this publication, please visit: www.i-s-e-t.org/SHELTER

Citation: Singh, D., Singh, B., & Hawley, K. (2014). *Sheltering from a gathering storm: Flood Resilience in India*. Boulder, CO: ISET-International.

ACKNOWLEDGMENTS

The authors wish to thank the Climate and Development Knowledge Network (CDKN) for funding this research. We would also like to express our gratitude to Mr. Fawad Khan, Dr. Marcus Moench, and Dr. Shiraz Wajih for their valuable comments and suggestions on our study design and analysis. We would like to acknowledge the climate team, Dr. Sarah Opitz-Stapleton, Dr. Caspar Amman, Mr. Ken MacClune, and Mr. Anil Kumar of Arup International, for their keen insights into Gorakhpur's climate aspects. This project would not have been possible without the critical support and partnership of many individuals, especially SEEDS India in leading the Resilient Housing Design Competition. Furthermore, we would like to thank the officers from the Flood Division and Irrigation Department–Gorakhpur Municipal Corporation, District Disaster Management Authority-Gorakhpur (Mr. Gautam Gupta), Indian Meteorological Department-Gorakhpur, local masons and contractors who provided information on local construction practices and costs, and finally the communities from the rural and urban areas who participated in this research. The authors would also like to acknowledge Ms. Michelle F. Fox for art direction and graphic design support, Ms. Lea Sabbag and Ms. Abrina Williams for editorial support, Linda Gorman for copyediting support, and Jamie Stroud for the illustration of maps.

The analyses and opinions in this report are those of the authors and do not necessarily reflect the views of the CDKN. The authors alone remain responsible for any errors in this report.

SHELTERING FROM A GATHERING STORM
FLOOD RESILIENCE IN INDIA

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ACCCRN Asian Cities Climate Change Resilience Network

CBA Cost-benefit analysis

GEAG Gorakhpur Environmental Action Group

GIS Geographic information system

IMD Indian Meteorological Department

RBC Reinforced brick concrete

RCC Reinforced cement concrete

SLD Shared learning dialogue

Flood- and climate-adapted shelter designs protect livelihoods and assets and reduce the types of climate-disaster-related losses that impoverish families, thus playing a critical role in enabling vulnerable groups to accumulate the resources required for long-term adaptation.

GEAG, 2013

KEY POINTS IN BRIEF

1 **Gorakhpur is a rapidly growing city.** Located in eastern India, Gorakhpur is experiencing huge in-migration from the surrounding villages and districts, but the city has lower levels of urban service delivery systems compared to other Indian cities.

2 **Gorakhpur's geophysical characteristics make it vulnerable to climate-related risks.** Because the city is bowl shaped and at places the elevation is lower than that of the adjacent rivers, there is recurrent flooding and waterlogging in the city, which is further exacerbated by the embankments constructed on the western side.

3 **Flooding and waterlogging are recurring problems in Gorakhpur.** Flooding (in peri-urban areas, outside of the embankments) and waterlogging in the city's core areas have emerged as major problems for the people of Gorakhpur. Not only do they lead to losses in income and assets, but they also contribute to the rising problem of endemic vector-borne diseases such as Japanese encephalitis, dengue, and malaria.

4 **Climate change may affect rainfall events.** Climate change may increase the intensity of Gorakhpur's extreme rainfall, particularly the intensity of shorter, more common events that already cause significant flooding in multiple wards throughout the city (Opitz-Stapleton & Hawley, 2013).

5 **Projected temperature increases will negatively impact the people of Gorakhpur.** Climate models indicate that the number of hot days will continue to increase. At the same time, models project a significant increase in the nighttime minimum temperatures that could well extend into the monsoon months. This increase in peak temperatures, accompanied by a reduction in nighttime cooling, will have significant implications for the city's residents, ranging from physical discomfort to harsher working and living conditions to increased morbidity and mortality, especially for people from low-income groups (Ammann & MacClune, 2014).

6 **Flood resilient housing is a priority.** Flood resilient housing for low-income groups emerged as one of the priority action areas in the City Resilience Strategy of Gorakhpur.

7 **Construction measures to improve resilience are not available to everyone.** Households in urban areas, especially peri-urban, have changed construction practices to incorporate features to reduce flood risks. One of the main practices adopted is raising the plinth of the house. However, many low-income households are still unable to build flood resilient houses due to financial constraints as well as nonavailability of resilient housing designs. The skills and knowledge of local masons also influence current design practices.

8 **Perceived value of risk mitigation options varies.** Community perceptions indicate that while many of the autonomous adaptive features adopted by the community are cost-effective, some of the costlier options (like a pucca reinforced cement concrete roof) have lower perceived benefits than some cheaper options (such as concrete shelves).

9 **Design competition produced innovative housing model.** The winning entry in the Resilient Housing Design Competition addressed several resilience building features, in addition to providing improved living conditions. Extensive use of locally available material (bamboo) instead of reinforced cement concrete resulted in this design being much cheaper on a per-square-foot basis. The design also incorporated the prevalent practices of a raised plinth and having an upper floor to retreat to in case of extreme events.

10 **Resilient housing has economic benefits.** The economic returns on building a flood and temperature resilient house in Gorakhpur (based on the winning design from the Resilient Housing Design Competition) are highly significant compared to those of a conventional house, with benefit-cost ratios above one for features related to The Resilient Housing Design Competition.

11 **Policy interventions are needed to promote and improve access to resilient housing.** Access to affordable financing is one of the major constraints on the adoption of resilient housing designs by low-income groups. Policies and programs need to intervene to make access to financing easier for this group of households. Capacity building of local masons and awareness generation among households are some of the other key strategies that need to be pursued to promote resilient housing in flood-affected areas.

1. INTRODUCTION

1.1 Rationale

Flooding and inundation are recurring problems in the city of Gorakhpur, which is located in the mid-Gangetic Plain between the Rapti and Rohini River basins. Gorakhpur is bowl shaped, with a low-to-flat gradient and high groundwater tables. The City Resilience Strategy[1] identified housing and related issues as key areas where vulnerability needs to be addressed (Wajih, Singh, Bartarya, Basu, & ACCCRN ISET Team, 2010).

Shelter is one of the most important factors influencing the exposure of people and assets to disaster risks. Flood- and climate-adapted shelter designs protect livelihoods and assets and reduce the types of climate-disaster-related losses that impoverish families, thus playing a critical role in enabling vulnerable groups to accumulate the resources required for long-term adaptation. Also, following disasters, the construction of temporary and permanent shelters is one of the largest cost items for governments and disaster response organizations, which could be reduced or eliminated with design improvements.

Information asymmetry exists between those households deciding to incorporate resilient shelter designs, local builders, engineers and architects who know how to construct such resilient features, and transformative policy interventions that could be used to encourage adoption. The research investigates this distinct gap and the reasons why the practice of integrating design/construction features that ensure building resilience have not been adopted. Shelter investments are made on the basis of short- to intermediate-term considerations; therefore the formation of policies and the creation of institutional frameworks necessary to guide development over the long term are central to adaptation.

1.2 Overall Context

India is urbanizing at a fast pace; according to the 2011 census reports, the urban population was 31.2% of the total population, compared to 27.8% in 2001—the increase being significantly greater in larger towns and cities (Tripathi, 2013). A report by the High Powered Expert Committee (2011) estimates that by 2031 nearly 600 million people will live in urban centers, while another report estimates that of these urban households, 91 million will be middle class, as compared with 22 million in 2009–2010. For such a large increase in urban centers and population, it is estimated that 700–900 million square meters of residential and commercial space will need to be built, which is quite significant. As per the estimates from the Technical Group on Urban Housing Shortages (TG-12), under the aegis of the Ministry of Housing and Urban Poverty Alleviation, almost 19 million households face housing shortages in urban India. The TG-12 based their estimates on the data from the 2011 census and the report on urban slums by the National Sample Survey Office (2010). However, one of the key findings of the TG-12 report was that more than 95% of this shortage impacted households belonging to low-income groups and economically weaker sections of society. Since about a quarter of the country's total urban population falls into these two categories, the issue of affordable housing for the urban poor becomes important. A report by McKinsey estimates that by 2030 approximately 38 million households will be unable to afford housing at market prices (Sankhe et al., 2010). In addition to the acute housing shortage, lower income groups are also the most affected in terms of loss of (or damages to) housing during disasters such as floods or earthquakes. Provision of shelter is one of the most important components of strategies for disaster risk management, and it is beginning to emerge as a central factor in adaptation to climate change.

Gorakhpur, in eastern Uttar Pradesh, is a typical, rapidly growing city with a large migrant population. The current population of Gorakhpur is close to 700,000, and the city is spread out in a geographical area of about 147 km^2 divided into 70 administrative wards (Government of India, 2011). Housing practices are changing in Gorakhpur, and as in other urban areas of India, predominantly modern *(pucca)* houses are being built. In rural and peri-urban areas, there is a slow shift from traditional *(kutcha)* to modern, concrete housing construction. However, there are still many semi-pucca houses, and as well as some kutcha houses, in rural areas. In the peri-urban and rural areas of Gorakhpur, flooding has a greater impact than in the urbanized core city areas, which suffer mainly from waterlogging. The 1998 floods had a significant influence on the building practices that followed.

However, though there are more modern houses now, many of them have been built without design considerations or regulation, resulting in houses that remain vulnerable to floods.

Climate change brings a new dimension to the problem as more intense, unseasonal, and erratic rainfall has resulted in unexpected changes to flooding and inundation patterns. In recent years, floods that occurred earlier than normal caught people off guard and caused more damage than usual.

Climate change is also affecting the temperature. Historically, the climate of Gorakhpur has summer average mean temperature highs around 30°C. However, in recent years, the average mean temperatures have been around 32–34°C even during monsoon months. Coupled with humidity levels of over 60%, the local weather creates an environment conducive to heat stress and vector-borne diseases. For people living in slums and low-income colonies, housing conditions exacerbate these stress conditions mainly due to the structural design (a roof made of tin or asbestos, thin walls, little or no ventilation), congestion (little space between houses), and lack of air-conditioning (Tran, 2012).

1.3 Objectives

The *Sheltering From a Gathering Storm* project aims to improve understanding of the costs and benefits of climate resilient housing and contribute to the transformative change necessary to make communities more resilient to future disasters. Using cost-benefit analysis, this applied research project aims to provide insights into the economic and nonfinancial returns on adaptive, resilient shelter designs that take into consideration hazards such as flooding, waterlogging, and temperature and humidity increases.

A larger goal of this project is to generate information and evidence that would support decision making at various levels and to promote investment in climate adaptive measures for risk reduction that are also cost-effective and beneficial for all stakeholders in the long term. Ultimately, the project aims to influence government policies and programs that target and/or provide housing to the economically weaker sections of the population, such that they include these concepts and ideas of resiliency when building new houses. The goal is also to influence housing practices among local stakeholders such as masons and individual households, so they start to include design features that would improve housing resilience.

This case study report is structured as follows: the remainder of this section introduces project stakeholders and policies, section 2 presents the research methodology and its limitations, section 3 highlights results and discussions, section 4 discusses policy implications and recommendations, and section 5 presents the project's conclusions.

1.4 Key Stakeholders and Policies

Housing is a state matter in India, meaning that the state governments make policies and develop programs for the provision of shelter for residents in their respective states. However, the central (or national) government provides overall direction in terms of policy guidelines and building codes that govern the housing programs implemented by state governments. The national government also implements (through state governments) a number of national programs aimed at providing shelter for poor and lower income groups (social housing schemes).[2]

Key Stakeholders

National level. At the national level, there are two government ministries that deal with housing: the Ministry of Urban Development and the Ministry of Housing and Urban Poverty Alleviation. (The Ministry of Rural Development implements programs related to housing for the rural poor through the State Rural Development Departments.) Other agencies, institutions, and organizations—such as the Town and Country Planning Organization, Building Material Training and Promotion Council, National Institute for Urban Affairs, and National Housing Bank—support these ministries (and state governments) through research, analysis, capacity building, and financial assistance.

State level. State governments have specific departments, such as the Urban Development

Department, Rural Development Department, and Housing and Urban Planning Department, that implement both national and state government programs related to housing.

City level. At the city level, the Municipal Corporation is responsible for implementing housing projects for urban poor, while the City Development Authority and District Urban Development Agency are responsible for planning and zoning new development and expansion plans of the city.

Policies and Programs

The overall guiding policy for housing in the country is the *National Urban Housing & Habitat Policy, 2007*, which was formulated by the Ministry of Housing and Urban Poverty Alleviation (Government of India, 2007). The policy focuses on providing affordable housing for all citizens in the country. Broadly, the policy specifies earmarking land in the housing projects (by state governments or under national programs) for the provision of affordable housing for economically weaker sections and low-income groups. Concerning the technical aspects related to building norms and codes, the *National Building Codes* is the main and universally binding document for building standards related to housing in India (Singh, Hawley, & Singh, 2013). Although there is no specific policy or program that incorporates climate change impacts into the housing guidelines, the *National Mission on Sustainable Habitat,* under the charter of the National Action Plan on Climate Change, lays down guidelines and principles for sustainable urban planning and development with regard to the changing nature of climate and the risks and impacts associated with it (Government of India, 2010).

Jawaharlal Nehru National Urban Renewal Mission, a national program, was launched in 2005 wherein about 1.5 million houses for urban poor were to be constructed under its sub-missions *Basic Services for the Urban Poor* and the *Integrated Housing and Slum Development Programme.* In addition, there are specific programs for the provision of housing for the urban poor. *Rajiv Awas Yojana* aims to create a Mortgage Risk Guarantee Fund to enable provision of credit to economically weaker sections and low-income households, as well as enable the state governments to adopt policies that will improve the housing conditions of slums in the cities. The *Interest Subsidy Scheme for Housing the Urban Poor* program is aimed at increasing housing affordability for the urban poor through the provision of an interest subsidy of 5% per annum on a loan amount of up to INR 100,000 for the acquisition or construction of houses. *Indira Awas Yojana* is a cash subsidy scheme for the rural poor (households living below the poverty line) for the construction of dwelling units using indigenous materials and designs (Singh et al., 2013).

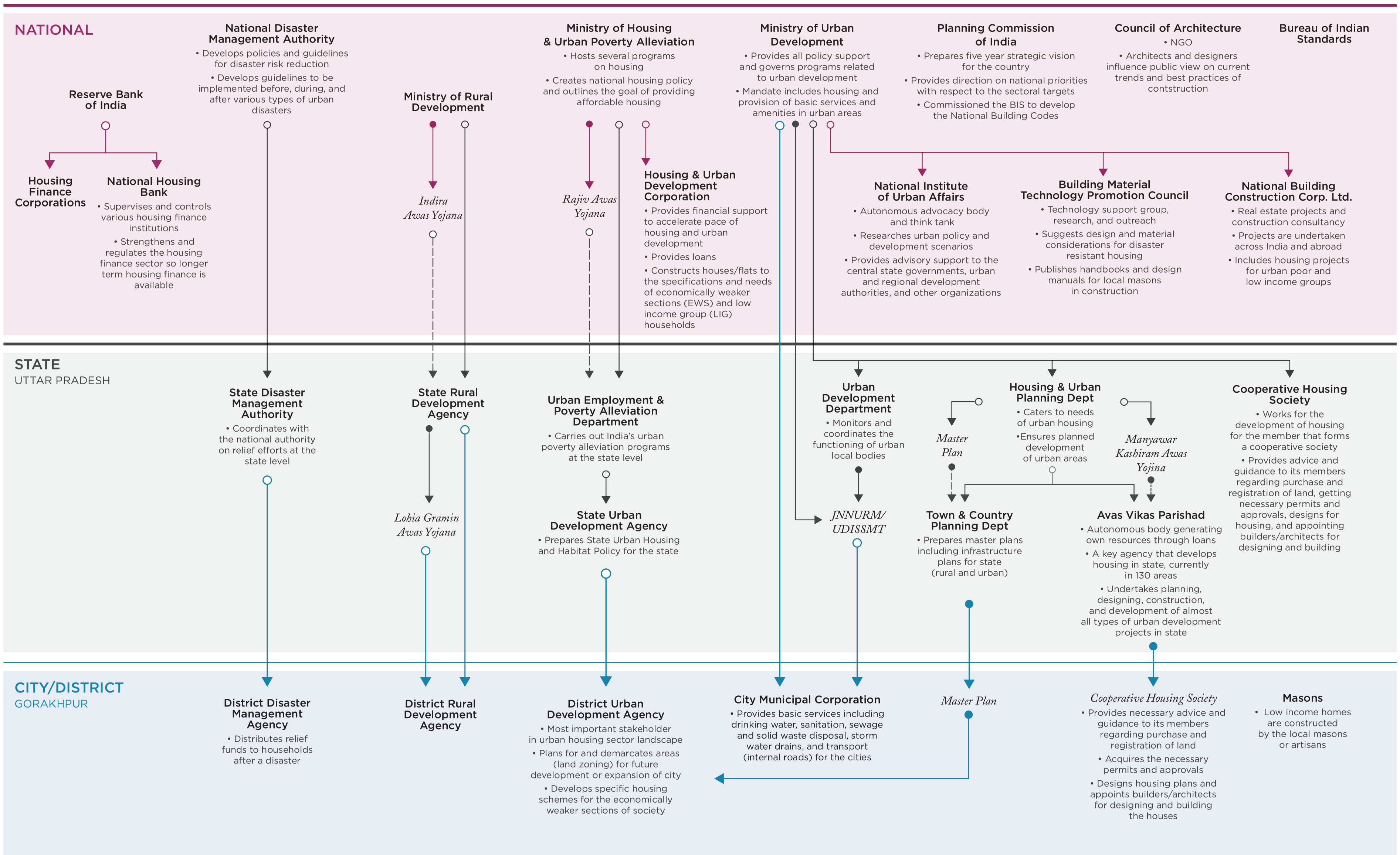
While the state governments implement national programs mentioned above, there are other specific initiatives that provide affordable housing to economically weaker sections of the population. In Uttar Pradesh specifically, programs such as *Lohia Awas Yojana, Manyavar Shri Kashiramji Shahri garib Awas Yojna, Sarvjan Hitay Garib Awas (Slum Area) Malikana Haq Yojna,* and *ASRA Yojana* have been initiated for disadvantaged groups such as economically weaker sections, widows, and slum dwellers.

Endnotes

1. The City Resilience Strategy for Gorakhpur was developed as part of the 3-year project by the Asian Cities Climate Change Resilience Network (ACCCRN) aimed at building climate change resilience in urban areas.

2. For further information concerning the policy landscape, see "Indian Housing Policy Landscape: A Review of Indian Actors in the Housing Arena" (Singh, Hawley, & Singh, 2013).

INDIAN HOUSING POLICY LANDSCAPE
A Relationship Map of Actors in the Housing Arena



Name of Organization
Name of Program

indicates relationship with organization
indicates relationship with program
indicates information originates from an organization
indicates information originates from a program

National Level
State Level
City/District Level

2. RESEARCH METHODS

2.1 Introduction

Gorakhpur Environmental Action Group (GEAG), a city-based nongovernmental organization (NGO), partnered with ISET-International for this research study. SEEDS India, another NGO, was included as an additional partner to provide support in organizing the Resilient Housing Design Competition. The overall purpose of the research was to investigate the economic returns of climate resilient shelter. The first step in this study was to conduct secondary literature and data research on the availability of information on climate and flood impacts (losses and damages incurred by households). Next, the research team conducted a series of shared learning dialogues (SLDs) with different stakeholders at various points during the study to build a better understanding of the issues related to floods and vulnerabilities. Climate modeling was carried out to project the trends of precipitation and temperature events. Based on community SLDs, the design competition and questionnaires for damage/loss surveys were designed. The results from the community survey on damages/losses (avoided damages are considered benefits) and the Resilient Housing Design Competition were used for conducting the cost-benefit analysis.

Document Review

A comprehensive review of policy and program information related to the housing sector was conducted, which included information from the Government of India and the Government of Uttar Pradesh ministries and departments, such as the Ministry of Urban Development, the Ministry of Housing and Poverty Alleviation, and the Urban Development Department at the state level. Under previous research programs, a complete review of Gorakhpur's 2021 Master Plan was carried out, which linked directly to the high priority area of the housing sector. A literature review of damage information was also conducted. However, extremely limited data was available for Uttar Pradesh, resulting in the collection of primary data. To authenticate the primary data, we reviewed the Kosi floods (in the neighboring state of Bihar) damage data for relevance. The areas flooded by the river Kosi in Bihar have similar geological, physical, and economic conditions to Gorakhpur, which allowed for comparison.

Shared Learning Dialogue (SLD)

The SLD process, which brings together different stakeholders with various types of scientific and local knowledge, has been the key strategy for this project. SLDs are founded on the principles of meaningful public participation—bringing together stakeholders with different interests, perspectives, information, knowledge, and power—in a public arena of debate on a level playing field (ISET-International, NISTPASS, & TEI, 2012). As part of this project, SLDs were conducted with different stakeholder groups at various stages.

Community SLDs

The first set of SLDs were conducted with local villagers living in the peri-urban areas of Gorakhpur to understand the nature of the challenges related to flooding, as well as specific housing design features that villagers (men and women separately) thought would reduce their losses and increase their resilience. Another set of SLDs were conducted with the community to comprehend the kinds of adaptive mechanisms that people have already initiated and to qualitatively compare the costs and benefits of these features, as perceived by the community. The third set of SLDs and consultations were conducted with the communities in peri-urban and urban areas and with the medical fraternity in Gorakhpur to understand the impacts of excess rainfall, temperature, and humidity on the lives of people and to gauge the threshold values for these parameters.

Consultations With Government Departments

During the course of the project, various government departments, especially the Gorakhpur Development Authority, and officials from Gorakhpur Municipal Corporation were consulted regarding the housing programs and policies of their respective departments in the district. The District Disaster Management Authority was consulted specifically to ascertain the policies and guidelines of the organization related to housing reconstruction and the rehabilitation of housing in the aftermath of a disastrous flood.

Local masons are an important constituency in the housing sector, especially for low-income groups, for whom almost all the housing construction is done by this informal and unorganized group of workers.

GEAG, 2013

Consultations With Masons and Architects

Local masons are an important constituency in the housing sector, especially for low-income groups, for whom almost all the housing construction is done by this informal and unorganized group of workers. Consultations were held with local masons and architects to ascertain the local construction practices and designs used in urban and peri-urban areas and their associated costs.

Field Work

Field work was carried out by GEAG with support from ISET-International. Urban, rural, and peri-urban villages were visited, as well as locations throughout the urban center.

2.2 Cost-Benefit Analysis Process

The research on shelter design used climate-based probabilistic cost-benefit analysis (CBA). Using historical data, we estimated the probability of asset losses (livelihood, shelter, and contents) in extreme flood and temperature events under existing climate conditions. To reduce these losses, climate resilient measures can be adopted, which then result in a reduction in damages. The research team compared three options: (a) raising the plinth level to above projected climate change flood levels, (b) adopting the winning climate resilient housing design, and (c) employing the risk reduction measures identified by the communities during shared learning dialogues.

Study Parameters

The parameters of this CBA analysis recognize the costs and benefits through the household perspective. Many perspectives could be taken, such as those of government agencies or international entities, but the research team was mostly concerned with the affordability of the interventions for households to adopt on their own. We investigated extreme rainfall events that lead to flooding and extreme temperature events that lead to heat waves as the main hazards. (Gorakhpur faces other hazards, such as drought and extreme cold, but they are beyond the scope of this study.) These main hazards were investigated into the 2050s via the use of climate models (further explained in section 3.1), and the results from the CBA show potential returns in a climate impacted future. Data was unavailable at the household level, leaving the research team to conduct household-level surveys throughout Gorakhpur to estimate past damages.

Information Gathering and Analysis

A framework for data collection was developed to scope and frame all relevant data for the research.

The research team conducted the research in five phases:

Phase 1
Hazard Assessment

Phase 2
Exposure and Fragility Identification

Phase 3
Impact and Damages Assessment

Phase 4
Risk Mitigation Options

Phase 5
Investigation of the Costs and Benefits

Phase 1: Hazard Assessment

Threshold analysis. GEAG, with support from ISET, conducted a series of consultations with communities in the Mahewa ward of Gorakhpur. The aim of the consultations was to identify climatic thresholds related to rainfall intensities, duration, and magnitude that contributed to critical waterlogging in particular areas.[1] The consultations facilitated a qualitative understanding of the various magnitudes of waterlogging and flooding events in the past, the extent of resulting impacts, and the specific characteristics of rainfall (intensity and duration) that contributed to such waterlogging and flooding. Similarly, consultations were conducted to identify temperature-related thresholds, where communities identified specific events when excessive temperatures and humidity caused impacts.

Climate analysis. The climate analysis for this project focused on two parameters: precipitation and temperature. For the precipitation analysis, a historical daily rainfall data set for Gorakhpur had to be compiled and interpolated from a number of data sources due to the incompleteness of available records. Additional historical data was accessed to validate and supplement gaps in the sparse station records. (See details in Opitz-Stapleton & Hawley, 2013.) Temperature and humidity data were collected from the meteorological station housed at the Gorakhpur Airport. The relative heat and humidity conditions identified via the data from the airport correlate well with the extreme heat- and humidity-induced events as recounted during the community consultations in Mahewa ward. Like the precipitation data, temperature data was assessed for quality and consistency to ensure the ability of the research team to investigate future climate temperature scenarios.

Phase 2: Exposure and Fragility Identification

Fragility information was collected via geographic information systems (GIS) maps and flood modeling computations completed by ARUP International. The fragility information allowed the research team to pinpoint the locations where flooding was a major concern. Most households throughout Gorakhpur have experienced some sort of loss due to the almost annual flooding that occurs. A rapid survey was conducted in 10% of the 450 villages that were located within the peri-urban boundary (as shown in Figure 1). Since the level of flooding in any area depends upon its elevation (meters above the mean sea level), these 450 villages were stratified into different elevation groups, and from each group 10% of the villages were selected, which totaled to 45 villages.

Phase 3: Impact and Damages Assessment

To assess the damages or losses incurred by households during past flood, waterlogging, and excessive temperature events, household-level surveys were carried out. The surveyed villages were chosen randomly from local maps, with attention paid to their spatial distribution so that selected villages were uniformly distributed in the peri-urban area. Similarly, of the 70 wards within Gorakhpur Municipal Corporation limits, communities from the most vulnerable (to waterlogging) wards were selected for the household-level survey. The households were selected through a purposive sampling process, where only low-income households that experienced flooding or waterlogging were interviewed. A total of 25 households were interviewed (face-to-face, with a questionnaire) about issues related to excessive temperature and humidity, while 30 households were surveyed to assess damages due to flooding.

Phase 4: Risk Mitigation Options

To identify housing features that are essential for building climate resiliency and also to understand the value that community members place on different strategies, the research team conducted SLDs with stakeholders and gathered qualitative findings related to the costs and benefits of climate resilient features in housing designs. Discussions with the community focused on different options and construction practices undertaken to mitigate or minimize losses by floods or waterlogging. Community perceptions on the relative ranking of these options, for both costs and associated benefits toward building resilience, were noted and analyzed. Collecting people's perceptions was an important step in order to incorporate the value of non-monetized aspects such as aesthetics, status in society, the environment, and so forth that people may accord to a specific resilience building option. The ranking of perceived benefits would ultimately help in the prioritization of options and features to be included in a resilient housing design.

Resilient Housing Design Competition. A housing design competition was held among architecture professionals and students across the country to identify resilient housing designs that could withstand the impacts of future floods and temperature increases. The Resilient Housing Design Competition was organized in Gorakhpur to address the increasing losses experienced by houses due to waterlogging and flooding. This competition, open to Indian nationals, was held from May through August 2013. Both professionals and students of architecture and building design were invited to submit designs for a single flood resilient unit that also had features that provided better thermal comfort during summer months. Design criteria for the houses were developed based on the SLDs with the local people. The submissions were evaluated by a three-member panel of judges comprising eminent architects from Gorakhpur, Delhi, and Bhopal. The winning entries were selected and awards were given to one professional firm as well as one student group. The estimated construction costs of the professional firm's winning resilient housing design was then used for the quantitative CBA.

Phase 5: Investigation of the Costs and Benefits

The information gathered allowed the research team to develop a probabilistic climate model and investigate the economic returns of different risk mitigation options related to flooding and temperature. The costs and benefits utilized a social discount rate of 12% (Zhuang et al., 2007). The model was run under two different scenarios: (a) with climate change projections included and (b) without climate change projections. A sensitivity analysis was also carried out to ensure robust results in a limited data environment.

FIGURE 1

GORAKHPUR INTERVENTION VILLAGES

2.3 Limitations

There were several limitations to the research study, as discussed here.

Availability of data on damages from floods. Secondary data for damages to households and assets during past floods was not available. This necessitated the use of a primary survey of the households (recall method) to assess the damages and losses incurred by households during past events. Due to resource constraints, the number of households surveyed was small. Similarly, the secondary data from hospitals on the number of patients with vector-borne diseases was not available, and this information was also collected from a sample survey of households. Due to the small sample size, some bias will result.

Flood model limitations. A flood model simulation was completed by Arup International in 2013, and the outputs from this model were used in the CBA. Overall, due to data deficiencies, the flood model might be underestimating the potential for flooding in some areas of Gorakhpur.[2]

Acceptability by people. The CBA in this study was carried out based on the winning design entry from the Resilient Housing Design Competition. Though this design is technically sound and has resilient features, its acceptability by the people needs to be assessed. Since the current practice of construction (both in government schemes as well as by individual households) involves building the house with reinforced cement concrete (RCC), the use of alternative material like bamboo, which is cheaper as well as climate friendly, may not be readily accepted.

Endnotes

1. The data collected via community consultations was corroborated by hospital and government records, such as data on dates and duration of pumping by the Irrigation Department/*Jal Nigam* to drain water from the impacted areas.

2. The hydraulic model used land survey maps as the source for ground levels; however, the land survey maps (from 1979) have only a few ground levels, and other ground levels have been extracted from Google Maps at a resolution of only 500 m by 550 m. In addition, current land use maps do not accurately reflect the true buildup of the city, and estimates of different land use categories were integrated to reflect this. Furthermore, the current drainage system has carrying capacity for only a 1-in-2-years event and overflows whenever rainfall exceeds the system. Therefore, the drainage system has not been considered in the overall flood model with potential for flood storage in the system (A. Kumar, personal communication, September 25, 2013).

3. RESULTS AND DISCUSSIONS

3.1 Climate Analysis for Gorakhpur[1]

The depth, duration, and location of flooding within Gorakhpur, or any urban area, are largely determined by land use and urban development as well as solid waste and wastewater/storm management systems. Even without climate change altering the frequency and intensity of Gorakhpur's extreme rainfall events, flooding is likely to increase in severity and frequency in the city because of urban and peri-urban development. The analysis (using a combination of different climate models and emission scenarios) conducted by the project team for future rainfall projections indicates likely changes in the frequency and intensity of Gorakhpur's extreme rainfall events, which are defined as 24-hour events in the 95th or above percentile of the historical rainfall record. For extreme 24-hour or longer duration events, most of the models project a potential increase in precipitation intensity between 2006 and 2055 when compared with the past, 1961–2005. That all models are in agreement about the direction of the change (increasing) in extreme rainfall events lasting a day or longer provides some measure of confidence in the projections. The projected increases in extreme rainfall events, with an overall potential decrease in small or regular rain events, are consistent with changes already being observed both in India and in other regions of the world (Dash, Kulkarni, Mohanty, & Prasad, 2009; IPCC, 2012).

These rainfall intensity projections were used in a flood model assessment completed by Arup, a partner in the project. Arup developed a three-dimensional integrated catchment flood model of Gorakhpur and the projected development areas in the city Master Plan, using available GIS, drainage systems, and land use data of the city. The flood model was then run with two rainfall scenarios and two land use development scenarios to estimate how flooding might evolve in the city. The flood depths produced by the model during the verification slightly underestimated actual recorded flood depths at points throughout the city and at villages surveyed during the household-level surveys, but were still a good fit considering the lack of accurate land use data for the city (see Figure 2).

TABLE 1

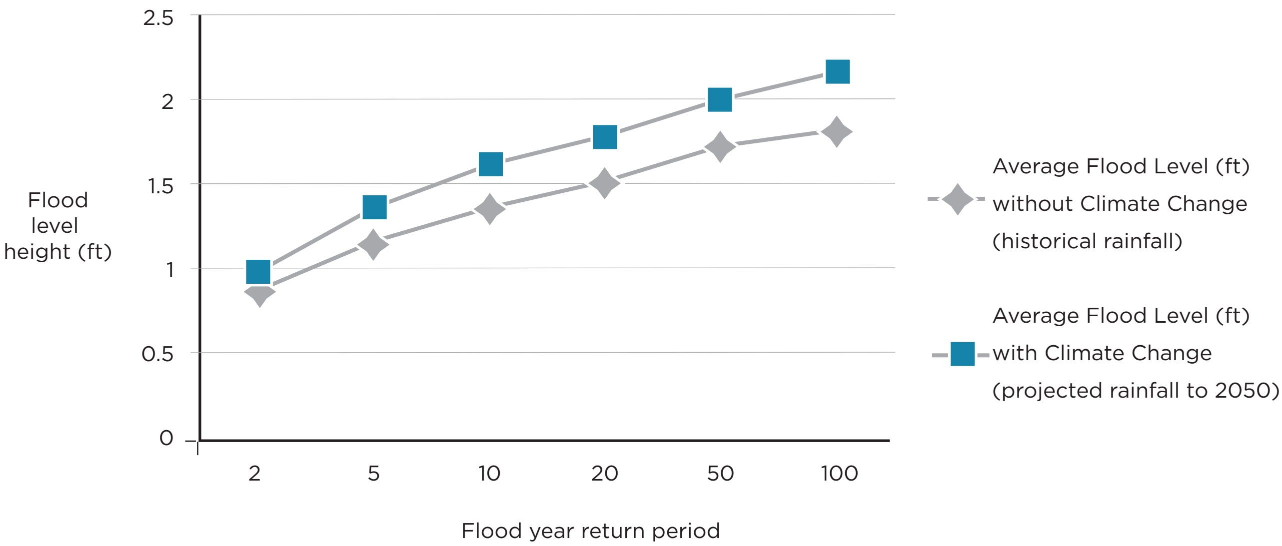
PERCENTAGE CHANGE IN RAINFALL INTENSITY FOR EVENTS OF SELECT DURATIONS AND FOR SELECT RETURN PERIODS

Note. Percentage changes are derived from comparing IDF curves from multiple GCMs for the future (2006–2050) with historical IDF curves (1961–2005). The analysis should be repeated every 5 to 10 years in order to update rainfall statistics as the length of the historical rainfall record increases.

	Return period (years)		
Duration (hours)	2	10	50
1	11%–18%	-12%–52%	-22%–68%
12	10%–17%	1%–30%	-4%–33%
24	10%–20%	4%–23%	2%–25%

FIGURE 2

AVERAGE ESTIMATED FLOOD LEVEL (FT) WITHOUT AND WITH CLIMATE CHANGE



If Gorakhpur's Master Plan continues to be implemented as is, leading to a further reduction of green space and permeable area, flooding and waterlogging will increase (projected changes in flood levels with the land use development scenarios also considered are not shown). Climate change–induced increases in extreme rainfalls or threshold rainfalls plus 'development as is' are likely to significantly increase flood risk throughout the city. Threshold analysis of historic rainfalls, based on reported flood depths during the household surveys, found that specific amounts of rainfall over 1, 2, and 3 days (individually and cumulatively) caused critical waterlogging/flooding problems in specific locations within the city. Given the threshold discussions, we believe that the flood model underestimates observed flood levels due to the rapid pace of urban development, and it is likely that the projected flood levels are also an underestimation.

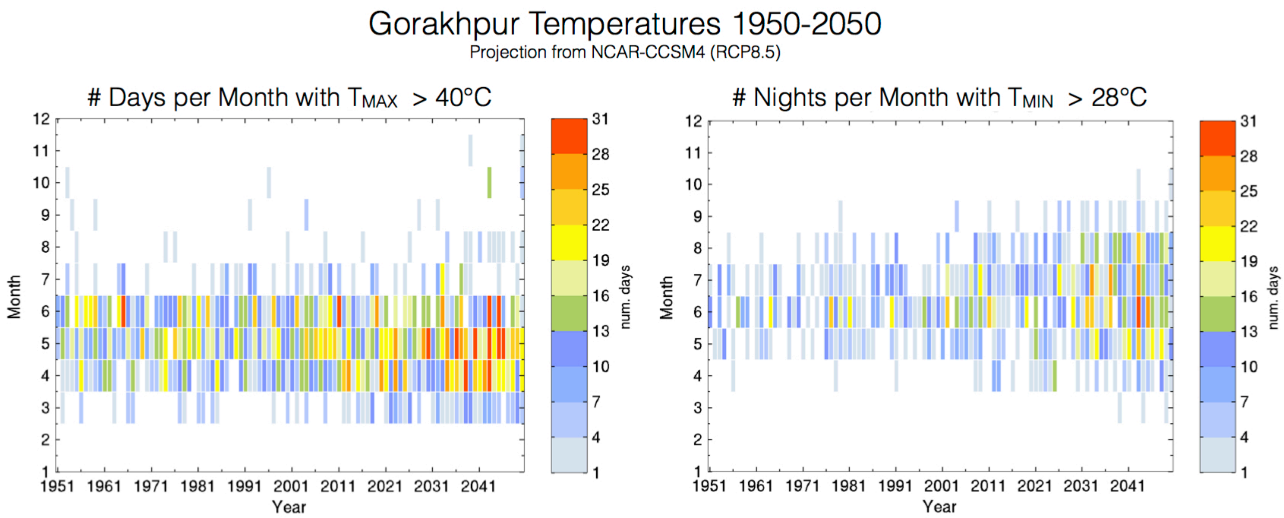
Extreme Temperature

Gorakhpur's climate features cool, dry winters and hot, humid summers when daily maximum temperatures can reach up to 46°C. The monsoon helps in reducing these hot temperatures by about 10°C, but it is during the moist monsoon period when mean nighttime temperatures reach their maximum, about 26°C, with some nights recording close to 37°C. During early monsoon (June), hot, humid nights are a regular occurrence and can go on for 10 days or more. These heat stress conditions have a greater impact on poor urban and peri-urban households, who have much less access to cooling mechanisms that provide relief during the night. The climate model–based projections suggest that such heat stress conditions, when nighttime temperatures are at or above 28°C, will become the norm in Gorakhpur by 2050, as compared to only a few occurrences today. Furthermore, the projections also suggest that such conditions will start earlier in the year (April, or even March) and last longer (about 6–7 months), adding an additional month or more by 2050.

FIGURE 3

PROJECTED NUMBER OF DAYS IN EACH MONTH WITH T^{A}_{MAX} ABOVE 40°C AND T^{B}_{MIN} ABOVE 28°C IN GORAKHPUR

[a]Daily maximum temperature. [b]Daily minimum temperature.
Source*:* Ammann & MacClune, 2014



The latest projections[2] (Figure 3) also indicate that the rise in temperatures, particularly the more extreme temperatures, will continue into the mid-21st century under all future emission scenarios (IPCC-SREX, 2012). The average temperature in Gorakhpur by 2050 is expected to increase by about 2°C, more or less evenly distributed throughout the year. Current daytime peaks will also be surpassed more often and will near or exceed 50°C by the 2050s.

The temperature increases are further exacerbated by the humidity. The heat index is a measure of the decreased efficiency of perspiration to cool the human body in a humid environment. Thus high temperatures with high humidity will have a greater adverse impact on the body than high temperatures alone. Like temperature, the heat index value, also known as the heat index temperature, is expressed in degrees Celsius. Any values over the human body temperature of about 37°C, particularly when experienced for sustained periods, require precautionary measures to prevent heat-related illnesses. Future climate projections for Gorakhpur suggest that the pre-monsoon and monsoon periods—the period with the highest heat index—will extend greatly. For example, for Gorakhpur the heat season will extend on average, 25% of the year in the mid-20th century to nearly 60% of an average year by 2050 (see Figure 4).

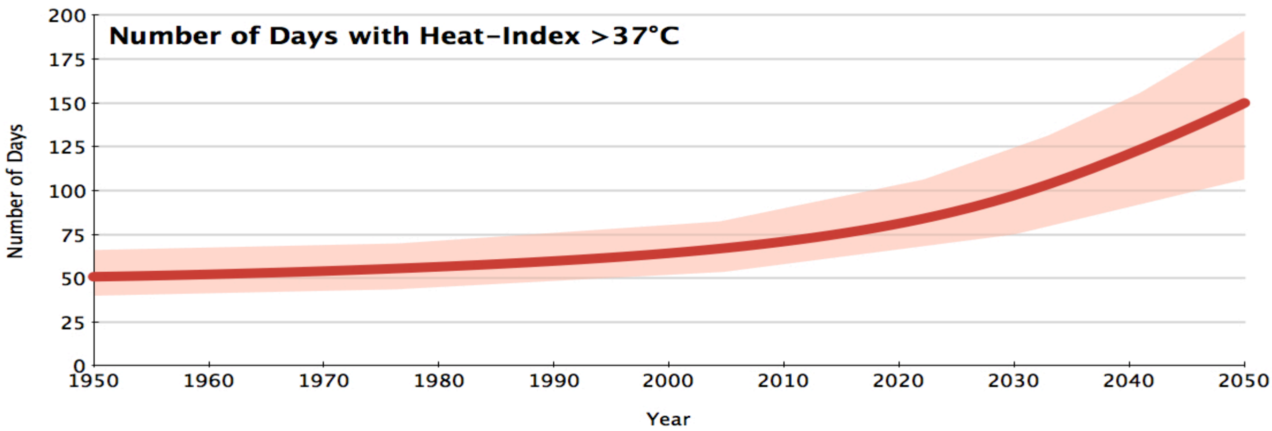
Though projections of future humidity are more uncertain than temperature, its correlation with monsoon phase suggests that on average the pattern of relative humidity with temperature will remain roughly the same. In Gorakhpur presently, only the month of June has an average heat index above 37°C. The projected changes suggest that more than 5 months will see average heat indexes above this human body temperature threshold. The expected 1.5°C–3°C increase in temperature will translate into a 5°C–7°C rise in the heat index.

In summary, Gorakhpur will see an increase in both rainfall extremes and temperature extremes by the 2050s. These conditions will increase the vulnerability of poor and low-income communities and households who are already impacted by the existing waterlogging, flooding, and temperature-related stress conditions. Improved shelter systems in urban and peri-urban areas could mitigate some of these stresses by assisting with adaptation to these future impacts and providing relief from these projected extremes.

FIGURE 4

NUMBER OF DAYS IN GORAKHPUR WITH THE HEAT INDEX ABOVE THE HUMAN BODY TEMPERATURE OF 37°C

Source: Ammann & MacClune, 2014



3.2 Risk Mitigation Options

Community Perceptions of Costs and Benefits[3]

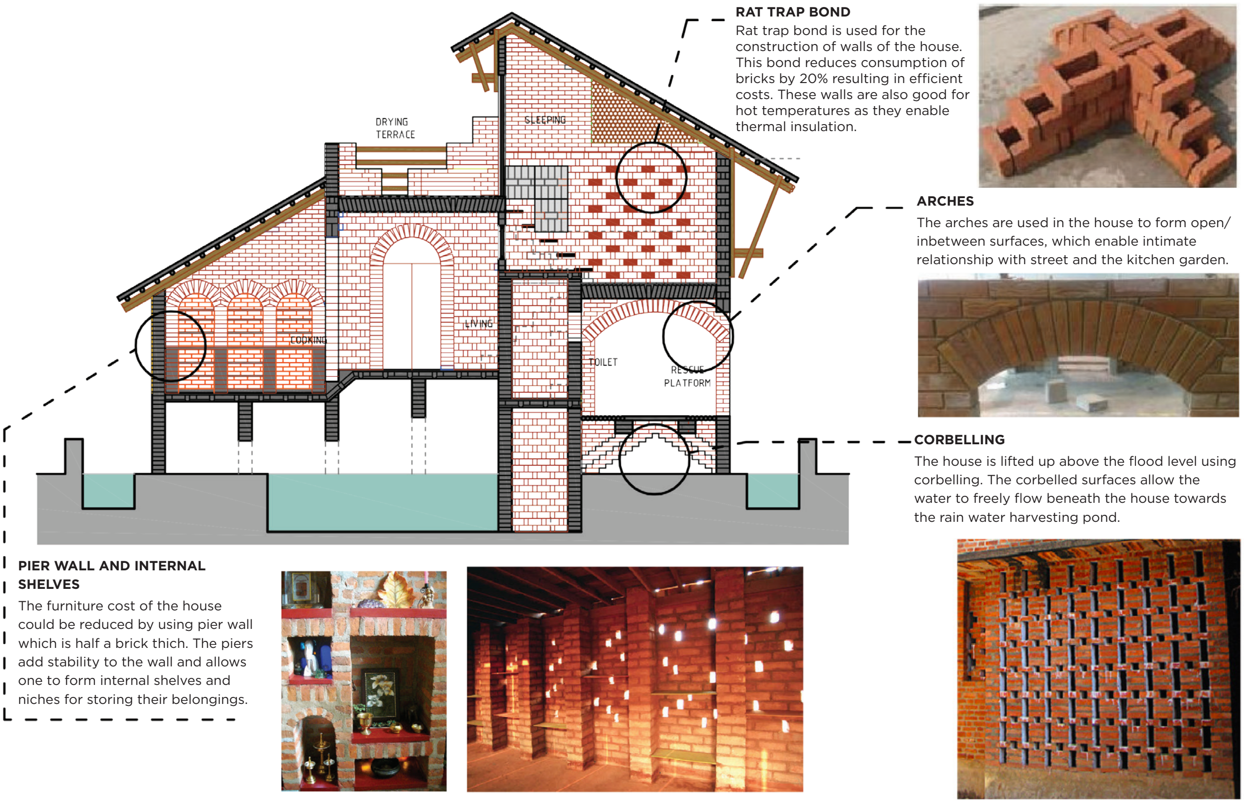
Through SLDs conducted throughout the city, comprehensive ground-level qualitative and quantitative information was collected concerning socioeconomic conditions, housing structures, types of houses, depth of water inundation, duration of flooding, nature of damages, flood impacts by gender, impact of floods on health, housing costs, and measures adopted for coping with floods at the village level. In addition to a raised plinth (elevated foundation), which is almost standard practice now, people have adopted several other housing construction practices that reduce damages.[4]

- Double roof
- Reinforced brick concrete (RBC) roof
- Reinforced cement concrete (RCC) roof
- Raised plinth with mud
- Construction of staircase
- Concrete shelf
- Almirah construction
- Raised plinth with brick wall
- Hook on the roof
- Pillar house (double storied)
- Raised door

In the second step, people from three villages were again consulted regarding the measures adopted to reduce flood risks in their houses. Because the adopted measures and types of materials used in the houses varied according to the economic status of the household, different socioeconomic groups were consulted and housing construction costs are used only as proxies. The estimation of costs and benefits of different adopted measures in the houses was an intense consultative process. The study team used simple methods so that each person (both men and women) could participate and provide an opinion. Evaluation of the costs and benefits of different resilient options adopted by the people reveals a contrasting picture. It is worth noting that the costlier options are not always viewed as providing the greatest benefits. For example, the cost of *raised plinth with brick wall* was given a lower ranking than *RCC roof* in two villages (Uttarasoth and Domarghat) as opposed to the benefits that people derive from them, respectively. Also, some options (like a double roof) were viewed as providing greater benefits in Domarghat as opposed to the same options in the other two villages; in the *double roof* instance, the reason

FIGURE 5

WINNING DESIGN IN THE RESILIENT HOUSING DESIGN COMPETITION



would be because large number of households in Domarghat are engaged in dairy (using the double roof to store fodder). Overall, it is important to note that the cheaper options, such as *raised door* and *concrete shelf,* are perceived to provide greater benefits than their perceived (or near to actual) costs as compared to costlier options, such as RCC or RBC roofs.

Resilient Housing Design Competition

Using the results from the community consultations and SLDs, the Resilient Housing Design Competition hosted in 2013 by GEAG, SEEDs, and ISET-International created an avenue for innovation in traditional shelter systems. The winning design from the housing competition integrated a number of key features for living with increased flooding levels and temperature extremes (see Figure 5).[5]

The specific features of the winning design that make the shelter resilient to flooding while providing comfortable living conditions are as follows.

Raised house with space for water to flow. This is an obvious (and currently also widely used) method to prevent floodwater from entering the house. The difference is that this design allows for the free flow of water, which will help in natural drainage. Also, the house has several levels to ensure that even in the case of unprecedented flood heights, the occupants will have access to safe areas within the house, where they can also store their assets.

Rat-trap bonds and *jali* walls. The use of rat-trap bonds for wall construction (a technique that creates space inside the wall and thus provides thermal insulation) and inclusion of *jali* walls would help in keeping the inside temperature low, especially during the night.

Sloping roof with terra-cotta tiles. A sloping roof made of bamboo rafters and terra-cotta tiles ensures that even in a heavy rainfall the water will run off the roof quickly, hence reducing the cost of the roofing as compared to an RCC. Also, the use of terra-cotta tiles as a roofing material ensures that the house remains cooler, as the tiles reflect the sun's rays.

TABLE 2

ESTIMATED MONETARY LOSSES DUE TO PAST FLOOD EVENTS

Type of loss	Average damage-pucca house (INR 2012)	Average damage-pucca house (USD 2012)	Average damage per sq ft-pucca house (USD 2012)
Direct			
Structural losses (damages to floor, walls, door, windows, and roof)	72,298.52	1,346 .92	1.00
Asset losses (damages to household assets—TV, automobile, etc.)	15,932.41	296.82	0.22
Indirect			
Flow losses (total wages lost + cost of sickness)	4,235.99	3.14	0.06
Total Estimated Monetary Losses	*92,466.91*	*1,646.88*	*1.27*
(count)			
Days to clean up	21.94		
Total work days lost	9.35		
Total school days lost	9.59		
Total Estimated Days Lost	*40.88*		

3.3 Cost-Benefit Analysis

Knowing the average lifetime of a pucca house, about 30 years in Gorakhpur, we looked at the probability of when future flooding events might occur and their projected flood levels (see section 3.1). We investigated the economic returns on three options: (a) raising the plinth level to above projected climate change flood levels (which many households that can afford it are doing), (b) building the winning climate resilient housing design, and (c) employing the risk reduction measures identified by the communities during the SLDs.

Estimated Monetary Losses From Past Events

Heavy rainfall occurred in June 2013, with a total of 395.5 mm of rain falling over 4 days. This rainfall event impacted a large portion of Gorakhpur, and these types of events are expected to increase with climate change. Information about damages (direct and indirect monetary damages)[6] experienced during the June 2013 flood was gathered through household surveys. All respondents had water enter their homes during the flood, which was calculated as a 1-in-50-years rainfall event.[7] Water 2–3 feet in depth entered houses and remained for 16 days, on average. Most households experienced a disruption in work days and school days and had to spend a significant amount of time cleaning up.

Damage estimates show that households that experienced flood damages in 2013 spent, on average, about 12% of their annual income on recovery efforts. Due to the purposive sampling method, a total of only 30 households were interviewed; thus damage values gathered through these surveys may be subject to bias[8] (See Table 2).

Depth-damage curves[9] were developed specifically for pucca houses. As water depth increases within the house, greater structural damage occurs and more household assets are lost (flow losses were

FIGURE 6

ASSET AND STRUCTURAL LOSSES

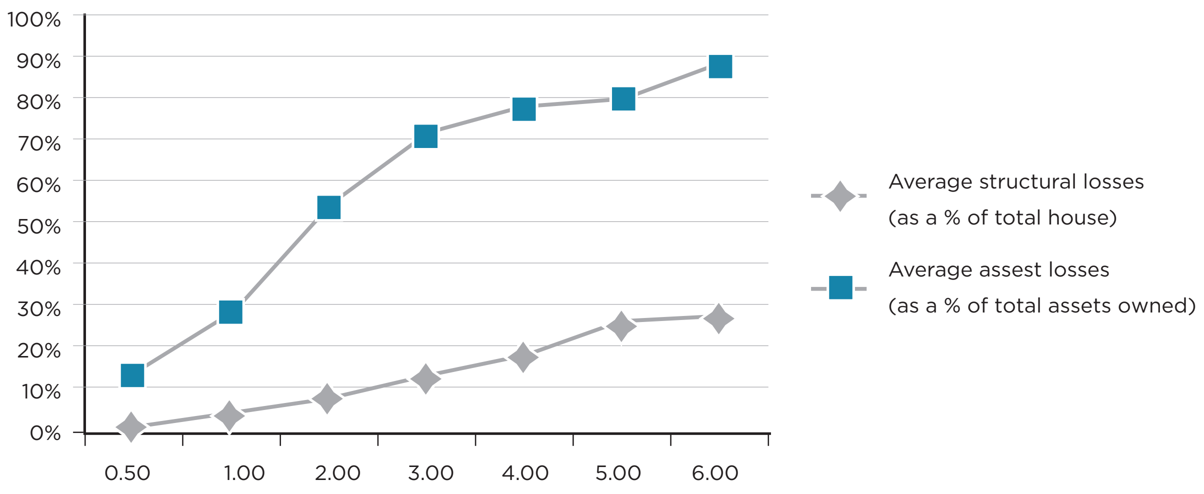
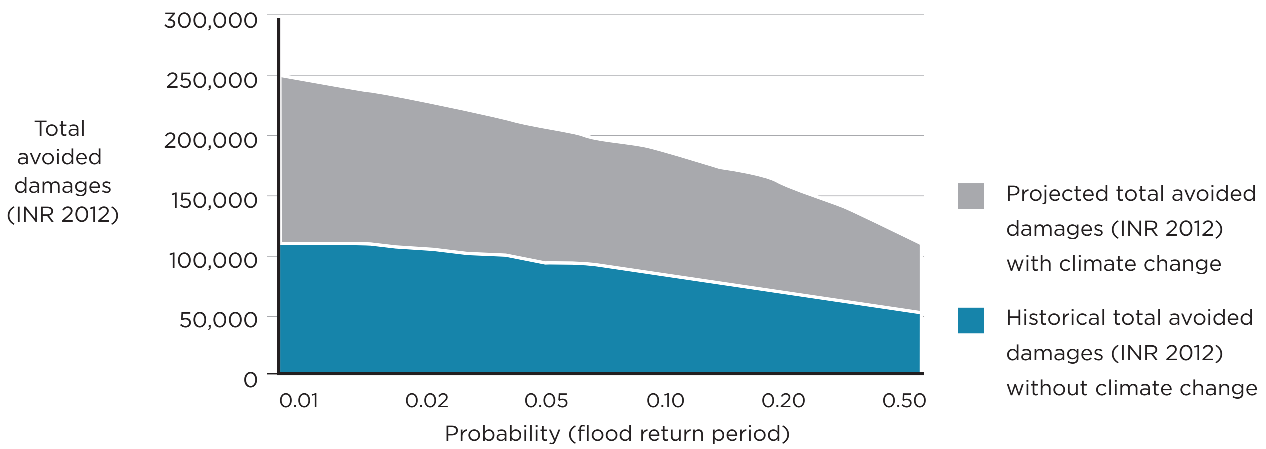


FIGURE 7

ESTIMATED AVERAGE ANNUAL AVOIDED DAMAGES (BENEFITS) FOR A LOW-INCOME HOUSEHOLD FOR EACH FLOOD RETURN PERIOD



not based on water depth). The rate of increase in damages per foot-depth of flooding is greatest initially, with the largest increase occurring between 0.5 and 2 feet (see Figure 6).

Estimated Monetary Losses From Future Events

Using the results from the depth-damage curves, we were able to link historical flood depths with past damages and the resulting flood return periods. We then investigated the avoided damages (benefits) by linking the depth-damage curves with the historical and projected flooding assessments for Gorakhpur. As shown in Figure 7, damages do increase from historical to projected scenarios. However, it should be noted that the flood model predicted that at the 100-year flood return period (0.01 probability), Gorakhpur would, on average, experience 1.8 feet if historical flooding occurred into the future and 2.2 feet if projected flooding with climate change occurred. The household-level surveys revealed that during the 1-in-50-years flood event in 2013, 2.8 feet of water entered most houses. Therefore, the flood model potentially underestimates both future flood levels and future avoided damages, which is taken into consideration, in the sensitivity analysis.

Cost-Benefit Analysis for Without and With Climate Change Scenarios

The CBA was completed for two scenarios: (a) without climate change and (b) with climate change. Avoided damages were used from Figure 7 to calculate overall average annual avoided damages (benefits). To calculate the net benefits, the average annual damages are distributed over the lifetime of the house, 30 years, and the cost of construction of the risk mitigation options are subtracted. The benefits and costs are discounted at a rate of 12% and sensitivity analysis is performed on the major uncertain assumptions of the equation. The model evaluates the economic returns with and without climate change until 2050, assuming annual average avoided damages (replacement costs) as the sum of structural, household asset, and flow losses by square foot.

Option 1. Option 1 compares the cost of construction of raising the plinth with brick walls and mud fill (typical of the homes of most low-income households in Gorakhpur) to not building a plinth at all.

Option 2. Option 2 compares the additional cost of construction of a climate resilient house (winning professional design) to the cost of a typical pucca house built in Gorakhpur.

Option 3. Option 3 compares the cost of incorporating four of the risk mitigation options for flood resilience identified by community consultations to not integrating those features in the design.

Further metrics included in the analysis are presented in Table 3.

TABLE 3

ASSUMPTIONS AND METRIC TABLE

Assumption	Metric	Description
Overall Assumptions		
Estimated annual avoided damages w/o climate change	26.51 per ft^2 (INR 2012) 0.49 (USD 2012)	Replacement values have been used for the damage estimates. Does not include livestock, fuel, grain, or fodder losses due to the inconsistency of survey responses.
Estimated annual avoided damages w/ climate change	30.92 per ft^2 (INR 2012) 0.58 (USD 2012)	Replacement values have been used for the damage estimates. Does not include livestock, fuel, grain, or fodder losses due to the inconsistency of survey responses.
Assumed house area	75 m^2/810 ft^2	Based on award-winning housing design two-room house.
Discount rate	8.75%–15%	Varying discount rates were used. We use a base social discount rate of 12% (Zhuang et al., 2007)
Typical pucca house construction cost	676 per ft^2 (INR 2012)	Based on interview with general contractor in Gorakhpur (Jaiswal, 2013).
Estimated annual avoided moveable asset losses w/o climate change	3.16 per ft^2 (INR 2012) 0.06 (USD 2012)	Based on the assumption that moveable assets are 12% of an average household's total owned assets (structural and moveable assets).
Estimated annual avoided moveable asset losses w/climate change	3.69 per ft^2 (INR 2012) 0.07 (USD 2012)	Based on the assumption that moveable assets are 12% of an average household's total owned assets (structural and moveable assets).
Option 1: Raising plinth with brick and mud fill		
Plinth cost	18.32 per ft^3 (INR 2012)	Based on shared learning dialogue that occurred in 2012 (Singh et al., 2013)
Plinth height	3 ft	Height assumed with climate change estimated maximum flood level is 2.2 feet.
Plinth lifetime	30 years	Standard useful life of a house including that of plinth.
Percentage of structural and moveable assets saved by plinth	100% if raised to 3ft	Average plinth height from households survey is 1.8 feet.
Operations and maintenance (O&M)	2% per year	
Option 2: Climate Resilient House		
Additional cost to be a climate resilient house with bamboo reinforcements	-97,796 (INR 2012) -1,821.94 (USD 2012)	Overall cost for construction of climate resilient house is less than a typical pucca house[10], 14% labor cost and 10% professional fees included.
Additional cost to be a climate resilient house with RCC reinforcements	159,476 (INR 2012) 2,971.04 (USD 2012)	Based on estimates provided by local general contractor in Gorakhpur (Jaiswal, 2013).
Lifetime	30 years	Standard useful life of house.
Percentage of structural and moveable assets saved	100%	Assumed all assets will be saved.
O&M	5%	The resilient housing design uses innovative materials for reducing the cost of the structure. However, this may result in higher O&M costs.
Option 3: Community Identified Risk Mitigation Options		
Risk Mitigation Option	*Lifetime/Percentage of structural and moveable assets saved/cost of construction*	*Description*
Construction of Staircase	45/20%/35,000 (INR 2012)	The percentage of assets saved by risk reduction measures varied greatly, conservative estimate used. Based on shared learning dialogues that occurred in Feb. 2014 and community consultations (Singh et al., 2014).
Hook on Roof	50/8%/40 (INR 2012)	Same as above.
Almirah Construction	40/8%/ 3,150 (INR 2012)	Same as above.
Concrete Shelf	50/38%/3,600 (INR 2012)	Same as above.

TABLE 4

BENEFIT-COST RATIO OF RISK REDUCTION MEASURES

Scenario	Without Climate Change	With Climate Change
Raised brick and mud filled plinth	3.7	4.4
Additional cost to build a climate resilient house	44.7	49.5
Additional cost to build a climate resilient house with RCC reinforcements	1.0	1.2
Construction of Staircase	0.12	0.14
Hook on Roof	42.44	49.49
Almira Construction	0.54	0.62
Concrete Shelf	2.24	2.61

Risk Reduction Results

As seen in Table 4, almost all risk reduction measures result in a benefit-cost ratio equal to or above 1. However, when a homeowner decides to construct a concrete staircase or almirah closet, the economic returns become negative.

We compared the construction costs of a typical pucca house to the costs of a climate resilient house, which resulted in positive economic returns. The Resilient Housing Design Competition encouraged participants to create low-cost, innovative housing designs. The winning climate resilient housing design used bamboo reinforcements, which greatly reduce the construction costs compared to a typical pucca house. With the annual occurrence of floods in Gorakhpur, the return on investment is immediate for low-income homeowners if they construct a climate resilient house with bamboo.

However, local masons in Gorakhpur are currently not trained in integrating these innovative design elements, illustrating the need for technical capacity building and closing the information asymmetry gap. Furthermore, most homeowners are unaware of design options such as integrating bamboo reinforcements and may be hesitant to adopt such a new practice. Therefore, we investigated the costs of what it would take to build a universally acceptable alternative to the winning design. Utilizing the same climate resilient housing design but with reinforced cement concrete, the benefits (avoided losses) are equal to the costs without climate change considered. With climate considered, the return on the investment made in an RCC-reinforced climate resilient house occurs in year 14 instead of year 1.

Many homeowners integrate other risk reduction measures into their house if they cannot afford to build a new house. The most prevalent risk reduction measure is the construction of a raised brick and mud-filled plinth. Other measures identified during SLDs included (a) construction of a staircase, (b) construction of a concrete shelf, (c) adding a hook on the roof, and (d) construction of a closet (almirah). Adding a hook or constructing a concrete shelf results in high economic returns for minimal capital investment; however, both the construction of a staircase and an almirah shelf are expensive strategies that save only a very limited amount of moveable assets.

TABLE 5

SENSITIVITY ANALYSIS OUTPUTS FOR "WITH CLIMATE CHANGE" SCENARIO

	With Climate Change						
	Discount rate 8.75%	Discount rate 15%	Cost increase: 100%	Cost increase: 75%	Cost increase: 50%	Avoided damages doubled	Avoided damages doubled but costs increased by 100%
Option 1: Plinth raising with brick and mud fill	5.6	3.6	2.2	2.5	2.9	8.4	4.4
Option 2: Additional cost to build a climate resilient house with bamboo reinforcements	43.6	55.9	0.5	0.8	1.5	82.8	1.1

Sensitivity Analysis

The three options discussed in the previous section are based on a number of assumptions and uncertainties but adequately reflect the limited data environment and best judgment of the research team. To ensure that the analysis contains robust results, several of the critical assumptions underwent sensitivity analysis. Those assumptions include the following:

- *Annual avoided damages (benefits).* Annual avoided damages are doubled to incorporate inconsistencies with the flood model results as well as the lack of incorporation of intangible benefits.

- *Winning housing design construction costs.* The cost of construction for the new housing design varies by region due to cost of materials, prevailing labor costs in the area, and so forth. Furthermore, the winning design integrates the use of bamboo reinforcements for cost savings and environmental purposes. To ensure acceptability of this measure, these reinforcements may need to be RCC pillars, which will result in a cost increase. Therefore, the winning design construction costs were varied by a 50% cost increase, 75% cost increase, and 100% cost increase.

- *Varying discount rates.* Discount rates were varied from 8.75% to 15%.

In summary, there is an economic incentive for a household to invest in climate resilient features when building a new house. However, we know not every household is making this investment decision, due to financial and other constraints. The next section therefore discusses policy implications.

Endnotes

1. Adapted from the technical report “Gorakhpur, India: Extreme Rainfall, Climate Change, and Flooding” (Opitz-Stapleton & Hawley, 2013).

2. Projections were coordinated through IPCC-AR5, 2013.

3. For more information concerning community perceptions on costs and benefits, please visit i-s-e-t.org/SHELTER

4. Based on SLDs conducted within three selected villages (Uttarasoth, Domarghat, and Semra Devi Prasad) in July 2012.

5. For more information on the winning design from India, visit http://www.i-s-e-t.org/images/pdfs/ISET2014_A%20Concept%20pf%20Resilient%20Housing_Gorakhpur_DesignCompetition_140117.pdf.

6. Nonmonetary damages were not taken into consideration but are qualitatively discussed in section 3.2 and their implications in the results section 4.3.

7. This calculation is based on India Meteorological Department (IMD) data (two stations). If calculated over 6 days (the IMD stations recorded rain the first 2 days of July), the event was roughly a 1-in-40-years event

8. A mix of various sampling techniques were used—initially the use of a stratified random sampling and then the use of purposive sampling (see more details in section 2.2)—to help reduce bias. Compensation bias might be another concern. While administering the questionnaire, as well as during the initial discussions in the (six) villages where the survey was undertaken, the team specifically mentioned that GEAG is an NGO doing this research only to ascertain the damages people suffered due to floods or waterlogging. Government departments make compensation decisions without any consideration as to the size of the household or the extent of assets lost or damaged.

9. Depth-damage curves are essential tools in estimating flood damage assessments (Prettenthaler, Amrusch, & Habsburg-Lothringen, 2010). However, depth-damage curve estimates were unavailable for Uttar Pradesh, India, and the region. Therefore, a hypothetical approach for collecting depth-damage estimates was developed for the household surveys.

10. Resilient Housing Design Competition asked participants to think about culturally acceptable designs as well as innovative ways to keep the cost down. This resulted in a more cost-effective design than a typical, pucca construction.

4. POLICY IMPLICATIONS

Though housing is a state matter in India, there are many policies and programs implemented by both state and local governments. However, most of the investment in housing in India is done by individual households. The results from this study have revealed several policy and programmatic implications that need to be influenced in order to promote flood (or disaster) resilient housing in affected areas.

4.1 Implications at Policy and Program Levels

Many state (and local district/city level) government agencies are involved in building houses for the poor and economically weaker sections under various state and national programs. To incorporate flood resilient design features into these programs, it is necessary to increase awareness of such designs as well as highlight the comparative long-term financial benefits amongst all stakeholders. Next, flood resilient features need to be included in the design guidelines of such programs. While there is adequate scope for incorporating such elements in specific government funded and facilitated housing programs, there is a greater need to clearly identify and demarcate flood risk areas and localities in city master plans and zonal plans.

4.2 Implications at Household and Individual Levels

A significant portion of housing construction in the country is done through the private sector, which includes individual households as well as large builders and developers. Most of the housing for low-income groups is designed and constructed at an individual level. Since this group is constrained financially, the necessary investment in flood resilient housing may not happen. Even with the lower costs of the alternate design that is suggested in this study, people from low-income groups may find it difficult to invest in this design in the absence of affordable financing. Secondly, housing designs are generally based upon the currently prevalent practices and the skill set or knowledge of the local masons. In addition to the benefits accruing due to the avoidance of losses of house structure and assets, there are larger benefits to individuals and society as a whole with the adoption of resilient housing. Enhanced security and safety and a reduction in disruption time are some aspects that are difficult to valuate in monetary terms.

4.3 Recommendations

Access to Financing

Access to affordable financing is one of the key constraints faced by low-income households when considering an investment to build a house. In areas that are affected by recurrent floods, the government should encourage such investment by individual households through supportive policies for low-cost loans, preferential loans (for resilient designs), and deferred payments or subsidies, as well as technical assistance in the form of free availability of designs. Local banks and other financial institutions should develop specific loan packages, including micro-finance or group-finance schemes, or low interest rates for such people. To encourage and facilitate the banks to offer such schemes, the government should provide support to banks and financial institutions with refinancing or guarantee schemes.

Capacity Building and Awareness Generation

As mentioned above, local masons are one of the key stakeholders in housing construction for low-income households. Most houses for this group are built by local masons, who also determine the designs for the houses based on current practices and their knowledge and skill level. Capacity building for masons at the local level is critical if resilient housing designs are to be promoted.

Secondly, it is common for low-income households to aspire for the houses built by higher income groups. However, their financial constraints may lead to a maladapted design that is at risk from floods and waterlogging. The adoption of new designs that are flood resilient (and cost-effective) will need large awareness generation programs aimed at people in flood-affected areas.

5. CONCLUSIONS

As a rapidly growing city, Gorakhpur is experiencing recurrent floods and waterlogging events whose frequency and intensity are increasing and becoming unpredictable. Many of the city's low-income households (most of whom are migrants) live in low-lying areas and are the most vulnerable to these risks. Housing construction practices in Gorakhpur have changed drastically in the past decade due to ongoing learning from recurrent floods. The primary reason for changes in construction practices (raising the plinth level of the house) stems from the 1998 floods, which affected almost all areas of Gorakhpur. Though most people from the economically weaker sections aspire to build better houses, they are either unable to afford them (and therefore remain vulnerable to floods and waterlogging) or become indebted to private moneylenders as they are not able to negotiate affordable banks loans due to land ownership issues.

This research investigated the costs and benefits of climate resilient shelters in order to identify potential policy interventions that might encourage low-income households to invest in safer shelter structures. To investigate the economic returns, a Resilient Housing Design Competition was hosted in 2013 in which winning designs were chosen that met criteria for flood and temperature resilience. The key features of the resilient design are a raised plinth and an upper-level room. These housing features are already commonly adopted by higher income households, and hence, resilient design incorporates and builds upon the autonomous strategies already practiced by people. The housing design competition also brought out the fact that flood and waterlogging resilient design features in a house do not necessarily cost more. This implies that resilience to risks such as floods can easily be incorporated at similar or even lower costs than what people are currently investing in housing. Further, the inclusion of simple features like terra-cotta tiles for a sloping roof and *jali* walls and rat-trap bonds for wall construction reduce the cost of construction while lowering the inside temperature of the house. For a larger policy implication, this result demonstrates that actions to improve resilience do not necessarily require large (or larger) investments than those already being made. The finding was further illustrated by the results of the CBA that showed benefit-cost ratios greater than one for almost all risk reduction options. In the case of the winning resilient housing design which used bamboo reinforcements, for every rupee spent on flood and temperature resilience features, there was a payback of approximately 45 to 50 rupees. In addition to the clear economic benefits, there are other important nonmonetary benefits, such as enhanced security and safety, peace of mind (less stress), comfortable living conditions, enhanced self-esteem, and so forth, that would accrue with adoption of these resilient housing designs. Yet even though these benefits and the economics make sense, there are considerable barriers to adoption of these features by low-income households.

As was the intention of this study, many policy implications for promoting flood resilient housing designs in areas suffering from recurrent floods have been raised. The research clearly brings out the fact that a flood resilient house is cost-effective in the long run, and the state should promote such designs and practices both for public (government) construction as well as private (individual) construction. Since economically weaker households are less likely to be able to afford flood resilient housing, providing low-cost loans and easy access to financing becomes imperative. This can be done through government intervention with appropriate policy mandates. Linking resilient housing construction in specific flood-prone areas to bank loans and insurance schemes would be another way to encourage people to adopt such practices. The other important aspect—in a largely private housing construction sector—is that of increasing the demand for such designs and practices. This can be achieved through awareness campaigns (for people) and capacity building of local masons on resilient housing designs.

REFERENCES

Mr. Amit Kumar Jaiswal. (March 13, 2014).[Interview]. General Contractor, Aryan Infrastructure Engineers and Consultants.

Ammann, C., & MacClune, K. (2014). *Projecting the likely rise of future heat impacts under climate change for selected urban locations in South and Southeast Asia.* Boulder, CO: ISET-International.

Dash, S. K., Kulkarni, M. A., Mohanty, U. C., & Prasad, K. (2009). Changes in the characteristics of rain events in India. *Journal of Geophysical Research, 114*(D10109). doi: doi:10.1029/2008JD01057

Government of India. (2007). *National urban housing and habitat policy*. New Delhi: Ministry of Housing and Urban Poverty Alleviation. Retrieved from http://mhupa.gov.in/policies/duepa/HousingPolicy2007.pdf

Government of India. (2010). *National mission on sustainable habitat*. New Delhi: Ministry of Urban Development. Retrieved from http://www.urbanindia.nic.in/programme/uwss/NMSH.pdf

Government of India. (2011). *2011 census data* [Data file and code book]. Retrieved from http://censusindia.gov.in/

High Powered Expert Committee (HPEC). (2011). *Report on Indian urban infrastructure and services.* Retrieved from National Institute of Urban Affairs website: http://www.niua.org/projects/hpec/finalreport-hpec.pdf

Intergovernmental Panel on Climate Change (IPCC). (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation.* Cambridge, UK: Cambridge University Press.

International Monetary Fund. (2011). Interest rates, discount rate for India (INTDSRINM193N). Retrieved from Federal Reserve Bank of St. Louis website: http://research.stlouisfed.org/fred2/series/INTDSRINM193N

ISET, NISTPASS, & TEI. (2012). *Changing cities and changing climate: Insights from shared learning dialogues in Thailand and Vietnam.* Boulder, CO: Institute for Social and Environmental Transition-International. Retrieved from http://i-s-e-t.org/images/pdfs/isetinternational_changingcitiesandchangingclimate_nistpassandtei_2012.pdf

National Sample Survey Office (NSSO). (2010). *Some characteristics of urban slums 2008–09* (Report No. 534). New Delhi: Government of India, Ministry of Statistics and Programme Implementation. Retrieved from http://mospi.nic.in/Mospi_New/upload/534_final.pdf

Opitz-Stapleton, S., & Hawley, K. (2013). *Gorakhpur, India: Extreme rainfall, climate change, and flooding* (Technical Report). Boulder, CO: Institute for Social and Environmental Transition-International. Retrieved from http://i-s-e-t.org/images/pdfs/briefs/ISET_TechnicalBrief_Gorakhpur_130508.pdf

Prettenthaler, F., Amrusch, P., & Habsburg-Lothringen, C. (2010). Estimation of an absolute flood damage curve based on an Austrian case study under a dam breach scenario. *Journal of Natural Hazards and Earth Systems Sciences, 10,* 881–894. Retrieved from www.nat-hazards-earth-syst-sci.net/10/881/2010/

Sankhe, S., Vittal, I., Dobbs, R., Mohan, A., Gulati, A., Ablett, J., … Sethy, G. (2010). *India's urban awakening: Building inclusive cities, sustaining economic growth*. Retrieved from McKinsey & Company website: http://www.mckinsey.com/insights/urbanization/urban_awakening_in_india

Singh, D., Hawley, K., & Singh, B. (2013). *Indian housing policy landscape: A review of Indian actors in the housing arena* (Sheltering Series). Boulder, CO: Institute for Social and Environmental Transition-International. Retrieved from http://www.i-s-e-t.org/images/pdfs/CDKN_IndiaHousingPolicyLandscape_WithInfoGraphic_131017.pdf

Singh, D., Hawley, K., & Singh, B. (2014). *Community Based Evaluation of the Costs and Benefits of Resilient Housing Options: Gorakhpur, India* (Sheltering Series). Boulder, CO: Institute for Social and Environmental Transition-International.

Tran, K. (2012). *Assessing vulnerability to extreme heat among residents of urban slums in Ahmedabad.* (Master of Public Health in Global Environmental Health). Emory University, Atlanta, Georgia. Retrieved from http://pid.emory.edu/ark:/25593/br127

Tripathi, S. (2013). *An overview of India's urbanization, urban economic growth and urban equity* (Paper No. 45537). Retrieved from Munich Personal RePEc Archive website: http://mpra.ub.uni-muenchen.de/45537/1/MPRA_paper_45537.pdf

Wajih, S., Singh, B., Bartarya, E., Basu, S., & ACCCRN ISET Team. (2010). *Towards a resilient Gorakhpur.* Gorakhpur, India: Gorakhpur Environmental Action Group.

Zhuang, J., Lian, Z., Lin, T., & De Guzman, F. (2007). *Theory and practice in the choice of social discount rate for cost-benefit analysis: A survey* (ERD Working Paper No. 94). Manila, Philippines: Asian Development Bank. Retrieved from http://www.adb.org/sites/default/files/pub/2007/WP094.pdf

Sheltering From a Gathering Storm Publications

Additional materials can be found at **i-s-e-t.org/SHELTER**
These materials include:

CASE STUDIES

- Sheltering From a Gathering Storm: Typhoon Resilience in Vietnam
- Sheltering From a Gathering Storm: Flood Resilience in India
- Sheltering From a Gathering Storm: Temperature Resilience in Pakistan

SHELTERING SERIES

- Review of Housing Vulnerability: Implications for Climate Resilient Houses
- Qualitative Insights into the Costs and Benefits of Housing
- Indian Housing Policy Landscape: A Review of Indian Actors in the Housing Arena
- Temperature Impacts on Health, Productivity, and Infrastructure in the Urban Setting, and Options for Adaptation
- Potentials to Build Disaster Resilience for Housing: Lessons Learnt from the Resilient Housing Design Competition 2013
- Climate Resilient Housing: An Overview of the Policy Landscape in Pakistan
- Situation Analysis Gorakhpur, India: Climate Change, Flooding and Vulnerability
- Community Based Evaluation of the Costs and Benefits of Resilient Housing Options: Gorakhpur, India

TEMPERATURE BRIEFINGS

- Projecting the likely rise of future heat impacts under climate change for selected urban locations in South and Southeast Asia.

POLICY BRIEFS

- Gorakhpur: Extreme Rainfall, Climate Change, and Flooding
- Da Nang: Extreme Rainfall, Climate Change, and Flooding
- Da Nang: Typhoon Intensity and Climate Change

TECHNICAL REPORT

- Gorakhpur: Extreme Rainfall, Climate Change, and Flooding
- Da Nang: Extreme Rainfall and Climate Change

Sheltering From a Gathering Storm aims to improve understanding of the costs and benefits of climate resilient shelter designs and contribute to the transformative changes necessary to make communities more resilient to future disasters.

This case study, one of three in the project, focuses on key issues related to housing in Gorakhpur, India, and provides insights into the economic and nonfinancial returns of adaptive, resilient shelter designs that take into consideration hazards such as flooding, and temperature increases.

This document is an output from a project funded by the UK Department for International Development (DFID) and the Netherlands Directorate-General for International Cooperation (DGIS) for the benefit of developing countries. However, the views expressed and information contained in it are not necessarily those of or endorsed by DFID, DGIS, or the entities managing the delivery of the Climate and Development Knowledge Network, which can accept no responsibility or liability for such views, completeness or accuracy of the information, or any reliance placed on them.

This report was produced by The Institute for Social and Environmental Transition-International in partnership with Gorakhpur Environmental Action Group

For more information, please see:
www.i-s-e-t.org/SHELTER