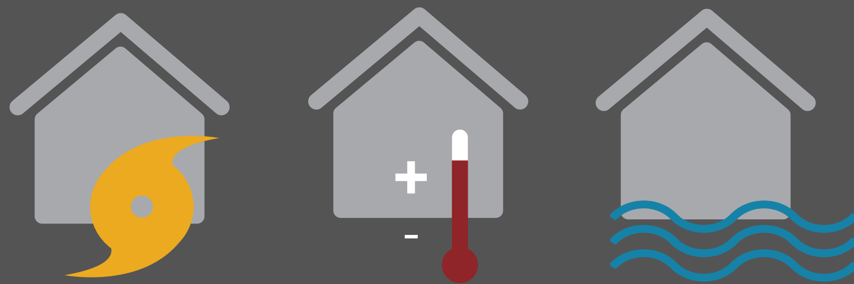

SHELTERING

From a Gathering Storm

The Costs and Benefits of Climate Resilient Shelter

Typhoon Resilience in Vietnam, Flood Resilience in India, Temperature Resilience in Pakistan

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Finally, while acknowledging these vital contributions to the publication, the authors take responsibility for its contents and conclusions, including any errors or omissions therein. The analyses and opinions in this report are those of the authors and do not necessarily reflect the views of the CDKN.

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Sheltering From a Gathering Storm
The Costs and Benefits of Climate Resilient Shelter

Dr. Marcus Moench & The Sheltering Team

Table of Contents

Key Points in Brief 2

1. The Role of Shelter in Climate Resilience and Adaptation 4

2. Research Methodology 6

    2.1 Cost-Benefit Analysis Methodology 6

3. Special Section: Climate & Heat in India and Pakistan Case Sites 10

4. Key Findings From Study Locations 16

    4.1 Typhoon Resilience in Vietnam 18

    4.2 Flood Resilience in India 22

    4.3 Temperature Resilience in Pakistan 26

5. Conclusions 32

    5.1 Findings From This Research Have Important Policy Implications 33

References 37

Related Reading Materials (inside back cover)

Abstract (back cover)

List of Tables

T1. The Five Most Cost-Effective Options for Reducing Heat Stress Under Current Conditions 30

T2. Returns on Investment (as a BCR) in Temperature Reductions in Current Conditions and Future Conditions (2050) 31

T3. Response Avenues and Key Messages in Study Locations 34

List of Figures

F1. The Climate Resilience Framework 7

F2. Risk Reduction Framing 8

F3. Daily Means for Temperature and Heat Index as Annual Cycles in Multan, Pakistan, With Both Present and Future Values 11

F4. Number of Days in Gorakhpur With the Heat Index Above the Human Body Temperature of 37°C 12

F5. Gorakhpur Annual Cycle of Heat 13

F6. Comparison of the Economic Returns With and Without Climate Change in Da Nang, Vietnam 21

F7. Economic Returns of Climate Resilient Features in Gorakhpur, India 25

F8. Heat Burden Per Person in Pakistani Rupees (PKR) 29

KEY POINTS IN BRIEF

Resilient housing designs can cost-effectively reduce losses by vulnerable communities due to floods, storms, and high peak daily temperature events. As climate changes, resilient designs contribute substantially to the adaptive capacity and resilience of poor communities by reducing structural, asset, and income losses.

Access to affordable resilient housing designs and the funding required to implement them is especially important to the poor and near-poor who have access to land and housing. Shelter design measures cannot address the needs of the most marginalized groups, who are unable to access permanent housing or afford to make existing shelters resilient.

Simple, low-cost design features have been identified through Resilient Housing Design Competitions. These features contribute to the resilience of shelters to floods and extreme storm events. They are cost-effective and in some cases reduce costs below those of standard construction practices.

Qualitative and quantitative analyses of investments in climate resilient designs show high benefit-cost ratios under a range of scenarios. Results are derived from case sites in Vietnam, India, and Pakistan. Shelter in these sites is characteristic of large areas in Asia. Results are therefore likely to be applicable throughout the region and in other areas with similar characteristics.

Access to affordable financing coupled with awareness and training of builders are the primary barriers vulnerable populations face in accessing climate resilient designs. In some areas, climate resilient elements are already being adopted by wealthy sectors of the population. Local masons and contractors are a key intervention area for training on climate resilient design principles.

While shelter designs can reduce the impact of extreme storms and floods, the ability to address increases in temperature through shelter design changes alone is limited. Extended increases in hot season nighttime minima in combination with humidity (the overall heat index) may prove particularly challenging without active cooling.

- **Temperature increases are significant.** Climate model projections for case locations suggest an overall increase of approximately 2°C–3°C in temperature maxima and minima by 2050, with minima increasing more rapidly than maxima, resulting in both a longer heat season and a greater number of consecutive days of heat stress. Projections for the 2050s indicate night temperature minima will remain above heat stress thresholds identified by local communities (26°C–32°C) for months in case locations.

- **The impact of temperature increases is compounded in areas or periods of the year when humidity is high.** Model results for case areas indicate that a 1.5°C–3°C increase in temperature will translate into a 5°C–7°C increase in the heat index (a measure of the decreased efficiency of perspiration to cool the body). Results indicate that the heat index is likely to exceed human body temperature (37°C) for over half the year by the middle of this century in case locations.

- **Passive measures for temperature control within shelters cannot reduce temperatures when ambient minima increase for extended periods.** Low-cost insulation and passive cooling techniques with high benefit-cost ratios are available to reduce but not fully address the impact of increases in peak daily temperatures. Projections for

Research indicates that design elements can substantially reduce the impacts of flooding and extreme storm events, but temperature changes appear more challenging.

Photo: Phong Tran, 2013

case locations in India and Pakistan suggest, however, that ambient minima (night lows) during the summer season and the overall daily heat index will increase above levels likely to have major impacts on health and productivity. These impacts increase significantly when people are exposed to high temperature levels over extended periods without access to breaks (lower-temperature periods at night) for recovery (Sabbag, 2013).

- **Increases in ambient temperatures may have major impacts on vulnerable groups, particularly women.** Vulnerability to increases in temperature is high among women, children, and the elderly. They are often confined to the house and have limited access to cooler locations. The health, productivity, and well-being of these and other poor and vulnerable groups may be affected, particularly in locations with high humidity levels. Sustained periods when minima increase above physiological recovery thresholds may, consequently, be as important as increases in peak daily temperatures. This is a critical area for future research.

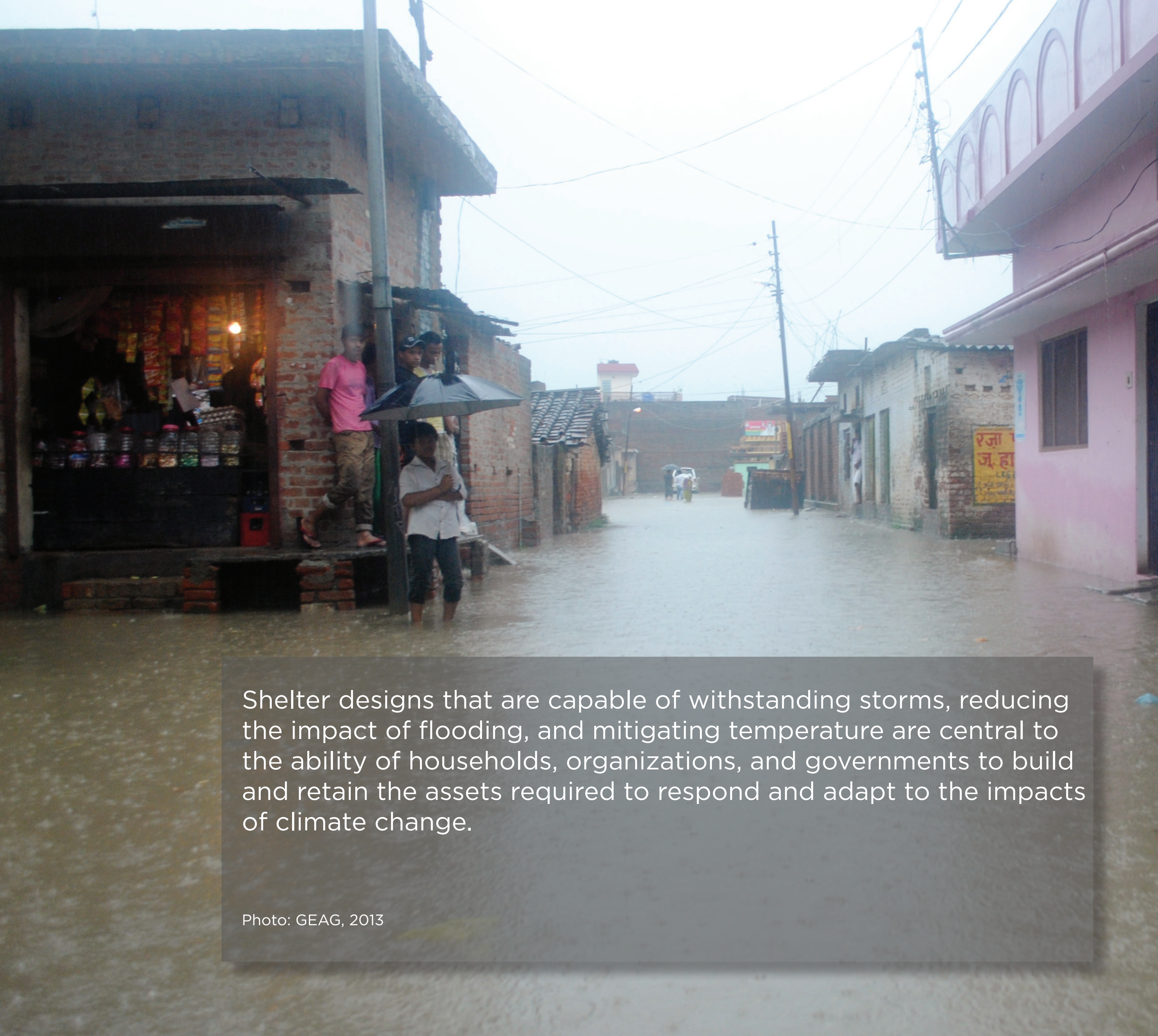
- **Active cooling measures will be essential in addressing the impacts of temperature increases on human health, productivity, and well-being.** Innovation to improve access to cooling either at the household level or in centralized locations accessible to all members of the community without increasing greenhouse gas emissions is another critical area for future research.

1. The Role of Shelter in Climate Resilience and Adaptation

Shelter accounts for the highest amount of monetary losses in climate related disasters (Comerio, 1997). Housing is often the single largest asset owned by individuals and families. It is also the location where other family-owned assets (tools, furniture, stored food, etc.) are concentrated and where many activities fundamental to livelihoods and education occur.

Resilient shelters are central to the adaptive capacity of most households. Adaptive capacity is the ability to retain and deploy assets to meet emerging needs as conditions change. Without such resources, individuals and households have limited options for adapting. While shelter design elements are important, design is only one aspect that contributes to resilient shelters; materials, training of builders, and use behavior are also central. Although such shelters may be technically feasible and economical, the private sector has little incentive to develop innovations for the poor and most vulnerable sectors. Information asymmetries among poor urbanizing households and masons who are the de facto architects and engineers of the structures and the technology available contributes to losses in extreme flood, storm, and temperature events. Shelters that reduce or avoid losses under current conditions enable families to retain and build the asset base required to respond to future conditions. Furthermore, because most housing is renewed at periods of 30 years or less (particularly in developing countries), designs that address current conditions and those anticipated over the short term can make a substantial contribution to the adaptive capacity of large population groups.

Recurrent costs for responding to natural disasters represent a significant drag on the ability of governments and other organizations to invest in adaptation and resilience at a societal level. Shelter designs that are capable of withstanding storms, reducing the impact of flooding, and mitigating temperature are central to the ability of households, organizations, and governments to build and retain the assets required to respond and adapt to the impacts of climate change. Recent evaluations of the impacts of climate change indicate that average temperatures may increase, including an increase in peak summer temperatures, and extreme rainfall events will increase in intensity, exacerbating flooding and water-logging issues (Amman & MacClune, 2014; Opitz-Stapleton & Hawley, 2013). Climate variability and the intensity (and possibly frequency) of extreme weather events (floods, storms, heat waves, and droughts) may increase globally, although there will be substantial regional variations.



Shelter designs that are capable of withstanding storms, reducing the impact of flooding, and mitigating temperature are central to the ability of households, organizations, and governments to build and retain the assets required to respond and adapt to the impacts of climate change.

Photo: GEAG, 2013

2. Research Methodology

In all locations, research to evaluate the costs and benefits of climate resilient housing utilized the Climate Resilience Framework (CRF; see Figure 1) to understand vulnerability and followed a similar cost-benefit methodological approach, which was adapted from the Risk to Resilience study (Mechler & the Risk to Resilience Study Team, 2008).

Using the CRF, the research team identified key agents and institutions in each country to understand their role in the shelter system and how climate change will shift vulnerabilities. The CRF enabled the research team to disaggregate considerations related to shelter design, the institutions that determine design acceptability and accessibility (cultural preferences, credit, and land tenure), and the role of different agents (home owners, builders and masons, architects, and developers). Using this background framework, the research team focused on the vulnerability of low-income home owners in peri-urban areas (areas just at the border of cities expected to become part of the urban boundary). These areas are growing particularly rapidly, have large marginalized and vulnerable populations, and are exposed to key hazards such as flooding, typhoons, and temperature increases. As a result, shelter design represents a strategic point of entry for addressing both current and future vulnerabilities.

In order to evaluate and build recognition of the importance of climate resilient shelter designs, the research focused on the identification of specific measures to build resilience through design competitions coupled with economic cost-benefit analysis. The choice of design for a house is a household decision, which depends on many individual factors, and the costs and benefits of including disaster-resistant features play a crucial role in decision making. The costs and benefits of such investments are also a central consideration in the allocation of funds by governments and international organizations. As a result, the research was designed to develop design and economic evidence of relevance at the household level and higher.

2.1 Cost-Benefit Analysis Methodology

The research on shelter design used climate-based probabilistic cost-benefit analysis at the household level. (Figure 2 illustrates the process.) Using historical data, we estimated the probability of asset losses (livelihood, shelter, and contents) in extreme storm and flood events under existing climate conditions. In the case of temperature, we focused on health and livelihood rather than asset losses. To reduce these losses, climate resilient measures can be adopted, which then result in a reduction in damages. Reductions in losses that could be achieved through changes in shelter design identified through the Resilient Housing Design Competition were then estimated under current climate conditions. These “avoided losses” represent the economic returns that would be generated if future conditions matched those experienced historically. Following this, available evidence on climate change was incorporated into an analysis of both the design elements and economic return. Overall, the approach was to investigate the damages associated with a typical house and the damages associated with a climate resilient house and identify future savings associated with implementing risk reduction under both current and projected conditions. (For further information related to quantitative cost-benefit analysis, visit http://training.i-s-e-t.org/module-series-3/)

FIGURE 1

THE CLIMATE RESILIENCE FRAMEWORK

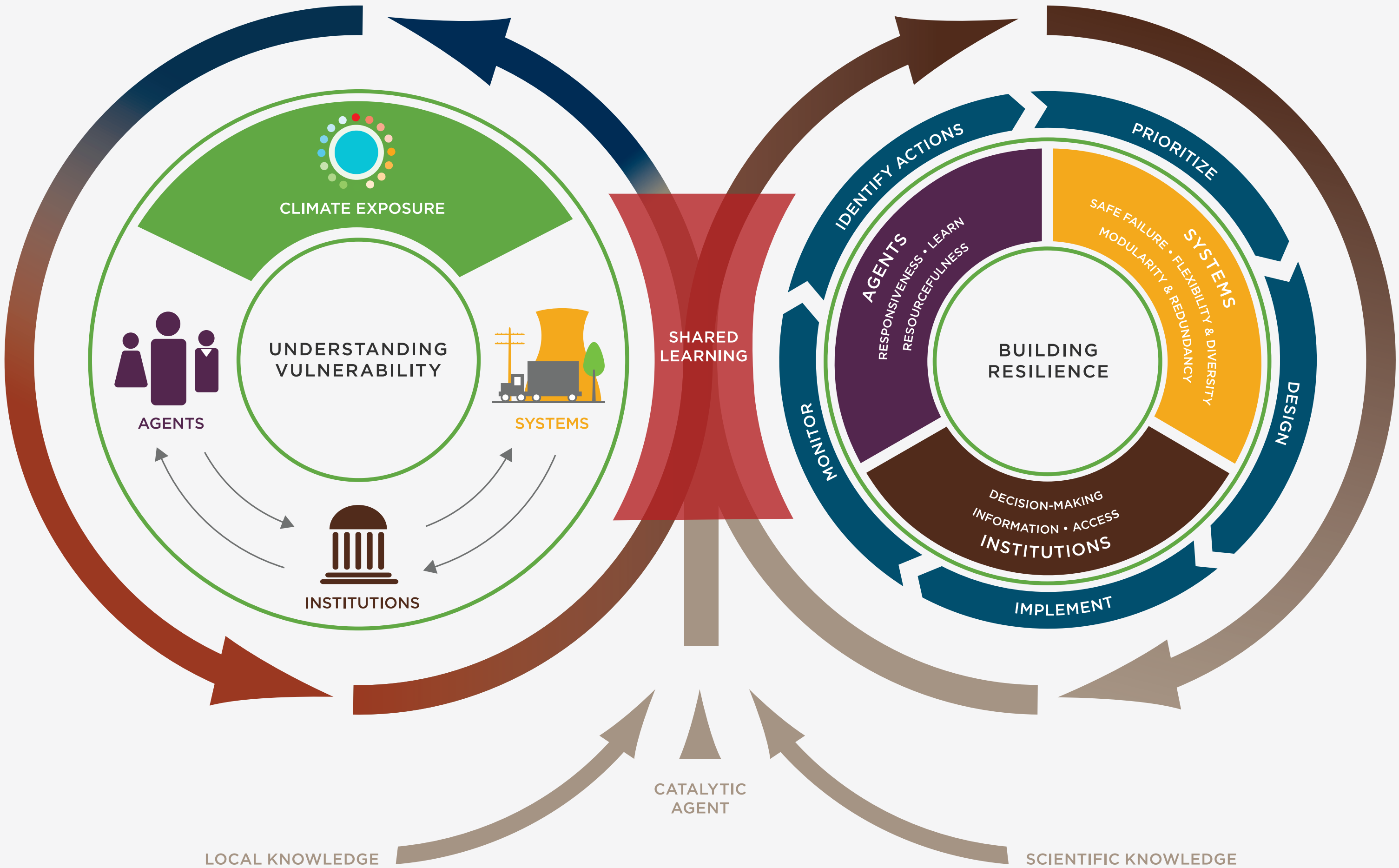
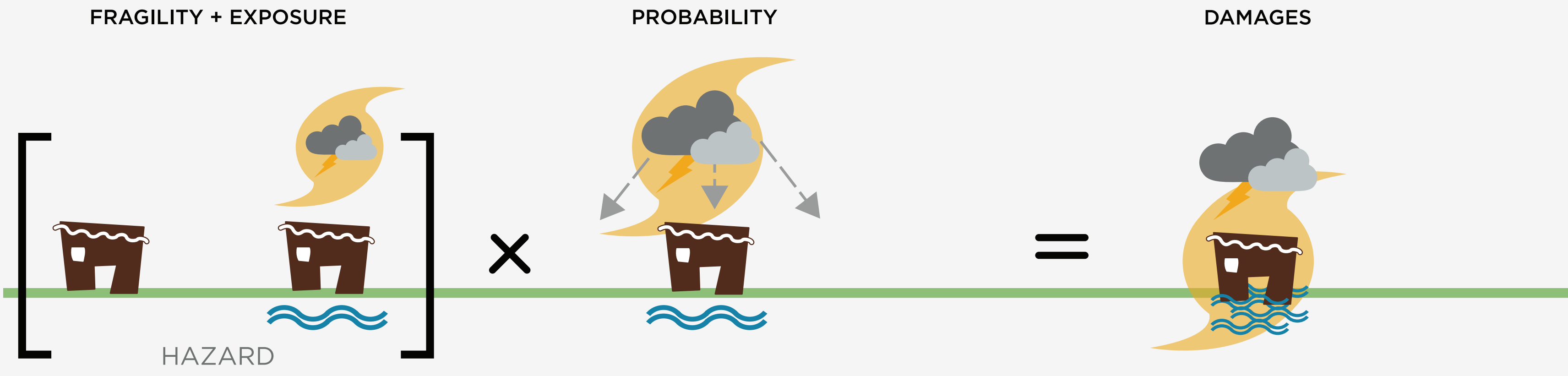


FIGURE 2

RISK REDUCTION FRAMING

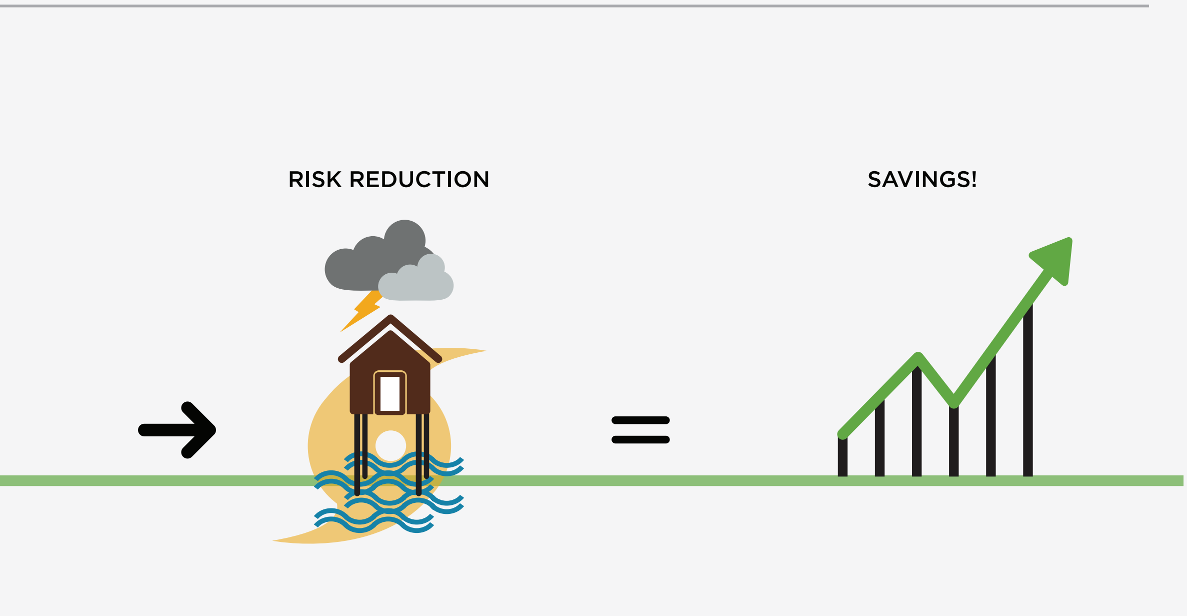
Illustration reflects the interactions at the individual shelter level.



FRAGILITY + EXPOSURE. Shelters belonging to low-income home owners are exposed to impacts from particular climate-related hazards—flooding, storms, and heat-related events. System fragility relates to the features of the shelter system (insulation, elevation above flood levels, susceptibility to storm damage, etc.) that cause losses when events occur. The value of losses relates to fixed asset losses (structural, household goods, etc.) and income losses or expense flows (income loss from inability to work, lost education, medical costs and care) when shelter systems fail.

HAZARD. We define hazard as the probability of an event occurring and the intensity of that event. Current hazard information is based on historical data regarding floods, storms, and other events. Future climate hazard data was obtained from climate change models. The models were used to identify likely scenarios regarding the probability of occurrence of various climate events and key hazards—flooding, typhoons, and high temperature.

DAMAGES (probability of loss). The combination of fragility, exposure and hazard characteristics determines the likelihood of disaster losses. Our research focused on investigating these losses at the household level. To accomplish this, secondary data on historical events, shared learning dialogue inputs from local communities and experts, and survey results were used to estimate losses due to historical disasters, as well as what losses might be in the future as the probability of extreme events changes as climate evolves. Shared learning techniques helped to identify key structural features and loss characteristics. This information, coupled with secondary data on events and officially recorded losses, was used to produce a baseline of loss probabilities. These probabilities were then projected for future conditions using climate information.



RISK REDUCTION. Risk reduction measures (new shelter designs resulting from the Resilient Housing Design Competition and housing retrofitting options) were identified and the costs estimated in the qualitative and quantitative steps of the research. For these analyses, we looked at the difference in costs between the conventional method and the resilient (or risk reduction) method of housing construction.

SAVINGS. Savings are achieved by changing the fragility of the shelter. The benefits of risk reduction measures are identified as the reduction in damages due to these measures and are shown by calculating the economic return, which is represented by net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR).

For further information related to quantitative cost-benefit analysis, visit http://training.i-s-e-t.org/module-series-3/

Definition of terms

Net Present Value (NPV)

The NPV takes the net benefits (benefits minus costs) each year and discounts them to their present day value. A result greater than 0 indicates that the benefits outweigh the costs. The higher the value, the stronger the financial argument for initiating a project. A project will have only one NPV number. A project can be ranked against the alternatives that also have positive or negative NPVs. The NPV is calculated to compare streams of income/savings or loss/damages across the lifetime of the investment. By putting the flow of costs and benefits in their present value we are able to compare costs and benefits along a temporal dimension.

Benefit-Cost Ratio (BCR)

The BCR indicates how much benefit will accrue for every $1 of cost. A ratio greater than 1 indicates that a project is worth investing in from a financial perspective; anything less than 1 indicates a negative return. Projects can also be ranked by BCR.

Internal Rate of Return (IRR)

The IRR is the rate of return used to measure and compare investment profitability. It is often used when determining economic efficiency and is expressed as a percentage. A project with higher rate of return over the investment period is preferred on economic basis.

3. SPECIAL SECTION:
Climate & Heat in India and Pakistan Case Sites

The broad regional story on climate change in South and South East Asia is well known. Climate change has significant implications for extreme flood, storm, and temperature events and may increase the intensity of extreme rainfall events. As a result, in many regions communities may experience longer periods of waterlogging and flooding by the 2050s. Where storm patterns are concerned, climate models are currently unable to accurately predict typhoons and other extreme storm occurrences. Results suggest, however, that intensities and frequencies may increase. Even without increases, extreme storms are currently a major cause of loss. As a result, there is great pressure on cities to build for resilience in the future. Recognition of these patterns serves as the basis for the case studies presented below for Vietnam and India. The story on heat is less well known and is central to the case study in Pakistan and the findings on temperature in India. As a result, this section focuses primarily on that.

The climate of South and Southeast Asia is dominated by the annual cycle of heating and cooling of the Asian continent and its associated evolution of the monsoon system. With the arrival of tropical moisture, the summer season turns from the relatively dry heat of the pre-monsoon months to a very humid heat, with monsoonal rains providing some relief from very high daily peak temperatures. Yet because of the high humidity, the effective heat remains high. Many of the poorest people in the region work outdoors or inside buildings with little active cooling, which can significantly reduce their productive capacity during high heat periods as basic human physiology forces them to rest. These people, presently on the margins of economic survival, rely on ambient cooling at night for a certain level of recovery. Projections of future climate conditions show that reliance on ambient cooling will increasingly become a losing strategy for the poor, taxing their productive capacity and requiring increased expenditure on cooling, health care, and other needs. Unless an inexpensive means for active cooling can be found for the poor, or they migrate away, future heat conditions will likely place many into a spiral of further poverty.

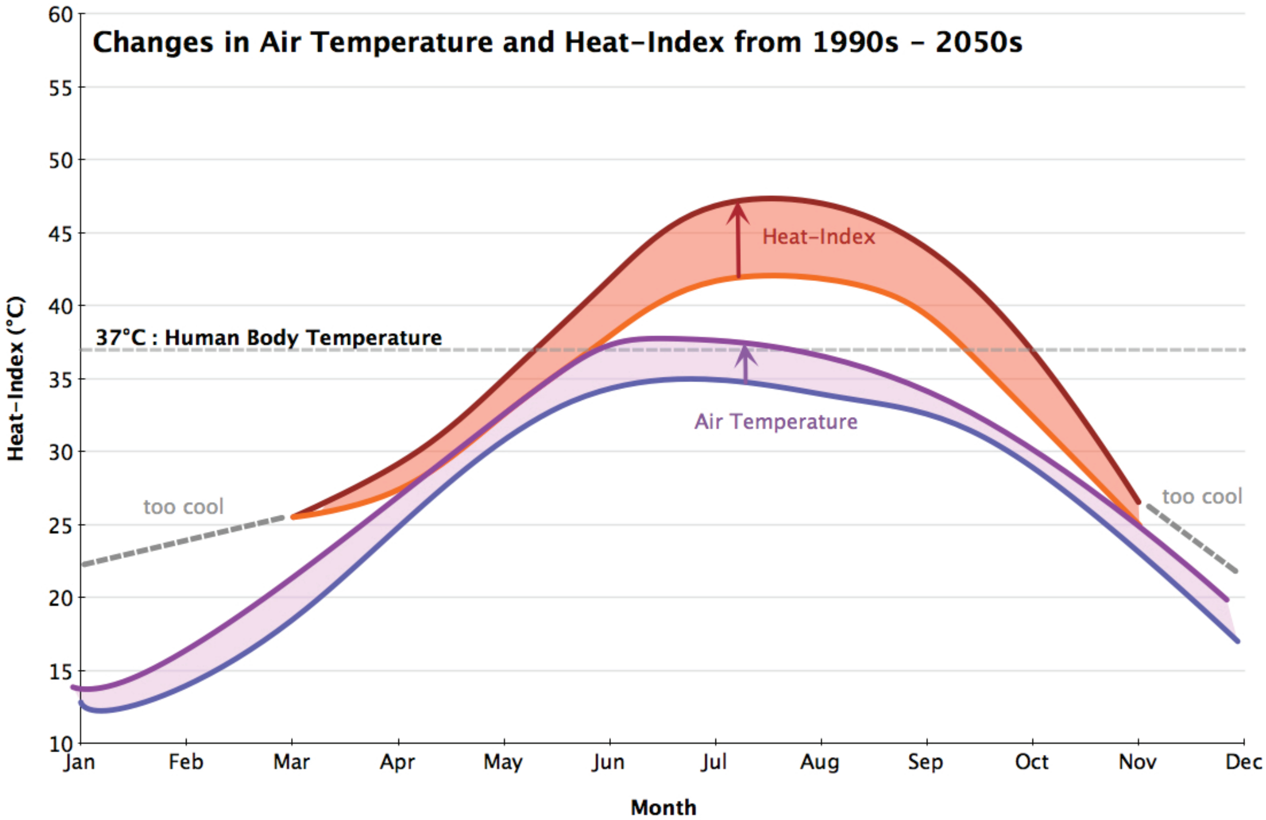
Projections of future temperatures under nearly all climate change scenarios[1] show continued warming through 2050 (Ammann & MacClune, 2014). For middle-range emission scenarios, both daytime-high temperatures as well as nighttime lows will continue on the recent upward trend. The expected temperature changes from 2000 to 2050 are 1.5°C–3°C (Ammann & MacClune, 2014), depending on the location and time of the year (see, for example, Figure 3 for Multan, Pakistan). The increase in temperature of about 2°C is surpassed by a projected change of more than 5°C in the heat index during the monsoon months. The ranges of variability during the peak months (right side of the graph) indicate uncertainty and variability.

1 The exception is the essentially unachievable situation where global greenhouse gas emission reductions start immediately.

FIGURE 3

DAILY MEANS FOR TEMPERATURE AND HEAT INDEX AS ANNUAL CYCLES IN MULTAN, PAKISTAN, WITH BOTH PRESENT AND FUTURE VALUES

Source: Ammann & MacClune, 2014.



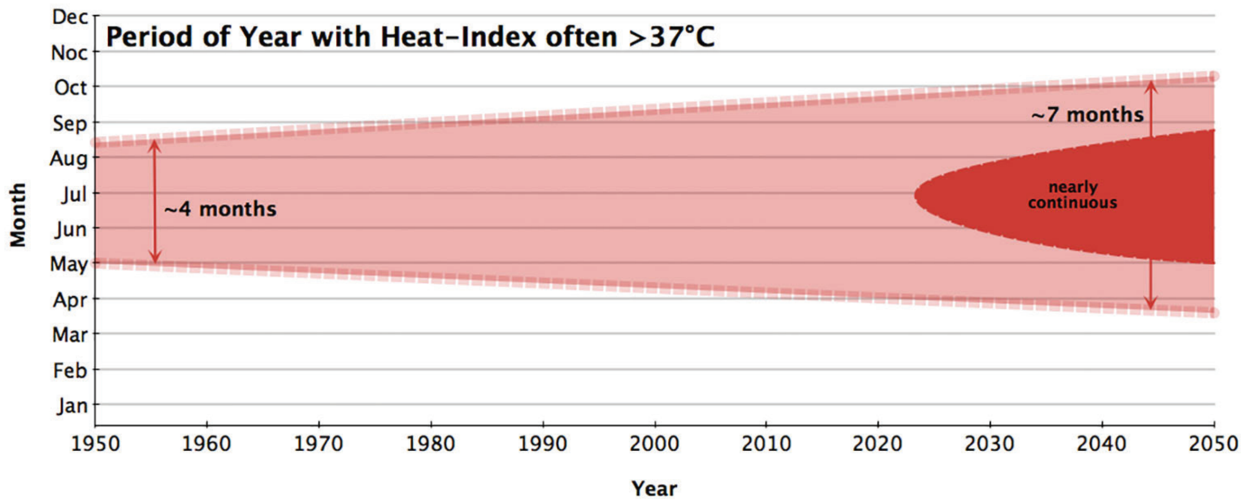
Heat Index Change 1990's–2050's

Air Temperature Change,
Day Time High 1990's–2050's

FIGURE 4

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

Note the expansion of the hot season from 4 months to 7 months and the new pattern of almost continuous exposure above the 37°C threshold. Similar patterns present in Pakistan sites.



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 from 25% of the year in the mid-20th century to nearly 60% of an average year by 2050 (see Figures 4 and 5). Similar patterns were also found in the Pakistan case sites.

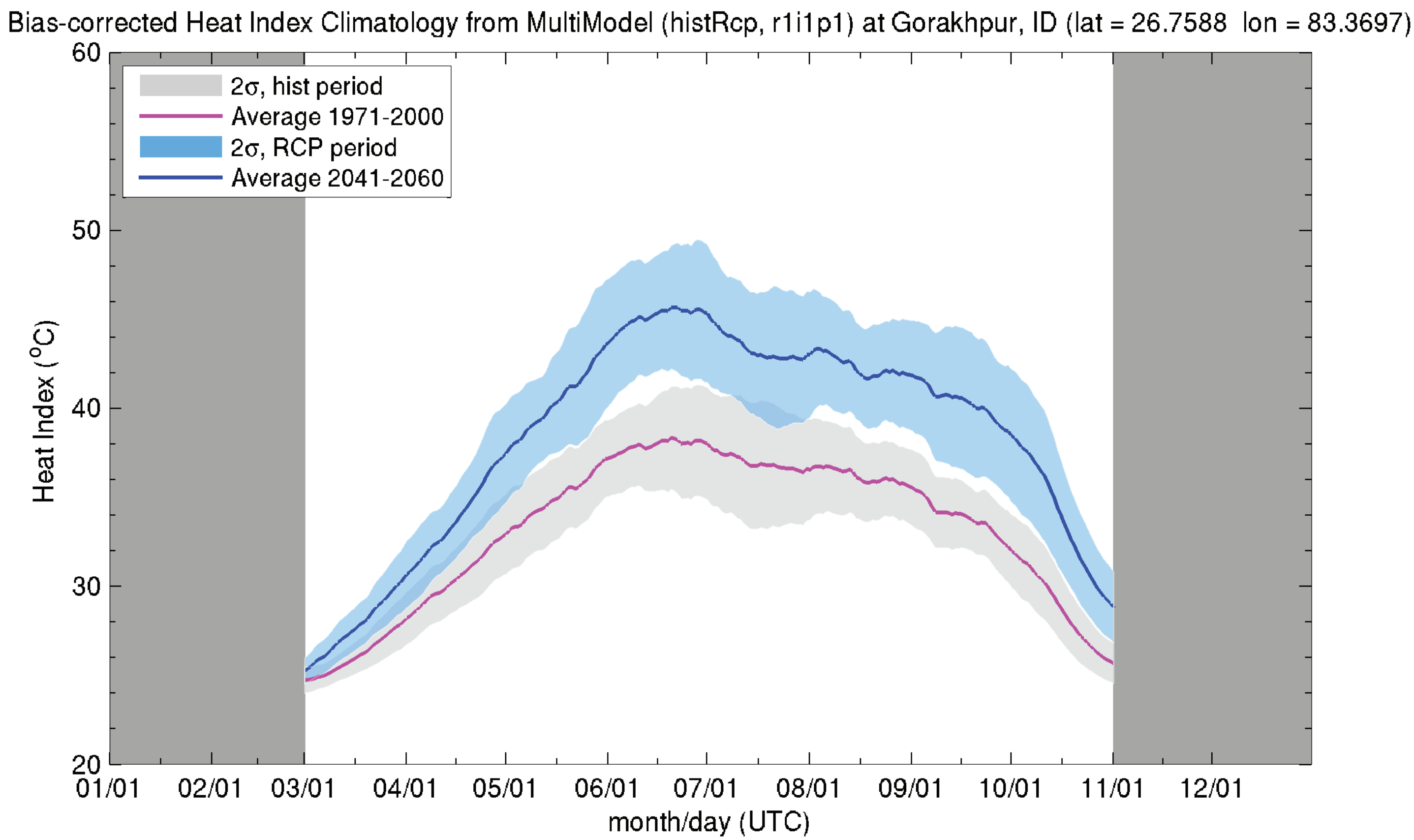
Though projections of future humidity are more uncertain than temperature, its correlation with monsoon phase suggests that on average the pattern of relative humidity with temperature will remain roughly the same. Projections show that the heat index will rise rapidly into the mid-century (Figure 8). In fact, the heat index increase is expected to be nearly twice as large (or greater) as the air temperature measured by thermometer. The expected 1.5°C–3°C increase in temperature will translate into a 5°C–7°C rise in the heat index.

In addition to an extended hot season, the expected changes in peak temperatures also raise concern. For example, for Gorakhpur, projections suggest that lengthy periods of high (35°C–44°C) and ultra-high (45°C–50°C) temperatures will become relentless as cooler recovery intervals become shorter and less frequent (Figure 9). Of particular concern will be the occurrence of increasingly uninterrupted periods with high heat index temperatures. Although climate model projections exhibit a deficiency in interannual and decadal variability, the warmest years in the mid-21st century will likely see nearly uninterrupted

FIGURE 5

GORAKHPUR ANNUAL CYCLE OF HEAT

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.



Lengthy periods of high nighttime temperatures, particularly with high humidity, are some of the most dangerous periods for human health. Such periods will increase substantially for many locations in South Asia in the future.

Photo: Atta ur Rehman Sheikh, ISET-Pakistan 2013 exceedance of what currently mark the most extreme days of even the hottest years, particularly from May through July. With prolonged episodes of nighttime heat index temperatures not falling to more comfortable levels, the citizens in the Gorakhpur area and the wider Gangetic Plain will need to find new ways of cooling.

Currently the impact of such high temperatures can be alleviated to some degree through reduced physical activity (rest during the period of the day with the highest temperatures) and shelter structural changes such as increased shade, reflective roofs, and good ventilation. These strategies for addressing daytime maximum temperatures are commonly used in regions with extremely high daily temperatures. Therefore the projected peak daytime temperature increases can at least be partially addressed through planning and policy actions that help to lower the barriers to accessing these strategies for the poor.

For the impact of increased nighttime heat, however, there are few measures in terms of current practice that can be used to address projected impacts. Though reflective roofs and good ventilation can reduce the daytime buildup of structural heat, projections show an increasing trend in the number of nights when the heat index temperature does not go below 37°C, and thus the use of ambient cooling will no longer be an effective strategy. Basements can be used as a refuge from the heat, but they are too costly for the poor, and in the flood-prone zones, where so many people currently live, they are maladaptive. Lengthy periods of high nighttime temperatures, particularly with high humidity, are therefore some of the most dangerous periods for human health. Such periods will increase substantially for many locations in South Asia in the future.

4. Key Findings From Study Locations

This study explored the costs and benefits of climate resilient housing designs in rapidly growing urban locations in Da Nang (Vietnam), Gorakhpur (India), and Rawalpindi, Faisalabad, and Multan (Pakistan). Each of these cities faces one or more key climate hazards that affect the livelihoods of poor and vulnerable populations. Da Nang sits along the central coastline of Vietnam, contoured by sea and mountains; storms bring typhoons and flooding to the area—significantly impacting the rapid urbanization of the city. Gorakhpur lies in the Terai, an inland, relatively flat zone between the Himalayas and the sea. The flat terrain combined with the two key river basins that cross through the city means that flooding has been a feature of life in Gorakhpur for centuries. However, with recent urban development the flooding and waterlogging have become a serious problem, as there is nowhere for the water to go. The three cities in Pakistan lie along a central transect of the country and illustrate the varying challenges that households face in peri-urban locations. These three cities are safe from riverine flooding but face major issues with increasing temperature and humidity, which promote the spread of disease and other health risks.

Detailed case studies for these three locations are available in print and online at i-s-e-t.org/SHELTER


TYPHOON
RESILIENCE
in Vietnam

3.1 TYPHOON RESILIENCE in Vietnam

The Story

Da Nang is the fifth-largest city in Vietnam and is experiencing rapid urban development. It is located on the south central coast and within the tropical storm belt, which results in annual catastrophes. The city is characterized by a sloping topography from west to east and has many mountain ranges, short rivers, deltas, and coastal areas that together create one of the most disaster-prone regions in Vietnam. Most residential houses in Da Nang have been built without technical guidance or instruction from professionals on disaster resistance (CECI, 2003), and as a result the housing sector is vulnerable to natural hazards.

Through the use of shared learning dialogues and surveys, we investigated the potential options for incorporating typhoon resilient features into housing construction. What we learned was that people have begun to use more durable and costly materials (e.g., cement blocks) instead of traditional materials (e.g., bamboo) in the construction of their homes. However, they are not employing appropriate construction techniques when adopting the new materials and are therefore creating new risks of disaster. An example would be a roofing system; under certain conditions, such as an earthquake, a modern roof system constructed of cement might collapse, causing much more harm relative to a traditional bamboo roof. Not only are these households located in high-risk zones, but more than 70% of their structures do not incorporate any form of typhoon or flood resistant features (Tran, Tran, & Anh 2014). Da Nang city experiences storms annually, but households experience the greatest losses during typhoons, which occur every 5 to 10 years. The ability of climate models to project the future frequency and intensity of typhoons varies, but most models show an increase in the intensity of heavy rainfall events. Such events contribute to flooding and infrastructure damage. Climate model uncertainty underscores the need for the city of Da Nang to plan flexible and resilient systems (Opitz-Stapleton & Hawley, 2013).

The shared learning dialogues with communities identified their preference for new construction over retrofitting current houses and set the research team on the path to investigate new designs for typhoon resilience. This resulted in the Resilient Housing Design Competition in Vietnam, where students and professionals submitted typhoon resilient designs for low-income households. Design innovations involved relatively simple measures, such as changes in roof design, an increase in wall thickness, the provision of a few cement wall supports, and a safe room. In addition to designing elements at the individual shelter level, the design competition winner identified key changes at the neighborhood level (nonparallel roads and building directions to disrupt wind tunnel effects) that could further reduce damages.[1] Furthermore, surveys of the target communities were completed to gather data on past damages associated with two catastrophic typhoons: Xangsane in 2006 and Ketsana in 2009. This information enabled the research team to investigate the economic returns of typhoon resilient shelters. (For more information on the resilient features and design criteria of the Resilient Housing Design Competition.)

1 The cost-benefit analysis was completed on a per household basis; neighborhood wind reduction impacts were not taken into consideration.

October 15, 2013
244 Beneficiary Households Safe From Typhoon Nari's Force

On October 15, 2013, typhoon Nari (typhoon no. 11) landed in Da Nang city at dawn with level-12 winds and level-13 gusts, equivalent to 130 kph. Persistent storm winds coupled with heavy rainfall led to flooding in many areas of the city, especially in Hoa Vang and Son Tra districts. The typhoon caused severe damage: many people were injured, thousands of houses were destroyed or had roofs blown off, and tens of thousands of trees either snapped at their trunks or were uprooted by the severe winds, which led to severe traffic congestion. On October 16, 2013, the day after the typhoon ended, ISET-Vietnam and the Da Nang Women's Union conducted an assessment of damages and the resilience capacity of beneficiary wards in the storm resistant housing project. We were pleased to find no damage to any of our 244 beneficiary households. The Da Nang Women's Union project adopted key principles of resilience from the Resilient Housing Design Competition and put them into practice.

Photo: Phong Tran, October 15, 2013

RESILIENT HOUSING
DESIGN COMPETITION
2013

The designs below comprise the winning entry in the Resilient Housing Design Competition 2013 submitted by TT-Arch Company of Vietnam.

For more information on the resilient features and design criteria, please visit i-s-e-t.org/SHELTER.

The Returns

Base case scenarios for investments in resilient housing assume that the frequency and intensity of typhoons will remain similar to the past 25 years, utilize a discount rate of 10%, and assume that the probability of a typhoon occurring in any given year is equally distributed. These factors result in a BCR of 1.93, with an IRR of 11%. If typhoon frequency were to double in the next 25 years, the BCR would increase to 2.36, with a 16% IRR. These estimates are based on a scenario where a house is completely rebuilt rather than retrofitted, as this scenario better reflects the rapid turnover and reconstruction of housing stock in Vietnam's rapidly growing urban areas.

The actual returns that any given household will accrue from rebuilding using climate resilient designs depend heavily on when typhoons take place during the time period evaluated. In the early case, when typhoons occur early in a shelter's life span (e.g., the first year following construction), the BCR is 3.15 with climate change not considered and 3.82 with climate change considered (Figure 6). The break-even point for investments is approximately 17 years, after which the economic returns become negative. In the late case, if a typhoon occurs only in the last year of the building's life span, the BCR would be 0.50, with projected returns increasing when climate change is considered, unless typhoon intensity exceeds design specifications.2[2] Therefore if the homeowner expects a return period of less than 17 years, s/he will invest in resilience measures. Neither scientists nor homeowners can be certain that events will occur within this period, but recent history indicates such a trend.

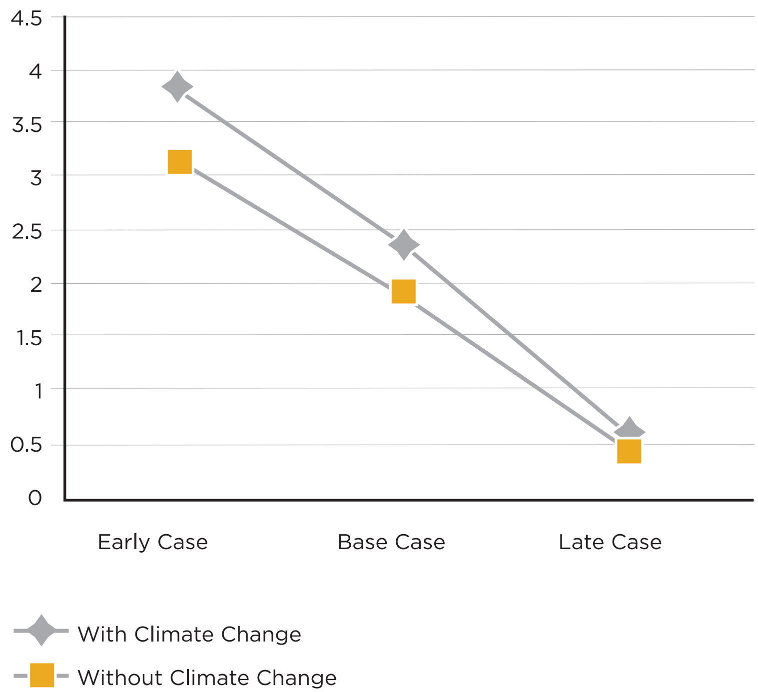
Making Change

In addition to the research, ISET-International supported the Da Nang Women's Union in providing credit for the retrofitting of 245 low-income houses using storm resilient design elements. All but one of these houses had been completely retrofitted by the time typhoon Nari hit the city on October 15, 2013. Excluding

2 Design specifications indicate a Category 12 typhoon as the housing construction standard.

FIGURE 6

COMPARISON OF THE ECONOMIC RETURNS WITH AND WITHOUT CLIMATE CHANGE IN DA NANG, VIETNAM



the incomplete house, none of the retrofitted houses were damaged by the typhoon, in contrast to over 11% of the housing stock across the city in the same income category that did suffer damage (Tran, 2013). In many cases, retrofitted houses were directly adjacent to non-retrofitted houses that collapsed or were damaged. This pilot project illustrates the importance of providing finance opportunities for low- and middle-income households to build resilience.

Definition of terms

Discount Rate

To interpret CBA results one must pay attention to the discount rate that is used to combine all income (benefit) and cost streams in the project life into a single number in the present. The discount rate allows us to compare benefits (or costs) in the future with benefits (or costs) in the present. The discount rate is basically the return one might expect if the same money was invested in an alternative project or put in a bank. For example, if we put money in a bank with an interest rate of 10% per annum, a $100 investment would become $110 in the next year. Thus getting a benefit of $100 this year is better than receiving $100 next year because we have the ability to generate 10% income from it in the meantime. Therefore, we can say that if we were to get a benefit of $110 next year, it would be worth $100 in the present, if we applied a discount rate of 10% per annum to it. In this analysis, we have chosen to use a social discount rate because disaster risk reduction is not necessarily a commercial investment and it creates public benefits. Social discount rates represent the returns (in percentage per annum) on other similar interventions, such as in say public health or education, and represent the current value of income streams versus foregoing public good-related investment.

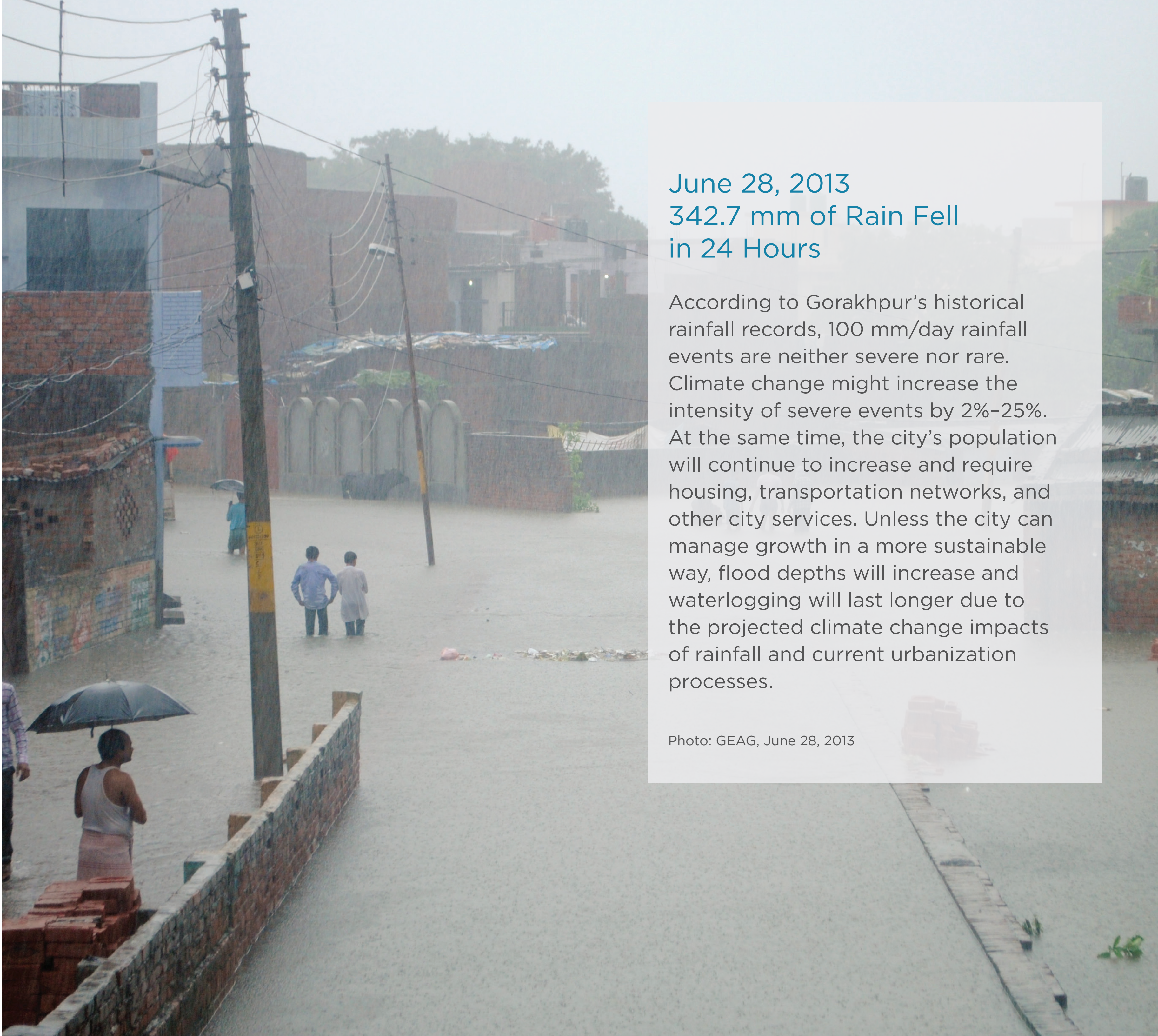
3.2 **FLOOD RESILIENCE**
in India

The Story

Flooding and inundation are century-old problems in Gorakhpur. The city is located in eastern India in the state of Uttar Pradesh, in the mid-Gangetic Plains between the Rapti and Rohini river basins. Gorakhpur is a rapidly growing city with many migrants and relatively low levels of urban service delivery compared to other Indian cities. Due to Gorakhpur's geophysical characteristics, flooding in peri-urban areas (outside of the embankments) and water-logging in the city's core areas have emerged as major problems/risks facing inhabitants. Climate change is projected to increase the intensity of small and large rain events, as well as flooding and water-logging issues within the city (Opitz-Stapleton & Hawley, 2013). Housing practices are changing in Gorakhpur, and predominantly modern (*pucca*) houses are being built. In peri-urban areas, there is a slow shift from traditional (*kuchha*) to modern (i.e., concrete) *pucca* housing construction. However, many of these more modern houses are being built without design considerations or regulation, resulting in houses that remain vulnerable to floods.

Shared learning dialogues in three Gorakhpur villages documented a large number of measures that have been adopted by households to reduce flood losses. These measures range from very low cost, such as the installation of a hook on the ceiling to hold possessions above flood level, to significant structural changes, such as raising plinth levels (elevated foundations). Many households have already adopted such measures, and qualitative evaluations of their costs and benefits in shared learning dialogue meetings support the positive perception of their value. Most new housing is constructed with plinths that are positioned above historical flood levels, particularly the major flood that occurred in 1998. In many cases this position is 1–2 m above current ground level (in some cases it is more); this work adds, according to local residents, as much as 30% to the cost of construction. Flood resilient materials, such as brick and cement, are now widely used, in contrast to traditional mud construction techniques. Given the high cost of materials and certain construction measures, such as raising plinths, affordability is a major factor that limits access to resilient housing, particularly in poor and marginalized communities.

Climate projections for the Gorakhpur region suggest that large-scale events may increase in intensity, possibly by as much as 25% (Opitz-Stapleton & Hawley, 2013). Except where floodwaters are blocked from spreading, these events are unlikely to result in flood depths that are substantially greater than historical levels due to the flat nature of the terrain. Events that reach historical depth levels are, however, likely to become more frequent. Furthermore, if development occurs in a manner that confines water and limits its flow path (e.g., through extensive construction of elevated areas, roads, and dikes), both depths and flow rates could increase significantly at the local level. Depth-damage curves developed on the basis of historical data, shared learning dialogues, and surveys indicate that asset and structural losses dominate at water depths of less than 1 m within a house (approximately 3 ft). Over 50% of all losses are incurred when water enters a house and rises to a depth of approximately 0.6 m (2 ft). Indirect losses (due to lost working days, etc.) are a relatively minor component of total losses.



June 28, 2013
342.7 mm of Rain Fell in 24 Hours

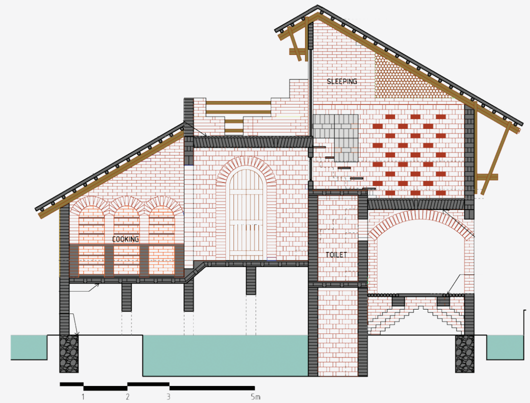
According to Gorakhpur's historical rainfall records, 100 mm/day rainfall events are neither severe nor rare. Climate change might increase the intensity of severe events by 2%–25%. At the same time, the city's population will continue to increase and require housing, transportation networks, and other city services. Unless the city can manage growth in a more sustainable way, flood depths will increase and waterlogging will last longer due to the projected climate change impacts of rainfall and current urbanization processes.

Photo: GEAG, June 28, 2013

RESILIENT HOUSING
DESIGN COMPETITION
2013

The design below is the winning entry of the Resilient Housing Design Competition 2013 submitted by Mad(e) in Mumbai.

For more information on the resilient features and design criteria, please visit i-s-e-t.org/SHELTER.



The Housing Types

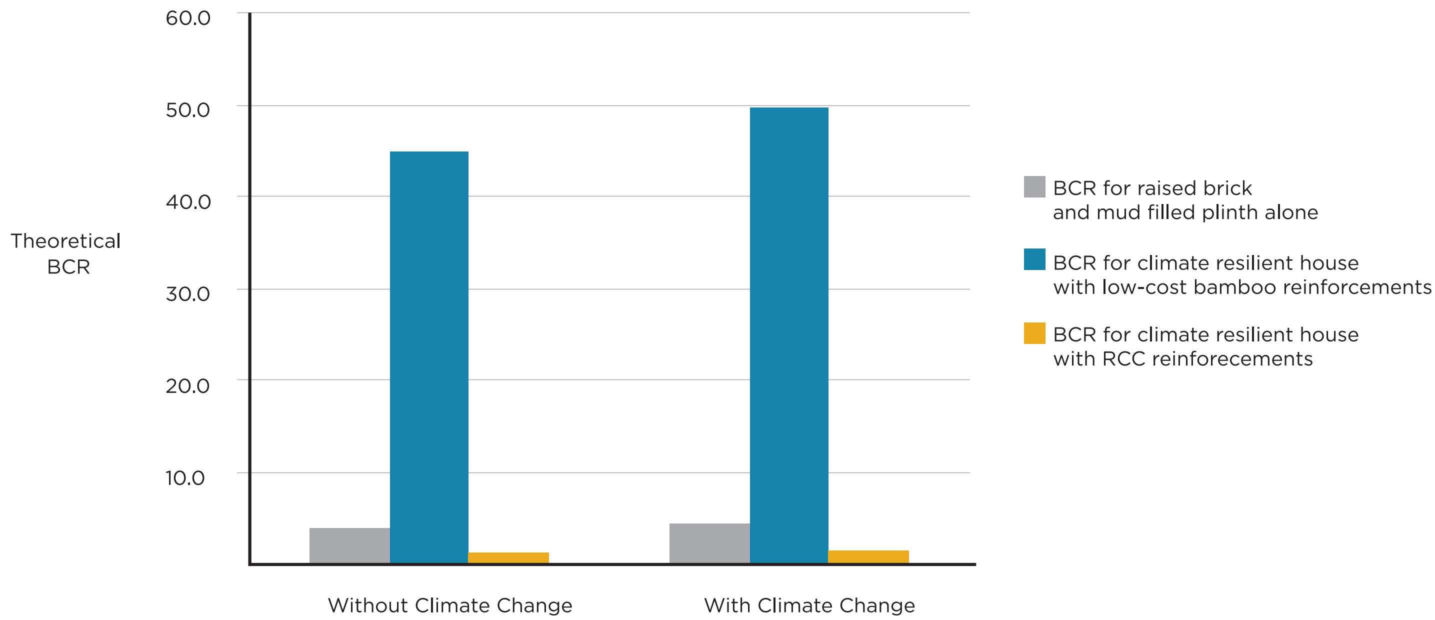
Results from the Resilient Housing Design Competition indicate that houses that incorporate key flood resilient features and use low-cost innovative materials can be constructed at lower costs than conventional techniques, yet still be highly livable shelters. For more information on the resilient features and design criteria, please see the Resilient Housing Design Competition.

The Returns

We investigated the 1) the additional cost of construction of a climate resilient house (winning professional design) with bamboo and with reinforced concrete cement components (RCC) compared to the cost of construction of a typical, *pucca* (well constructed) house, and 2) the cost of raising a plinth with brick walls and mud fill compared to not raising a plinth (which is typical risk reduction measure of low-income home owners in Gorakhpur). Probabilistic cost-benefit analysis for the climate resilient design constructed using low-cost innovative materials, with a discount rate of 12%, produced a theoretical BCR of 44.7 with bamboo reinforcements and 1.2 with RCC reinforcements under current conditions, and higher with climate change. Like the Da Nang case, the climate models project increases in potential rainfall, and our results incorporate these future climate impacts. Most of the reduction in losses comes from raising the plinth level above projected flood levels so that water never enters the house and there is no damage to household assets. Evaluation of plinth levels in relation to potential future flood depths suggests that except where drainage is blocked, raising plinths to levels sufficient to protect assets in large-scale historical floods will protect them over the 30-year lifetime considered here. The BCR ratio for plinth levels without and with climate change resulted in 3.7 and 4.4, respectively. The critical role of drainage is important to recognize, however. Current construction practices generally involve the use of soil to fill the space beneath plinths. When done over large areas, this blocks drainage and confines floods to the remaining open areas, thereby increasing both depth and flow rate. In contrast, the climate resilient design does not block the flow of water

FIGURE 7

ECONOMIC RETURNS OF CLIMATE RESILIENT FEATURES IN GORAKHPUR, INDIA



(e.g., through the use of pillars to raise housing levels). Such design considerations are likely to be important in areas where construction is dense. (See Figure 7.)

Making Change

Access to flood resilient housing is limited by (a) knowledge and acceptance of innovative techniques and (b) access to financing. Because some techniques for the construction of flood resilient housing are actually less expensive than conventional construction techniques, training masons (the main builders of low-income housing in Gorakhpur), increasing awareness, and actively promoting such techniques could result in their being widely adopted by vulnerable communities without additional support. For the poorest groups, however, affordability of any housing, along with access to land, is a major impediment. Affordability is even more of an issue if the use of innovative materials proves culturally unacceptable. As a result, programs such as the one in Da Nang that provide low-cost credit for resilient housing could be a major policy avenue for improving access and reducing the disaster damage compensation burden on public funds.

It is important to note that while shelter design can reduce losses significantly, as in the Da Nang case, the ability to fully mitigate flood impacts depends heavily on conditions at the neighborhood and city levels. Lack of drainage, allocation of space for water flow, and high levels of pollution, including the presence of raw sewage, have major impacts on health and the economic productivity of households and the city as a whole. These issues cannot be addressed by changes at the level of individual shelters. As a result, while policies that support climate resilient shelters are important, these other matters could be addressed by improvements in drainage and sanitation at the neighborhood and city levels.

3.3 TEMPERATURE RESILIENCE
in Pakistan

The Story

Pakistan is experiencing a considerable increase in temperatures. Heat wave events are a major cause of weather-related morbidity and mortality in Pakistan (Chaudhry, Mahmood, Rasul, & Afzaal, 2009). Rawalpindi (at the foot of the Hindu Kush mountain range), Faisalabad (central plains), and Multan (hot desert) represent a range of conditions in Pakistan and rank among the top five most populous cities in the province of Punjab. In all of these locations, increases in temperature are a central concern. Summer peak temperatures of 50°C in Multan have been officially recorded. Even Rawalpindi, at the base of the mountains, has recorded temperatures in excess of 46°C. A large number of communities in these cities are characterized as low income, are located in the peri-urban areas, and are relatively newly developed (15–20 years). They are, therefore, fairly representative of current trends in urban construction growth. Most houses do not have adequate ventilation or temperature reduction features integrated into their designs, which makes them vulnerable to future heat extremes and the associated health impacts (Khan, Malik & Rehman, 2014). Research in Pakistan focused on low-income households residing in informal settlements in Rawalpindi, Faisalabad, and Multan. These sites offer a continuum of temperature zones of 5°C, which is in the range of the predicted global warming in the current century.

The settlements are often well established, with brick and reinforced concrete houses, but because they are outside municipal boundaries they are considered a rural *tehsil* and do not require design approval, pay property and other municipal taxes, or receive basic services. In addition, some households illegally inhabit government land and cannot access services formally without showing ownership, that is, *katchi abaadi*, where *katchi* denotes the ownership status and not the construction type.

Among settlement residents, high temperatures were among the most important climate-related concerns regularly expressed in household-level surveys and shared learning dialogues. Interestingly, in the two sites in Rawalpindi, a significant gender difference exists with regard to the relative importance of temperature. In shared learning meetings, women consistently highlighted temperature as either their first or second concern. This difference appears to be related to mobility and the locations where women and men spend the majority of their time. Women, who tend to spend the majority of their time at home, highlighted the lack of shade, high temperatures, and poor electricity supply within houses and their small compounds. They also highlighted the inability to ventilate houses and cool them both during the day and at night due to poor sanitary conditions in the neighborhood. As a result, houses tend to be sealed, and at night people remain inside rather than sleep on the roof or in the open (a common strategy in rural areas) to limit exposure. Women, the elderly, and children tend to remain in locations where there is little relief from high temperatures throughout the day. Men also face the same conditions as women at night. However, they spend the majority of the day working in the city. Although exposed to high temperatures, they are also often in locations

2013

Heat waves in 2013 devastated Pakistan, as scorching temperatures impacted the country, claiming hundreds of lives and damaging crops. Temperature maxima hit 51°C, and new records were set in parts of the country (Vidal & Sethna, 2013).

Photo: Atta ur Rehman, ISET-Pakistan

where they can access shade, breezes, and other sources of cooling. Therefore, in Faisalabad and Multan, where daytime temperatures in summer are very high and men typically work outside in construction or other forms of manual labor, men rated heat as a major problem, above the level indicated by women in the same areas. In this situation, women rated the quantity and lack of quality of water, as well as communicable diseases, as greater hazards than heat.

Temperatures in the northern cities of Pakistan will increase markedly over the coming decades. Temperature maxima during the hot season are expected to increase by 2°C–2.5°C, while temperature minima are expected to increase by 2.5°C–3°C. Episodes of continuous heat—consecutive days with both high maximum and minimum temperatures—are also projected to increase significantly. Projections show that heat-related impacts on people and infrastructure will start earlier in the year, be more intense throughout the summer, and last longer in the fall. The effects of temperature increases will be particularly severe during periods such as the monsoon, when humidity is also high. In such situations, the heat index (a combined measure of temperature and humidity that indicates the effective temperature in relation to the body's cooling ability) will be significantly higher than the actual recorded temperature.

Projected increases in the heat index for case locations in both Gorakhpur (India) and Pakistan, along with the challenges they present, are outlined in the special section titled: "SPECIAL SECTION: Climate Heat in India and Pakistan Case Sites." While the impacts of rising daily maximum temperatures can be somewhat addressed through various strategies such as providing shade, it is particularly the increase in consecutive nights with very high minimum temperatures and humidity that are of concern. Nighttime temperatures exceeding 32°C with high levels of humidity are expected to more than double in the coming 3 to 4 decades. The loss of overnight respite that the projections show will affect how well the human body can recover from daytime heat exposure and thus will affect people's health and productivity. With few resources, a poor infrastructure, and an inconsistent electrical supply, the poor will struggle to adapt as the need for active cooling increases. These impacts may affect women in particular due to cultural norms and the sanitation issues that limit cross-ventilation in houses.

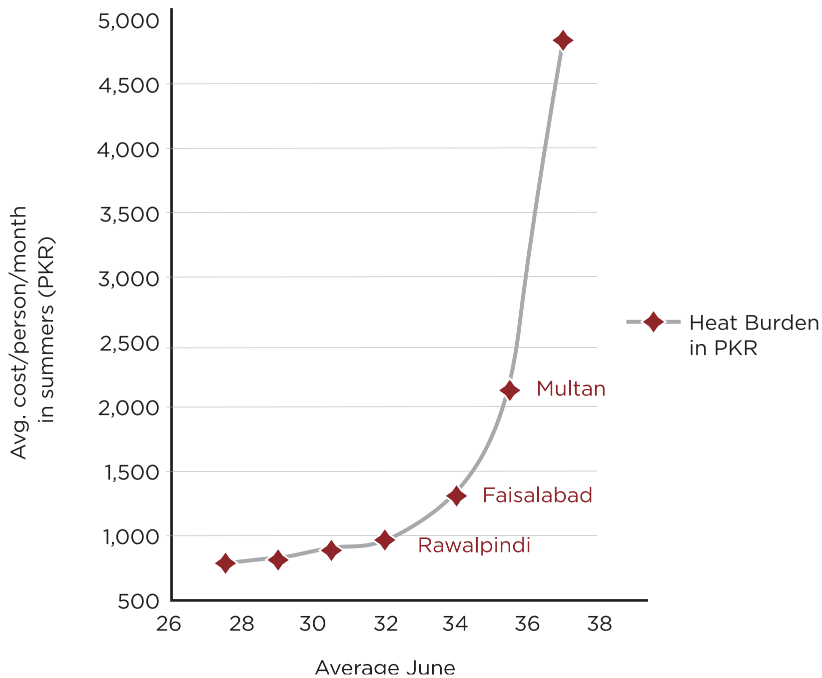
The potential economic magnitude of temperature impacts is important to recognize. In contrast to the more ethically sound "disability adjusted life years" (DALYs) which represent health burden in a way that is unaffected by wealth, the actual expenditure from disposable income is important to assess in order to determine whether the heat-vulnerable population can afford to protect itself from the projected climate change impacts without external support. Information on what people currently spend to address temperature impacts was collected through household surveys. The results in the research locations followed the J-curve pattern that has been documented elsewhere. Owing to the adaptation mechanisms of human physiology and the availability of systems and services that support the livelihoods of our growing and urbanizing sector of society, the economic burden on each person and household caused by health and other heat-associated costs commonly follows a J-curve (McMichael, Haines, Slooff, & Kovats, 1996). In public health literature, this trend highlights a disproportionate impact per unit increase (or even decrease beyond a certain limit) in temperature. In simpler terms, the impact of temperature rises exponentially when people move out of the temperature zones that the human body has evolved to adapt to.

As Figure 8 illustrates, results in the Pakistan case locations follow the J-curve pattern. For example, at an average temperature of 32.5°C in June (common in Rawalpindi), the heat burden per person would amount to 845 Pakistani rupees (PKR) per month and translate to PKR 7,600 for a family of nine. At a mean maximum temperature of 35.5°C in June (the level recorded in Multan), the burden doubles to an average of PKR 15,000 per month per household for the 6 months of summer. These heat-related costs constitute 25%–50% of the annual income of the households in our sample, whose earnings are PKR 15,000–30,000 per month.

FIGURE 8

HEAT BURDEN PER PERSON IN PAKISTANI RUPEES (PKR)

Data compiled from different case cities.



Temperature Risk Reduction Options

Research on shelter design highlights numerous passive measures for reducing the impact of peak daily temperatures on in-house conditions. These measures primarily involve increasing shading and reflectivity and improving insulation. Improvements in ventilation would also improve conditions greatly but would require concurrent improvements in overall sanitation within neighborhoods. Importantly, none of the interventions identified can address the impact of extended high ambient temperature minima, nor can they prevent the damage done to human health in terms of an increase of communicable diseases due to poor water, sanitation, and drainage planning and infrastructure. Insulation, shading, and similar interventions can ensure that temperatures inside houses remain well below daytime peak temperatures. These measures cannot, however, reduce temperatures below nighttime minima, particularly when they remain high for extended periods, nor can they reduce heat stress on people who work in the open during the daytime.

UN-HABITAT tested more than 20 options for reducing heat in buildings in Islamabad. The five most cost-effective options are shown in Table 1 (UN-HABITAT, 2010).

Cost-benefit analysis of these five interventions show that they are cost-effective only in Multan because the heat burden reduction outweighs the cost only in areas where the heat burden is already high (see Table 2). If the predicted increases in temperature due to climate change are taken into consideration, returns are higher and become positive (above a BCR of 1) for Faisalabad as well as Multan. However, it is not the efficacy of the technology but rather the immediacy of the climate-related economic burden that makes the ratios more favorable.

Making Change

Based on the data charted in Tables 1 and 2, most of the options tested are still beyond the reach of low-income groups. Only the most cost-effective measures are viable on a purely economic basis in Multan (and sometimes in Faisalabad). These measures are cost-effective because of the high heat burden that the population in these areas is already exposed to. The actual heat burden is much higher but cannot be accurately recorded; for instance, oftentimes illnesses are not treated due to lack of financial resources among low-income groups.

Most of the currently available technologies considered in this analysis are commercially available and already being adopted by higher income groups. More research needs to be done to identify and test options that are more accessible and affordable for lower income groups, as these groups represent the fastest growing segment of the society and face the largest risks.

TABLE 1
THE FIVE MOST COST-EFFECTIVE OPTIONS FOR REDUCING HEAT STRESS UNDER CURRENT CONDITIONS

	Time of day 6:00am	Time of day 3:00pm	6:00am Δ T (inside-outside temp. difference)	3:00pm Δ T (inside-outside temp. difference)	
Outside temperature °C	29.1	41	Inside-outside temp. difference	Inside-outside temp. difference	
Inside temperature (control) °C	32.6	36.2	-3.50	4.8	
Intervention	**Inside Temp.**	**Inside Temp.**	**Difference from Control**	**Difference from Control**	**Ranked cost per square foot (PKR/°C, Tmax[a] and Tmin[b] combined, 30 yrs NPV @ 18% interest)**
Lime wash on roof	31	33.1	1.6	3.1	6.50
Paper board false ceiling	30.2	32.2	2.4	4	7.47
White enamel paint on roof	30	33.1	2.6	3.1	7.74
Thermo pole false ceiling	29.5	34.4	3.1	1.8	9.25
Weather shield paint (white) on roof	30.8	33.7	1.8	2.5	11.5

TABLE 2

RETURNS ON INVESTMENT (AS A BCR) IN TEMPERATURE REDUCTIONS IN CURRENT CONDITIONS AND FUTURE CONDITIONS (2050)

			Current conditions		Climate change in 2050	
Discount rate			12%	18%	12%	18%
Feroz Colony	Multan	Benefit-Cost Ratio	2.1	1.9	9.1	8.2
Rehmanabad	Faisalabad		0.6	0.5	11.7	10.5
Habib Colony	Rawalpindi		0.1	0.1	0.5	0.5

At the same time, training and awareness building among local masons and contractors are key avenues for the integration of climate resilient principles in housing construction, as most houses are being built incrementally by local masons without regulatory supervision. Improvements in reflectivity, shading, insulation, and ventilation will result in reductions in heat absorption and can reduce the impact of increases in peak daytime temperatures. It is important to note, however, that increases in ambient temperature minima pose fundamental challenges. In the absence of active cooling methods (i.e., air-conditioning), there are few immediately evident avenues for reducing the economic and physical impact of sustained increases in ambient temperatures, particularly nighttime minima.

Air-conditioning is unaffordable for the majority of households and requires reliable access to electricity. As a result, relying on active cooling for individual houses with currently available technology is infeasible. Furthermore, reliance on air-conditioning increases energy demand and complicates efforts to reduce the greenhouse gas (GHG) emissions driving climate change. Unless low GHG–emission energy sources are implemented on a very large scale, reliance on air-conditioning is maladaptive. The impact of improvement in housing structures will affect everyone but will be particularly high on women, children, the elderly, and other people whose mobility is limited and who spend large amounts of time in poorly ventilated brick houses.

5. CONCLUSIONS

Designs that reduce the impacts of storms, floods, and temperatures on housing, particularly that owned by poor and marginalized communities in rapidly developing urban areas, represent a powerful point of entry for supporting adaptation and building resilience. By reducing the recurrent losses associated with large-scale hydro-meteorological events, such measures enable people to retain and build assets. This can contribute substantially to breaking the cycle of poverty and disaster while also enabling households to accumulate the resources required to invest in new strategies as climate and other conditions evolve. This will be of most importance to those who have access to land and can afford the cost of housing construction. However, while these measures benefit the poor and near-poor, they do not address the needs of the landless or other extremely vulnerable populations.

Though the specific measures that are appropriate in any given situation will depend on the type of flooding or storms likely to occur and the timing of their occurrence, resilient design components and the overall designs developed under the Resilient Housing Design Competitions have high BCRs and IRRs. This is true for both current and projected climate conditions. As a result, investments to increase the climate resilience of shelter systems are likely to generate high economic returns. While wealthy populations often make such investments themselves, poorer communities lack the resources required. Thus strategies that provide technical support and access to sources of financing to poor and marginalized groups represent a key avenue for governments and international organizations to reduce disaster losses, support resilience, and build adaptive capacity.

While investments in shelter design at the household level generate substantial returns, these returns would be enhanced by interventions to reduce risk and hazards at the neighborhood and city levels. As discussed earlier, through shelter design alternatives we are shifting the fragility of the cost-benefit equation, but not the exposure side of the equation. Changes in urban structure (the alignment of roads, provision of open space, etc.) and provision of basic sanitation services are also central to risk reduction and resilience, which can alter the exposure of households to disasters. However, these changes require coordinated action at levels above the household.

Numerous measures exist to increase flood and storm resilience in shelters, but temperature represents a particular challenge, particularly during periods when humidity is also high. Installation of air-conditioning is the primary measure most people are adopting to address temperature increases. This avenue is, however, unaffordable for the poor, is only possible where electricity supplies are reliable, and, in most cases, contributes to the root causes of climate change. Although numerous measures exist to insulate buildings and reduce the manner in which they absorb heat, these strategies cannot address increases in ambient temperatures that extend over periods of multiple days or months. Innovation is therefore required. This may involve solar or other "green" energy powered mechanisms for active cooling and ventilation or, where culturally acceptable, provision of public cooling spaces. Innovations need to especially focus on a combination of issues related to (a) carbon neutrality, (b) affordability, and (c) cultural acceptability.

Climate models indicate that urban areas globally will likely face sustained increases in both daily peak and night minimum temperatures. In the areas of India and Pakistan where this research was conducted, projections suggest that temperature minima and the heat index will remain above key physiological, health, and productivity thresholds for extended periods during the summer and monsoon seasons. This will have particularly large impacts on women, children, the elderly, and others who spend the majority of their time in the home.

5.1 Findings From This Research Have Important Policy Implications

1 Programs and investment in flood and storm resilient housing made either directly or through technical and credit programs represent major avenues for supporting adaptation by poor and marginalized communities. The interventions and design processes identified here have the potential for widespread replication and could generate substantial macroeconomic benefits in addition to the benefits already quantified at the household level.

2 Such programs need to be integrated within larger frameworks for responding to climate and disaster risks. As both the Da Nang and Gorakhpur cases indicate, improved urban planning overall would greatly increase the effectiveness of shelter designs. Similarly, approaches to addressing the impact of temperature depend heavily on energy, sanitation, water supply, and other core urban systems.

3 Continued efforts should be made to increase the synergy between action at the individual shelter level and conditions at neighborhood and city levels to alter both fragility and exposure of households.

4 Activities, such as training of masons and local architects coupled with communication directly to vulnerable communities are important to address information asymmetries. In many cases avenues for building resilience in shelters are available and affordable but are not widely adopted because information is not available to the most affected communities.

5 Additional research and innovation are required to address emerging temperature and humidity issues, particularly their impacts on women and other groups who spend large amounts of time at home.

TABLE 3

RESPONSE AVENUES AND KEY MESSAGES IN STUDY LOCATIONS

Findings and potential avenues for responding to the impact of climate change in each of the case locations are summarized below.

	Vietnam: TYPHOONS	India: FLOODING
Avenues for Action	Investment in storm resistant shelter is cost effective when compared to spending for post-disaster recovery. Financing opportunities need to be made available to low- and middle-income households. Additional design innovations are essential for replication in different physical and cultural contexts. Educating and empowering builders and individuals at the household level is the most cost-effective way to implement	Investment in flood resistant shelter is cost effective when compared to spending for post-disaster recovery. Flood resilient designs are feasible at costs below those of current standard construction. Additional design innovations are essential for replication in different physical and cultural contexts. Educating and empowering builders and individuals at the household level is the most cost-effective way to implement design insights.
Key Messages and Findings	Cost-effective design interventions that can increase the resilience of housing to typhoons and other extreme storm events are available. These interventions are not effective, however, if storm intensities exceed design thresholds (in this case, Beaufort level 12). Given their effectiveness, resilient designs could be a major area for government investment. Research is required to identify locations and conditions under which design thresholds are likely to be exceeded as climate evolves and where implementation of such measures could be maladaptive.	Autonomous strategies for building the resilience of shelters can be effective but can also be enhanced through improved city planning. Building resilience can, in some cases, involve choices and actions that don't require large investments beyond those already being made. Local masons and contractors are a key intervention area for training on climate resilient design principles.

Pakistan: TEMPERATURE

Innovation and investment will be required to address the impacts of temperature increases.

In addition to innovation, educating and empowering builders and individuals at the household level is the most cost-effective way to implement measures to address temperature increases.

Research is required to improve understanding of the impacts of temperature on interlinked urban systems. With increased dependence on active cooling, energy and water systems are central to the functionality of shelter.

As daytime and nighttime temperatures increase, Pakistani citizens will have no relief from the heat, and active cooling systems will need to be employed.

While insulation and improved ventilation can reduce the impact of increases in peak daily temperatures, extended increases in nighttime minima above physiological thresholds cannot be addressed by passive cooling measures. Air-conditioning appears to be essential, but current approaches depend on carbon-emitting energy systems and are thus ultimately maladaptive.

Women and others who spend most of their time at home face a higher risk of heat-related stress due to cultural and social norms.

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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: Vietnam Case Study (Typhoon Resilience)
- Sheltering From a Gathering Storm: India Case Study (Flood Resilience)
- Sheltering From a Gathering Storm: Pakistan Case Study (Temperature Resilience)

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

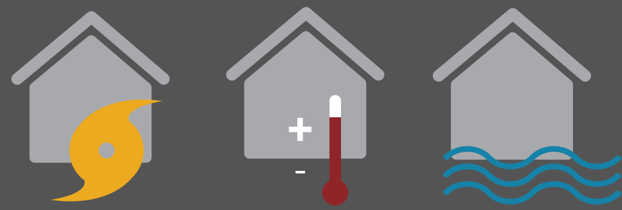
- Projecting the Likely Rise of Future Heat Impacts Under Climate Change for Selected Urban Locations in South and Southeast Asia.

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 the 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 synthesis report provides insights into the economic and nonfinancial returns of adaptive, resilient shelter designs that take into consideration hazards such as typhoons, flooding, and temperature increases. The research spans South and Southeast Asia, with a focus on Central Vietnam, Northern India, and Central to Northern Pakistan.

ABSTRACT:

Shelter design is one of the greatest factors influencing the loss of lives and assets during extreme climate events and is therefore a significant cost for governments, the private sector, and nongovernmental organizations working on disaster risk reduction or post-disaster reconstruction (UN-HABITAT, 2011). The project Sheltering From a Gathering Storm has generated substantive information on the costs and benefits of climate resilient shelter designs. This information will contribute to the transformative changes necessary to make communities more resilient to future disasters. Using cost-benefit analysis, this applied research project has produced outputs that provide insights into both the economic and nonfinancial returns of adaptive, resilient shelter designs that take into consideration hazards such as typhoons, flooding, and temperature increases. The research spans South and Southeast Asia, with a focus on Central Vietnam, Northern India, and Central to Northern Pakistan.

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