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Project Level

INSTITUTE FOR SOCIAL AND ENVIRONMENTAL TRANSITION-INTERNATIONAL

POLICY BRIEF

# Gorakhpur, India

## EXTREME RAINFALL, CLIMATE CHANGE, AND FLOODING

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## KEY FINDINGS

Climate change is likely to increase the intensity—how much rain falls per hour—of rain events around Gorakhpur over the next 50 years. At the same time, the city's population will continue to increase and require housing, transportation, and other city services. Unless the city can manage growth in a more sustainable manner, flood depths will increase and waterlogging will last longer due to the projected climate change impacts on rainfall and current urbanization process.

For more information about The Climate Resilience Framework, please visit: **www.i-s-e-t.org/CRF**

## Gorakhpur's Context

Gorakhpur is a rapidly growing city in eastern Uttar Pradesh, India. Gorakhpur district, which encompasses the city and peri-urban areas, is home to approximately 4.4 million people and has experienced an 18% population increase between 2001 and 2011 (Gov. of India, 2013). Much of this growth is due to significant rural-to-urban migration. Historically, the area experienced low levels of flooding each year during the summer monsoon (June–September), and depended upon such floods to replenish soil fertility. Yet, the depth and duration of floods in certain wards of the city are increasing, as the city expands to encompass sections of both the Rapti and Rohini rivers, and due to other urbanization processes. Some factors that enhance flooding and waterlogging include:

- Uncontrolled and unplanned development, particularly for housing;
- Loss of water bodies and green-space that once absorbed monsoon rains;
- Construction in the floodplain along the Rapti and Rohini rivers;
- Inability of the city to consistently provide services, such as solid waste management and wastewater/ storm water networks, that reduce flooding;
- Informal and irregularly maintained canal and embankment systems upstream of, and within, the urban area; and

- While embankments do protect some communities from initial flooding, they trap the rains and can lead to waterlogging lasting 2–3 months.

Flooding and waterlogging are triggered by rainfall events either in the city or upstream of the city in the Nepal Terai and Middle Hills. These urbanization processes have changed the nature of flooding and waterlogging hazards for the city, and as they accelerate, further alter the hazardscape of the city.

## Climate Change and Gorakhpur's Extreme Rainfall by the 2050s

Our analysis indicates that climate change is likely to increase the intensity of Gorakhpur's extreme rainfall, particularly the intensity of smaller, more common events that already cause significant flooding in multiple wards throughout the city. As previously discussed, flooding and waterlogging occurs in Gorakhpur because of land-use, the orientation of buildings, roads and other infrastructure, which interact with heavy rainfall within and upstream of the city. Figure 1 on the next page depicts how urban flood events will be magnified with increased urbanization and more intense rainfall events in the future.

Extreme rainfall is described by how frequently it occurs (Return Period), how intense the event was (average mm/hr) and how long the event lasted (Duration). Historically, Gorakhpur's extreme rainfall events had the following Intensity-Duration-Frequency (IDF) characteristics (Table 1):

Flooding already occurs in many of the low-lying wards of Gorakhpur, often after only 100 mm of rain in 24 hours—a common rain event with a return period of two years and average intensity of 4.2 mm/hr. Climate change will likely increase the intensity of similar rainfall events by 10 to 20% in the future. By the 2050s, rainfall events might experience percentage changes in intensity when compared with the past by the following ranges (Table 2).

**TABLE 1**

HISTORICAL IDF TABLE FOR GORAKHPUR FOR SELECT DURATIONS AND RETURN PERIODS CALCULATED OVER THE PERIOD 1961-2005.

| | Return Period (Years) | | |
|---|---|---|---|
| **Duration (hrs)** | **2** | **10** | **50** |
| 1 | 36.5 mm/hr | 62.3 mm/hr | 81.8 mm/hr |
| 12 | 7.6 mm/hr | 12.1 mm/hr | 15.9 mm/hr |
| 24 | 4.9 mm/hr | 7.7 mm/hr | 10.1 mm/hr |

**TABLE 2**

PERCENT CHANGES ARE DERIVED FROM COMPARING IDF CURVES FROM MULTIPLE GCMS FOR THE FUTURE (2006–2050) WITH HISTORICAL IDF CURVES (1961–2005).

| | Return Period (Years) | | |
|---|---|---|---|
| **Duration (hrs)** | **2** | **10** | **50** |
| 1 | 11 to 18% | -12 to 52% | -22 to 68% |
| 12 | 10 to 17% | 1 to 30% | -4 to 33% |
| 24 | 10 to 20% | 4 to 23% | 2 to 25% |

There is greater uncertainty (larger spread in the model projections and no clear trends) in how climate change might alter short duration events—those lasting less than 12 hours—than in events lasting longer than 12 hours as shown in the table. Some of this uncertainty is due to gaps in the historical observation records that affected the statistical distributions and will improve with time through efforts such as Gorakhpur's Environmental Action Group's (GEAG) automatic weather station, and coordination with the local Indian Meteorological Department office. Other sources of uncertainty are due to natural climate variability (not influenced by climate change), the differences between climate models, and the fact that no-one really knows what the world's population, energy use, greenhouse gas emissions, and land-use will look like in 2050. This is why it is important to use projections from multiple models, and build cities smartly to reduce natural hazard risks.

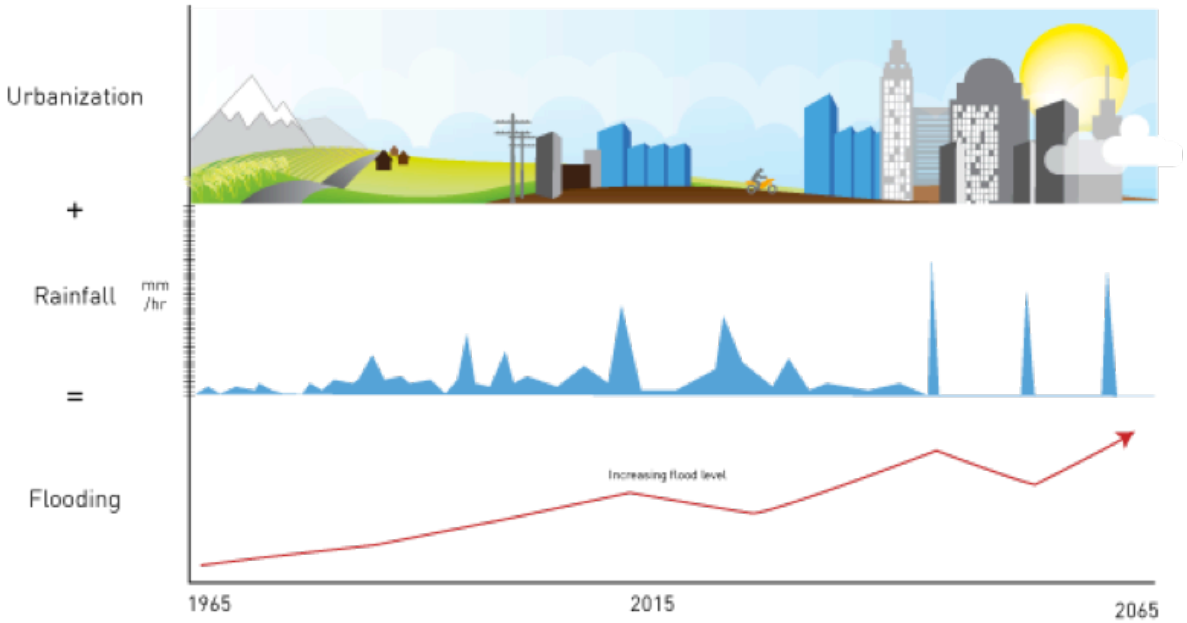
## Resilience Activities in Gorakhpur

Citizens, community groups, and GEAG are undertaking a variety of activities to build awareness about the multiple causes contributing to flooding and waterlogging, and taking steps to reduce vulnerability. Such activities include:

- Promoting flood resilient housing with raised plinth heights and raised storage areas for protecting household assets;
- Protection of Ramgarh Lake and other water bodies and green spaces as drainage areas and areas that provide critical ecosystem services supporting peri-urban livelihoods;
- Developing and funding a municipal solid waste management program to remove trash that clogs waterways;

**FIGURE 1**

DIAGRAM DEPICTING HOW FLOODING DEPTHS INCREASE AS URBAN DEVELOPMENT RATES ACCELERATE AND CLIMATE CHANGE LEADS TO MORE INTENSE EXTREME RAINFALL EVENTS.




- Working with the Municipal Corporation to improve sanitation and access to potable water, hopefully reducing vector-borne disease incidences especially during floods; and
- Pushing for a citywide ban on plastic bags that contribute significantly to waterway clogging.

GEAG, with the support of groups like CDKN and the Rockefeller Foundation, is working with community groups and other organizations to improve Gorakhpur's climate resilience. Through GEAG's and ISET–International's efforts, Gorakhpur joined the Asian Cities Climate Resilience Network (ACCCRN). GEAG is expanding their action research activities to other cities in Assam, Bihar, and West Bengal. With the outcomes of this analysis and a flood model by Arup, GEAG and ISET–International are sponsoring a flood resistant housing design competition. Winning designs will be evaluated for their cost effectiveness and promoted to the Gorakhpur Municipal Corporation, other policy makers, and community groups.

## About the Project

GEAG, Arup and ISET-International have been working together to explore the factors that lead to flooding and waterlogging within Gorakhpur. With support from the Rockefeller Foundation and Climate Development and Knowledge Network (CDKN), ISET-International conducted extreme rainfall event analysis of historical and projected rainfall to generate plausible storm intensity profiles for the 2050s. Arup is using these storm intensity profiles in an urban flood model of Gorakhpur to see how development and climate change might impact the city's future flood risk. The rainfall analysis and flood model supports two projects: 1) Investigating how climate-resilient housing has a positive cost ratio and helps vulnerable populations (CDKN), and 2) Investigating the costs and benefits of using multiple interventions and activities to build overall city resilience rather than relying on individual interventions (Rockefeller Foundation).

## Further Reading and Resources

This policy brief does not provide the technical details of the extreme rainfall event analysis for Gorakhpur. The technical report (Opitz-Stapleton et al., 2013) gives greater detail about the methodology and findings discussed in this Policy Brief. The following are more technical resources and/or provide more information on Gorakhpur and resilience activities:


- IPCC (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. In C. B. Field, et al. (Eds.), (pp. 582). Cambridge, UK.
- Mailhot, A., Duchesne, S., Caya, D., & Talbot, G. (2007). Assessment of future change in intensity-duration-frequency (IDF) curves for Southern Quebec using the Canadian Regional Climate Model (CRCM). Journal of Hydrology, 347, 197-210.
- Mitra, A., & Singh, B. (2011). Servicing the City: Migrant Workers and Deprivation in Gorakhpur, Uttar Pradesh, India. Gorakhpur: GEAG with support from The Rockefeller Foundation.
- Opitz-Stapleton, S., Hawley, K., & Sabbag, L. (2013). Technical Report: Gorakhpur's Extreme Rainfall and Climate Change by the 2050s. Boulder: ISET-International.
- Wajih, S.A., Singh, B., Bartarya, E., Basu, S. & the ACCCRN ISET Team (2010). Towards a Resilient Gorakhpur. Gorakhpur: GEAG with support from The Rockefeller Foundation.