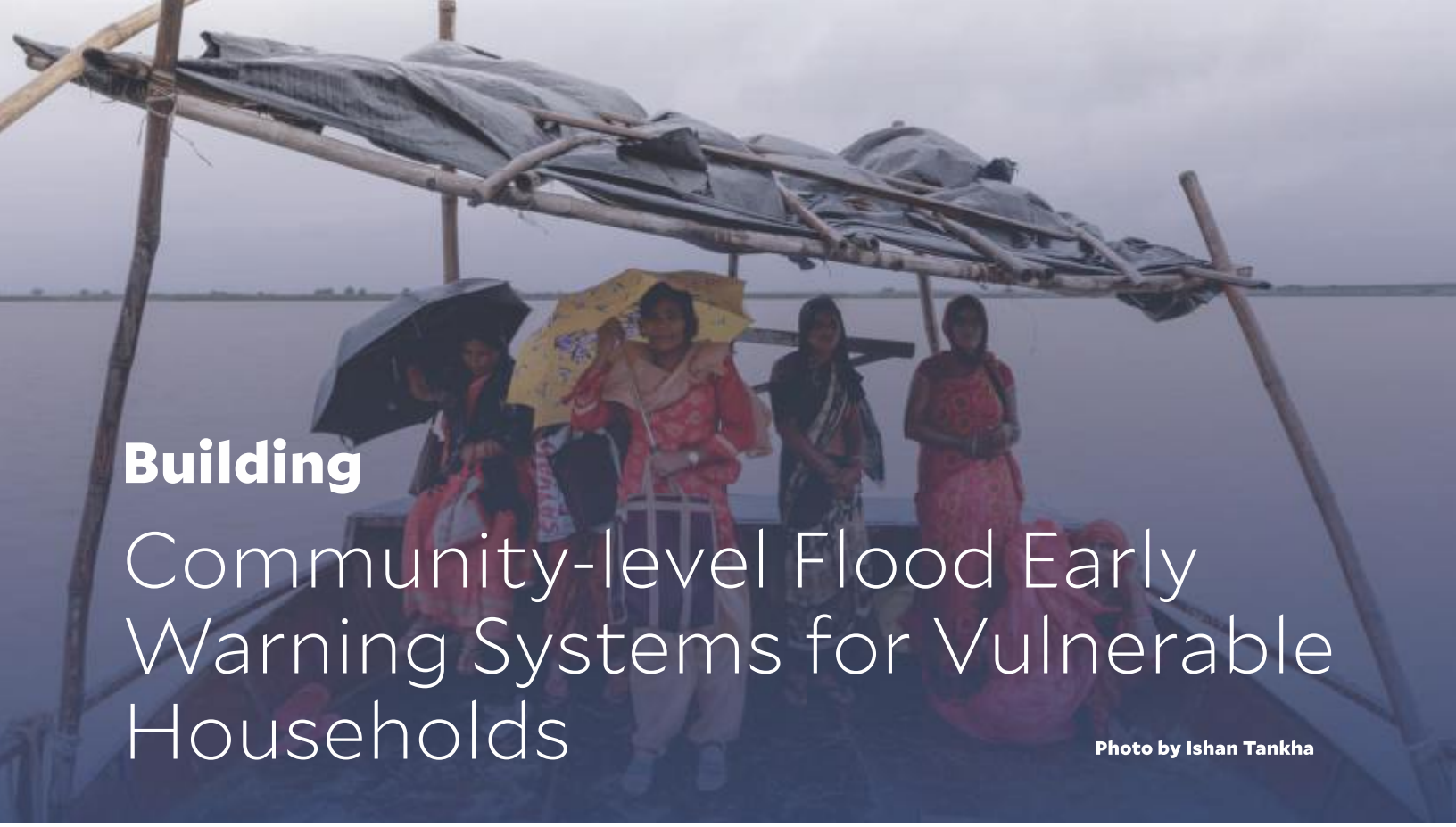

Building Community-level Flood Early Warning Systems for Vulnerable Households

Photo by Ishan Tankha

Climate change is escalating global flood risks, affecting one in every four people. This increases health and economic challenges, particularly in South Asia where 576 million people face flood risks. The Ganges-Brahmaputra River basin, which has 600 million residents and 200 million poor, is especially vulnerable. Even minor floods can impact millions in this region – between 2000 to 2010, floods caused 16,000 deaths, 200 million displacements, and 20 billion dollars in economic damages. [1] Flood early warning systems (EWS) have the potential to reduce flood-related morbidities and economic losses, yet a range of last-mile delivery difficulties may affect their effectiveness.

THE CHALLENGE: ENSURING ACCESS TO EARLY WARNING SYSTEMS

Bihar, one of India's most flood-affected states in the Ganges-Brahmaputra river basin, exemplifies the multi-faceted challenges faced by rural communities in South Asia. Annually, floods impact 6.87 million hectares out of Bihar's total area of 9.42 million hectares, making it home to 17.2% of India's flood-prone areas. Approximately 50 million people in north Bihar live under the yearly threat of floods - a challenge that climate change could exacerbate, by increasing the unpredictability as well as intensity of flooding in the future. Formative research reveals the severe disruption floods cause to lives and livelihoods in Bihar: following the 2019 flood season, 65% of households saw a decrease in agricultural income, 54% reported sickness, and over 20% experienced damage to livestock, homes, and personal belongings.

Despite an extensive flood forecasting network operated by India's Central Water Commission, many households still do not receive flood alerts before waters invade their communities. Only 20% of Bihar's flood forecasting stations are operational, and just 38% of people in flood-prone areas are aware of active EWS. [2] Formative research underscores these gaps: during the 2019 flood season, while over 95% of households were affected by floods, only 45% received any alert. Moreover, these alerts did not provide key information, such as forecast timing and predicted water depth.

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[1] Priya, S., Young, W., Hopson, T., and Avasthi, A. (2017). Flood risk assessment and forecasting for the Ganges-Brahmaputra-Meghna river basins. Technical paper, World Bank, Washington, DC.

[2] Tripathi, G., Pandey, A. C., and Parida, B. R. (2022). Flood Hazard and Risk Zonation in North Bihar Using Satellite-Derived Historical Flood Events and Socio-Economic Data. Sustainability, 14(3):1472.

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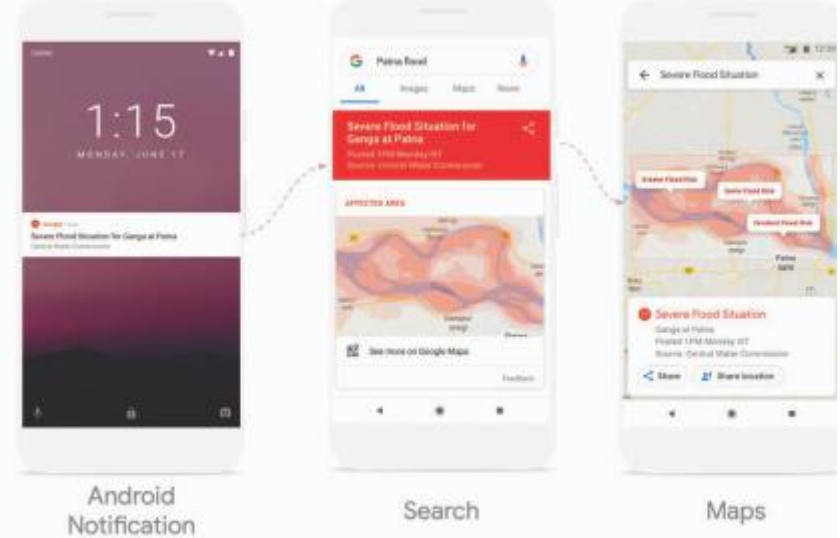

Figure 1: Selected examples of Google's flood alerts.

How can we build more effective early warning systems that deliver accurate, actionable alerts alongside increasing accessibility for vulnerable populations?

THE SOLUTION: HIGHLY-ACCURATE ALERTS PAIRED WITH COMMUNITY DISSEMINATION

In 2019, Google's Flood Forecasting Initiative partnered with India's Central Water Commission to generate highly-accurate flood alerts for communities in India. This system uses two AI models with public data: a hydrologic model forecasting river water flow, and an inundation model identifying flood-prone areas and estimating water levels, even in areas with limited coverage of flood forecasting systems. Google's service predicts floods 2 to 4 days ahead, with high levels of accuracy. [3]

Despite these advances in forecasting technology, vulnerable households in rural areas still lacked access to these alerts. Household members might be illiterate, lack smartphone access, or turn off location services in their phones.

In order to bridge this gap, the research team collaborated with a local non-profit to recruit and train community-based volunteers to effectively communicate flood alerts.

[3] Nearing, G., Cohen, D., Dube, V. et al. Global prediction of extreme floods in ungauged watersheds. Nature 627, 559–563 (2024). https://doi.org/10.1038/s41586-024-07145-1

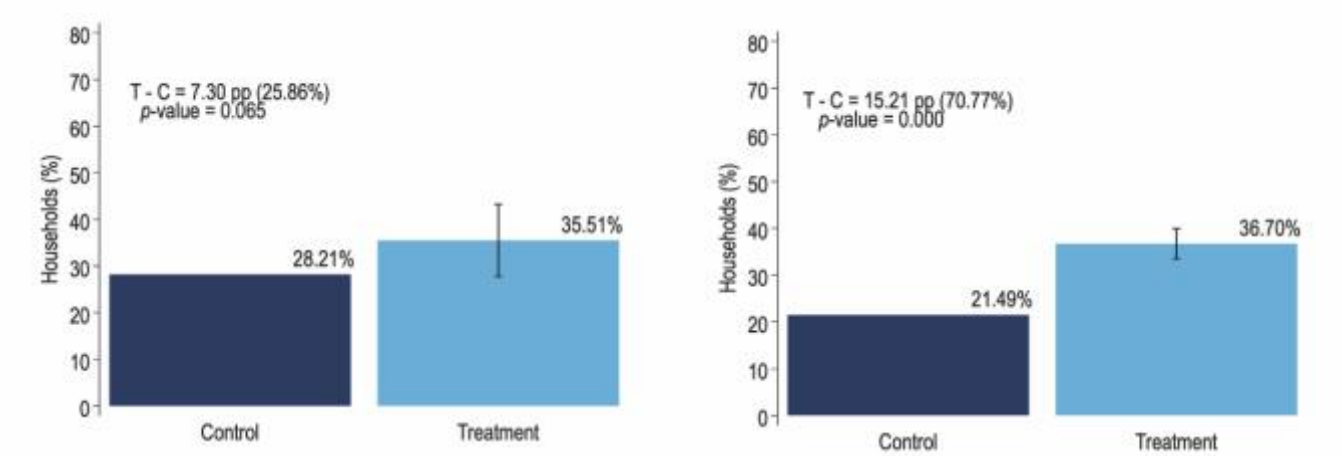

Figure 2: Access to Alerts in 2022 (left) and 2023 (right).

Starting in 2022, android-phone owning volunteers were trained at the start of the flood season to understand flood alerts from Google's forecasting and alerting system. When volunteers receive alerts of impending floods in their area, they warn their communities using both in-person methods, such as loudspeakers and flag signalling, and digital methods such as text and WhatsApp messages.

Since 2022, the research team has evaluated this innovation across 319 communities with more than 3.6 million people in 12 flood prone districts of Bihar. Approximately half of these communities are randomly assigned to receive access to volunteers, while the remaining communities have access to existing publicly-available flood early warning systems from multiple sources. This randomized controlled trial design allows a comparison between these two types of communities, allowing researchers to understand if differences across outcomes are due to access to community-disseminated flood alerts.

To evaluate the impact of this intervention, the research team tracked approximately 5,500 households across multiple flood seasons to measure their access to flood alerts, exposure to floods, adaptive steps taken to prevent flood losses, and health and economic impacts of flooding.

FINDINGS

Early results from this ongoing study suggest that community-disseminated flood alerts were highly effective at reducing household losses from floods.

Accessibility. Households in areas with volunteers gain access to more accurate, timely, and informative alerts: In 2022, households in volunteer communities received 2.40 more alerts (a 294% increase), were 26% more likely to receive any alerts, 45% more likely to receive alerts before water reached their area, and 56% more likely to say they trust the alerts completely. In 2023, treatment communities received 3.52 more alerts on average (a 503% increase), were 71% more likely to receive any alert, 83% more likely to receive an alert before water reached their area, and 91% more likely to say they trust alerts completely (see Figure 2).

Proactive Preparation. Households with access to community-disseminated flood alerts who faced the most severe flooding were more likely to engage in protective actions before waters reached them. Households in the top third for flood severity had a score that was 0.16 standard deviations higher on indices measuring proactive adaptation compared to households that were similarly affected by flooding without access to volunteers. Specifically, households in volunteer communities were more likely to take steps such as stocking supplies, safeguarding their animals, securing important documents needed for welfare programs, and protecting food and crops.

Health resilience. Households with access to community-disseminated flood alerts who faced the most severe flooding experienced fewer health issues. Households in the top tercile for flood severity had a score that was 0.18 standard deviations higher on indices measuring physical health compared to households that were

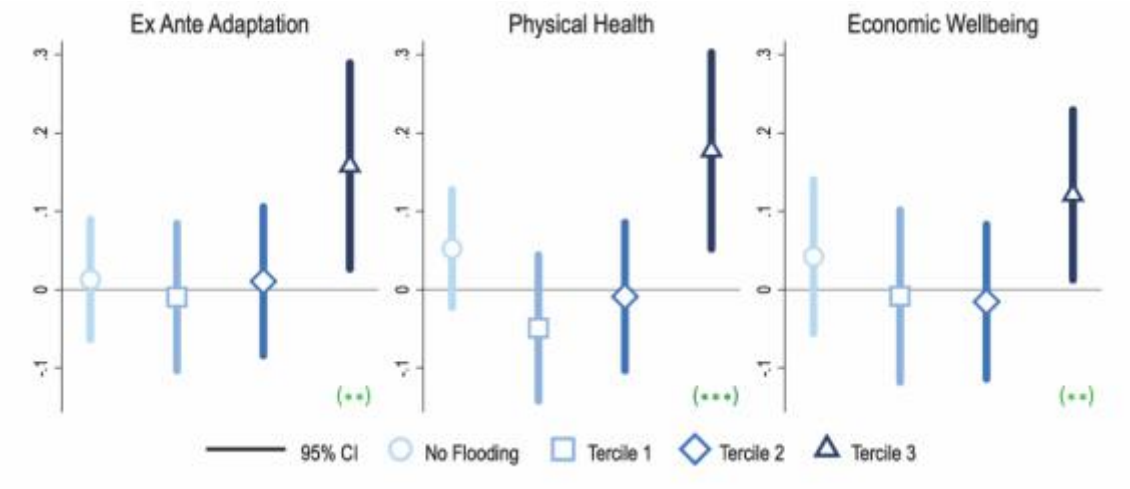

Figure 3: Treatment effects on summary indices, by severity of flooding.

similarly affected by flooding without access to volunteers. The most heavily impacted households in volunteer communities showed a decrease in sickness and injury, mainly due to fewer cases of waterborne diseases and slip-related accidents. As a result, these households incurred roughly INR 6,890 less on illness treatment (a 35.51% decrease) and INR 1,730 less on injury treatment (a 8.92% decrease).

Economic stability. With better preparation and improved health outcomes, households with access to community-disseminated flood alerts who faced the most severe flooding were also less likely to engage in reactive adaptive responses after flooding. Households in the top tercile for flood severity had a score that was 0.16 standard deviations higher on indices measuring economic well-being compared to households that were similarly affected by flooding without access to volunteers. Specifically, households in volunteer communities were less likely to have to take out money from savings, mortgage assets, reduce consumption of essential items, and take on new loans compared to control households (see Figure 3).

NEXT STEPS TO BUILDING EFFECTIVE EARLY WARNING SYSTEMS

Early results from our ongoing intervention suggest that community-disseminated flood alerts can be cost-effective at scale. In the conservative case that 10% of communities are severely affected by flooding, we estimate that the intervention saves households 12.14 to 36.43 USD in medical costs per 1 USD spent. Over the coming years, we aim to extend our multi-year experimental evaluation to estimate average program impacts when efficacy depends on the random realization of annual flooding intensity, rigorously evaluate changes in villagers' trust in the system and the implications for long-run effectiveness, and compare short- and longer-term cost-effectiveness. We will also explore additional financial instruments like flood insurance to enhance returns and consider scaling the intervention through self-help groups to further improve community-level resilience.

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