

# When Waste Blocks the City: Quantifying the Social and Environmental Amplifiers of Urban Flood Impacts in Nairobi

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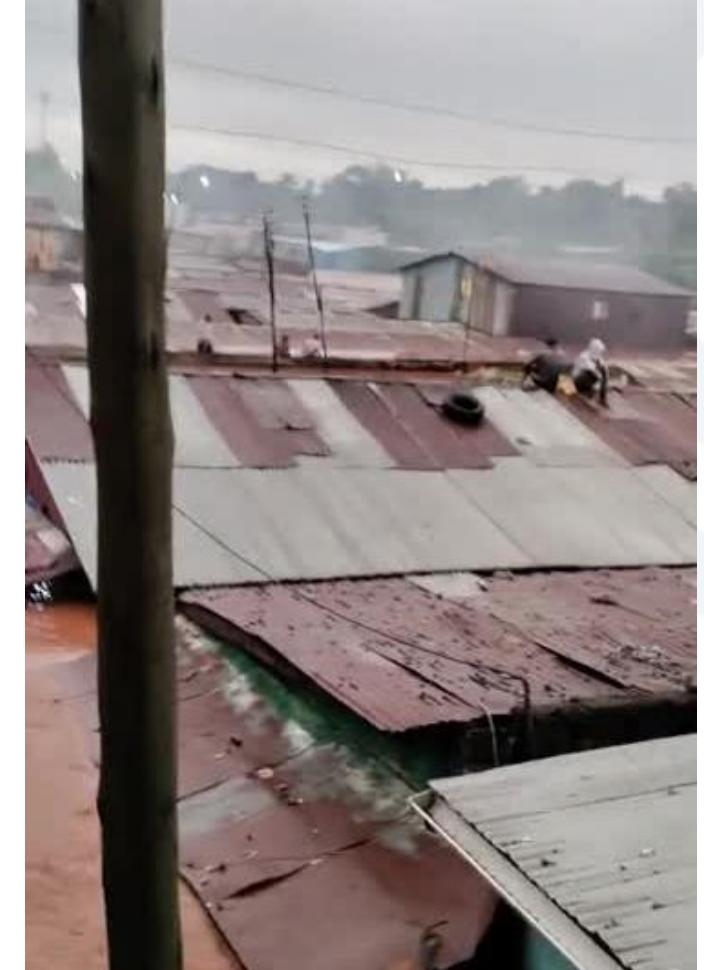
# Background - Urban Flooding

Between 2000 and 2018, the number of people living in flood-exposed areas increased by more than 1/3 worldwide, with the fastest growth in **sub-Saharan Africa**, South and Southeast Asia, and Latin America

Tellman et al., 2021

## Nairobi 2024

Deaths: 291 people,  
Displaced: 278,000 residents



# Background - Urban Flooding

- Urban flooding in sub-Saharan Africa is shaped not only by rainfall and topography but also by rapid, unplanned urbanisation and inadequate drainage infrastructure.

(Douglas et al., 2008)

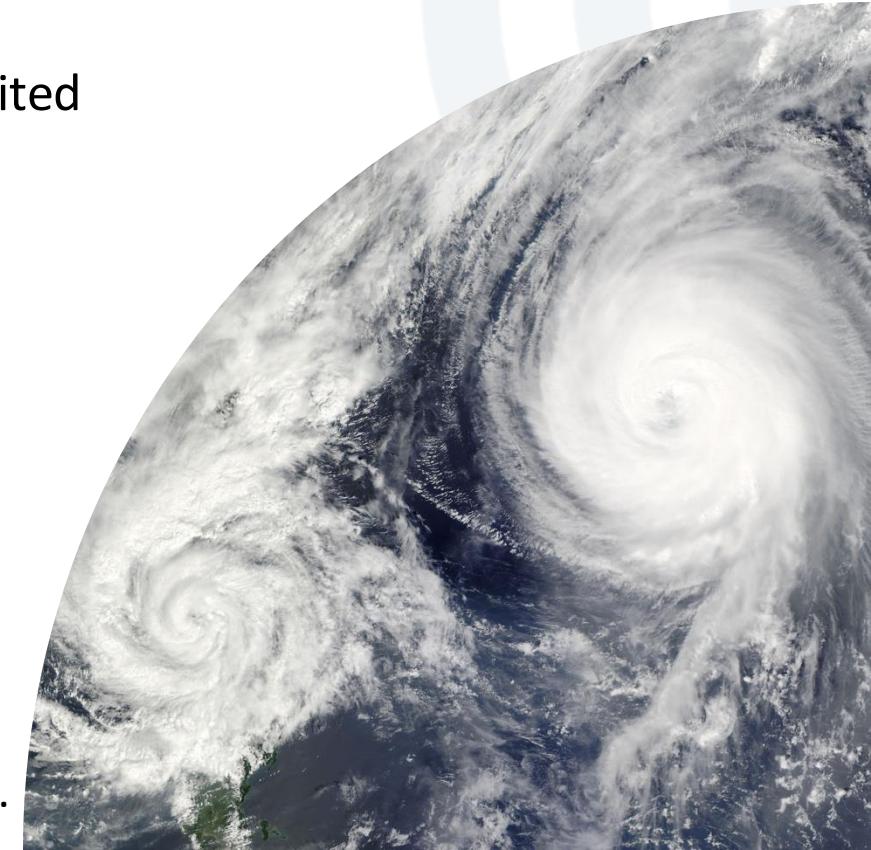
- Low-income communities often occupy flood-prone zones, where limited services and infrastructural neglect intensify exposure.

Tellman et al., 2021

Blocked drainage  
by waste

Nairobi, Kenya      Space4All project  
                          IDEAMaps project

Other countries:  
Pakistan, Cameroon, Indonesia, Malaysia etc.



# Background - Urban Flooding



# Aim

This study aims to evaluate how **environmental and social vulnerability** shape the **human impacts of urban flooding** in cities of the Global South.

## Research Question

To what extent does **waste accumulation**, as an expression of environmental and infrastructural vulnerability, contribute to **population change** during a **urban flood-related crisis** in Nairobi, Kenya?

# Hypotheses

- **H1. Flood intensity → human impact (main effect)**

Flood exposure should increase population change (i.e. more crisis impact).

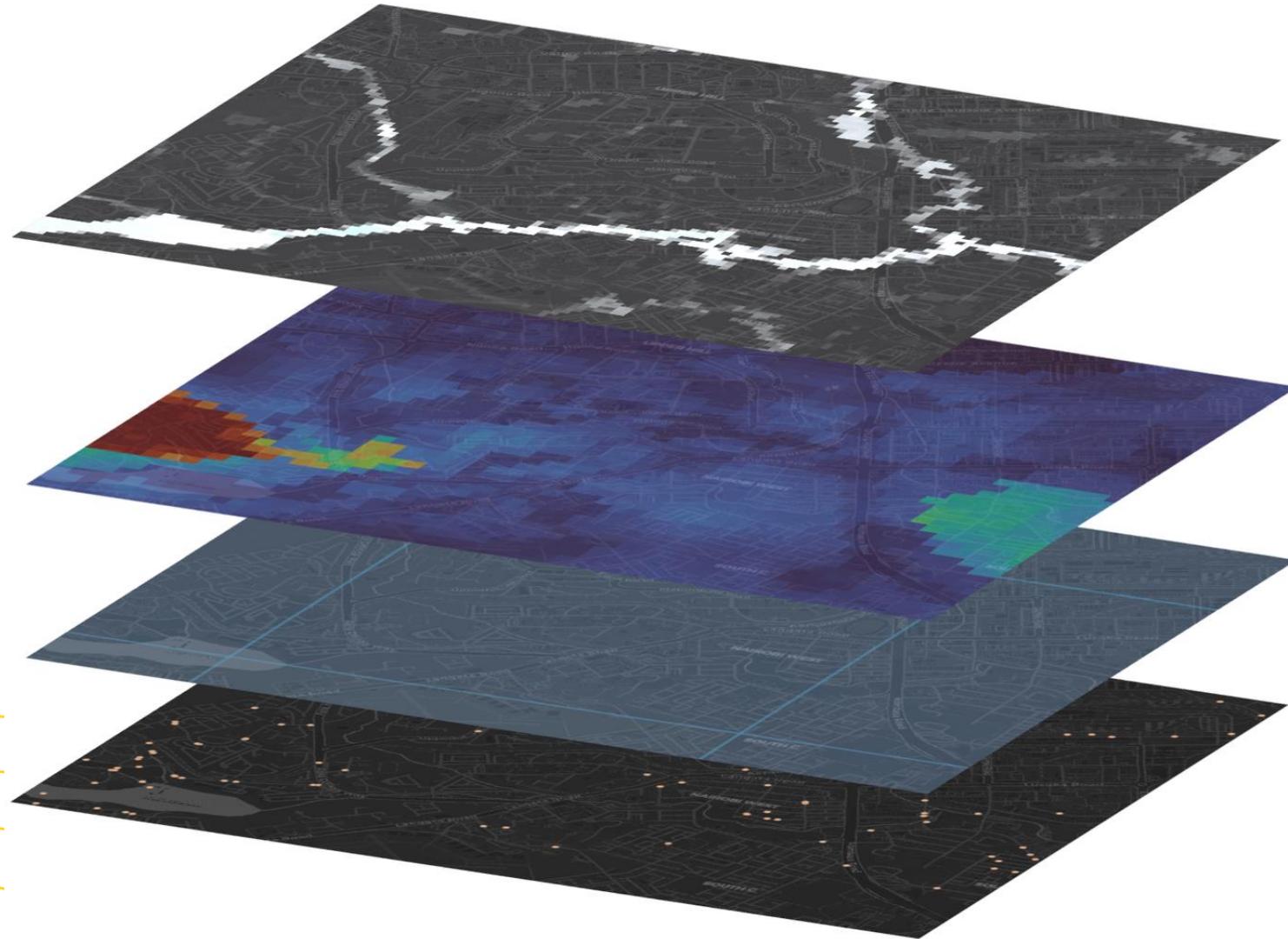
- **H2. Waste accumulation → human impact (independent effect)**

Areas with more waste should experience higher crisis population change, even when flood intensity is controlled.

- **H3. Interaction (waste × flood)**

Waste amplifies the effect of flood intensity, meaning that the impact of flooding on population change is stronger in waste-accumulated areas; indicating hazard amplification through infrastructural neglect.

# Data Source



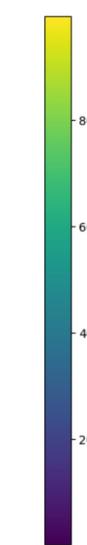
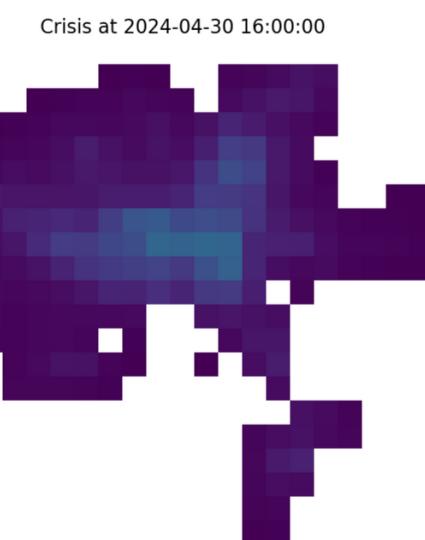
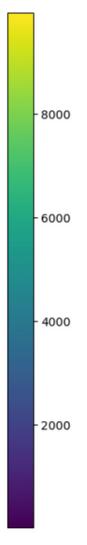
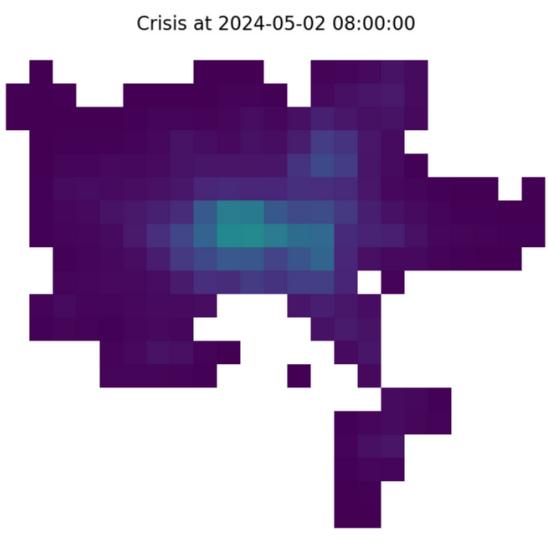
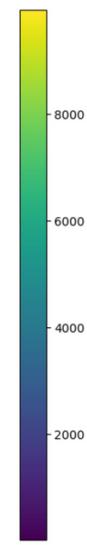
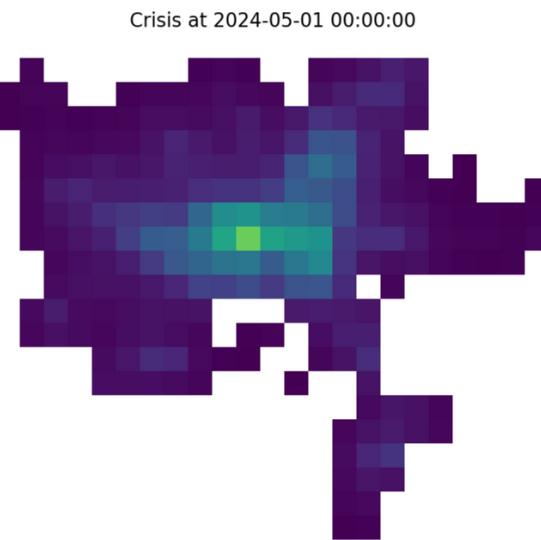
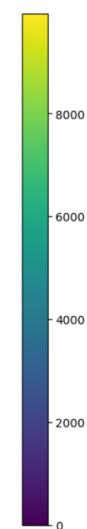
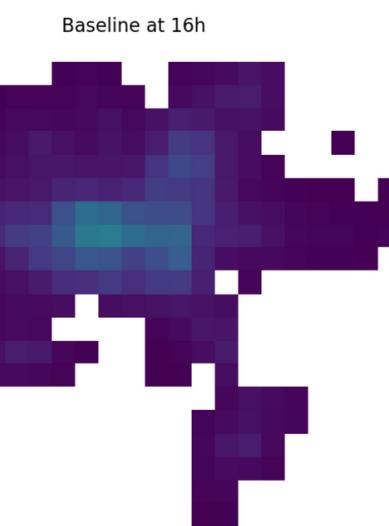
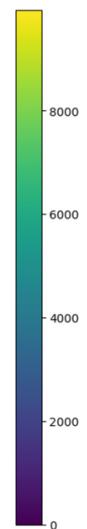
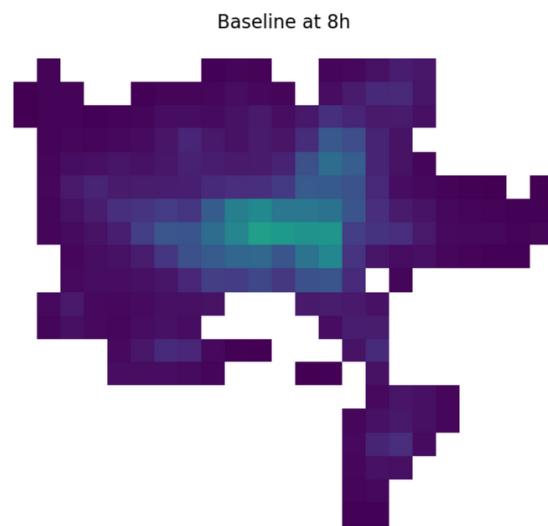
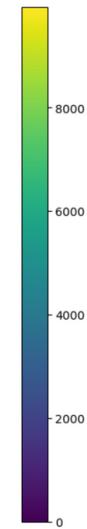
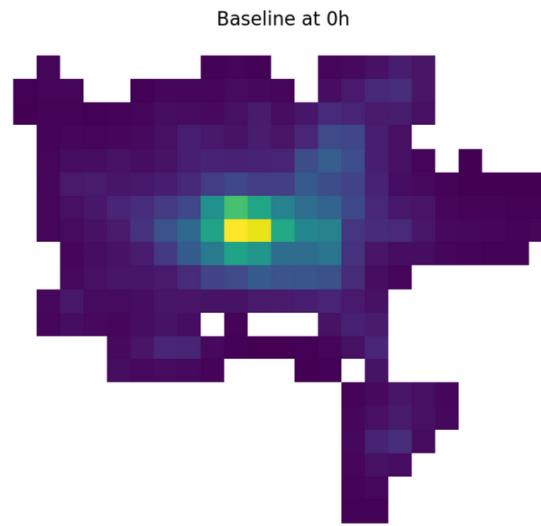
Simulated Flood:  
Fast flood model, 30m, raster

Population:  
World Pop 2020, 100m, raster

Crisis population data:  
Meta, 2.5km, vector grid

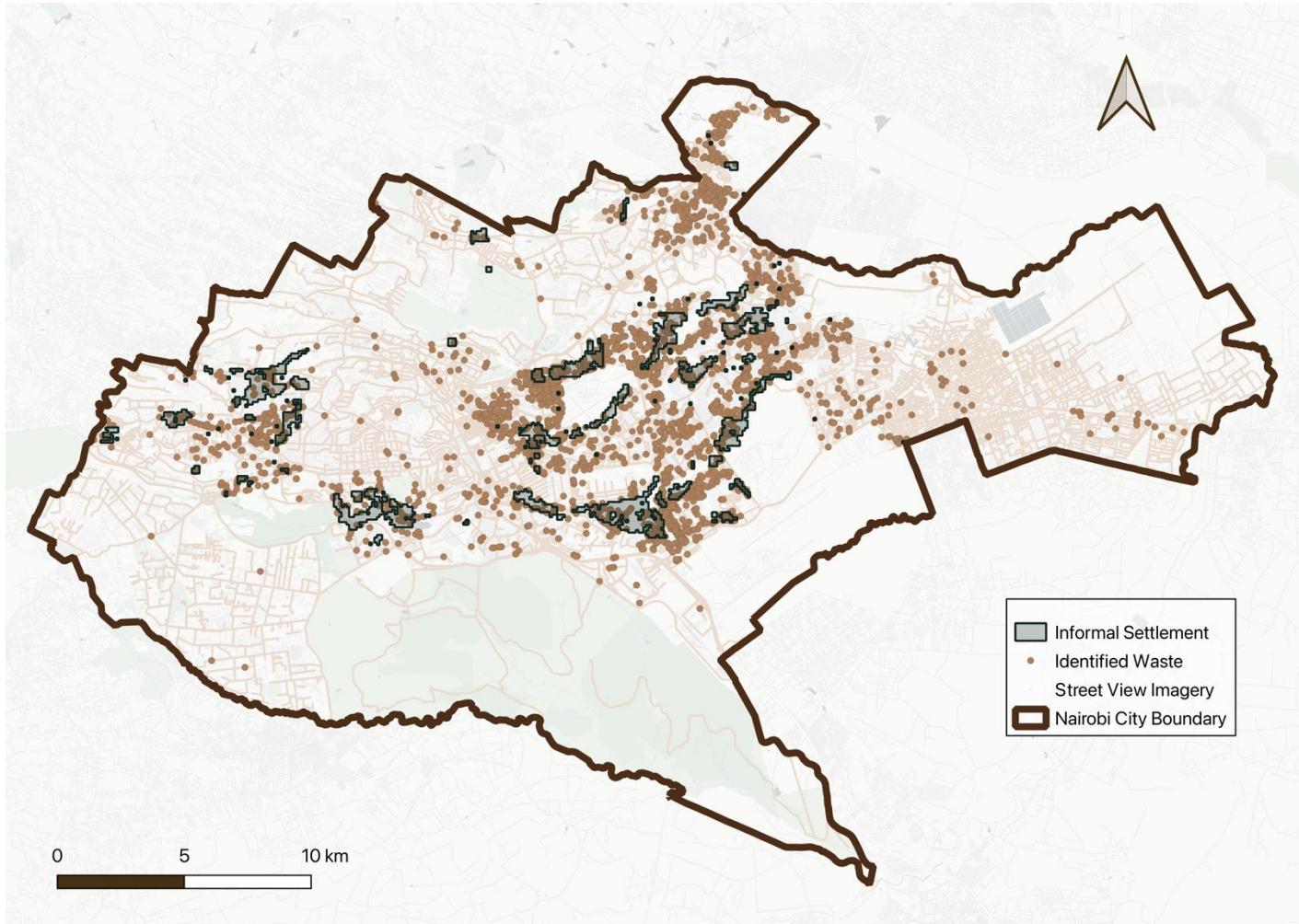
Waste accumulation map:  
From Google street view, vector point

# Data Source – Meta Population Distribution



; preserved.

# Data Source – Waste Accumulation Map



# Methodology - spatial lag model (SAR)

$$y = \alpha + \beta_1 \cdot \text{Flood} + \beta_2 \cdot \text{Near100} + \beta_3 \cdot (\text{Flood} \times \text{Near100}) + \beta_4 \cdot \text{Waste} + \gamma \cdot X + \rho \cdot W \cdot y + \varepsilon$$

- Dependent variable: crisis population change (Meta Crisis data).
- Independent variables:
  - Flood = simulated flood intensity
  - Near100 = location-based vulnerability indicator
  - Flood  $\times$  Near100 = interaction term capturing amplification of flood effects
  - Waste = waste accumulation indicator
  - $W \cdot y$  = spatially lagged dependent variable (to account for spatial dependence)

# Result - Key coefficients

Model N = 4 749; Spatial Lag (SAR, ML estimation)

Variable	Coefficient ( $\beta$ )	p-value	Interpretation
Flood intensity	<b>26.92</b>	< 0.001	Flooding is the dominant driver of crisis population change.
Near100 (proximity to waste)	<b>-31.82</b>	< 0.001	Baseline population change is lower near waste sites when floods are absent.
Flood $\times$ Near100	<b>+16.29</b>	< 0.001	Flood impact is substantially stronger in waste-affected areas.
Waste accumulation (continuous)	<b>+2.06</b>	< 0.001	Independent positive effect: higher waste density increases crisis population change.
Spatial lag ( $\rho$ )	<b>+0.52</b>	< 0.001	Strong spillover: neighbouring displacement reinforces local impacts.

# Result - Interpretation

- **Physical hazard:**

Simulated flood intensity is the strongest determinant of crisis population change ( $\beta = 26.9$ ,  $p < 0.001$ ). Areas experiencing more intense flooding show greater population movement during the crisis period.

- **Environmental vulnerability:**

Waste accumulation exerts an independent, positive effect ( $\beta = 2.06$ ,  $p < 0.001$ ), indicating that environmental neglect and poor waste management increase the scale of human disruption even under similar flood conditions.

- **Amplification effect:**

The interaction term ( $\beta = 16.29$ ,  $p < 0.001$ ) demonstrates that the impact of flooding is magnified in areas near visible waste accumulation. When flood intensity is high, proximity to waste increases crisis population change by roughly 60 % (from 26.9 to  $\approx 43$  units), confirming the role of waste as an amplifier of flood impacts.

- **Spatial spillover:**

The significant spatial lag ( $\rho = 0.52$ ) suggests that population change patterns are spatially interdependent—areas experiencing severe crisis population change influence adjacent neighbourhoods, producing clusters of heightened impact.

# Take Away

- **Flood intensity (simulated)** is the dominant driver of **Meta-user population change** in Nairobi.
- **Meta users near waste sites** show **lower baseline population**
  - likely reflecting **lower Meta app penetration in low-income neighbourhoods**.
- However, **waste** presence **amplifies** the impact of flooding when **floods are high**.
  - This indicates that **vulnerable**, lower-income groups face the most **extreme** flood impacts, combining physical exposure and social-environmental vulnerability (poor infrastructure, waste accumulation, public health threats)

# Limitation

- **Data**
  - **Drainage** are covered or blocked by waste and difficult to **detect**
- **Modelling**
  - No **causal** inference;
  - Meta data have limited **penetration and representativeness** in cities of the Global South
  - **Alignment** of Spatial data across datasets may **introduce noise**.
  - **No longer-term or multi-event (longitudinal) changes** in flooding, waste patterns, or population dynamics tested.
- **Practical**
  - Cost - benefit analysis (maybe simulated? )

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