

# Designing Climate-Resilient Urban Waterscapes: Hydrological Adaptation for Equitable Cities in a Warming World

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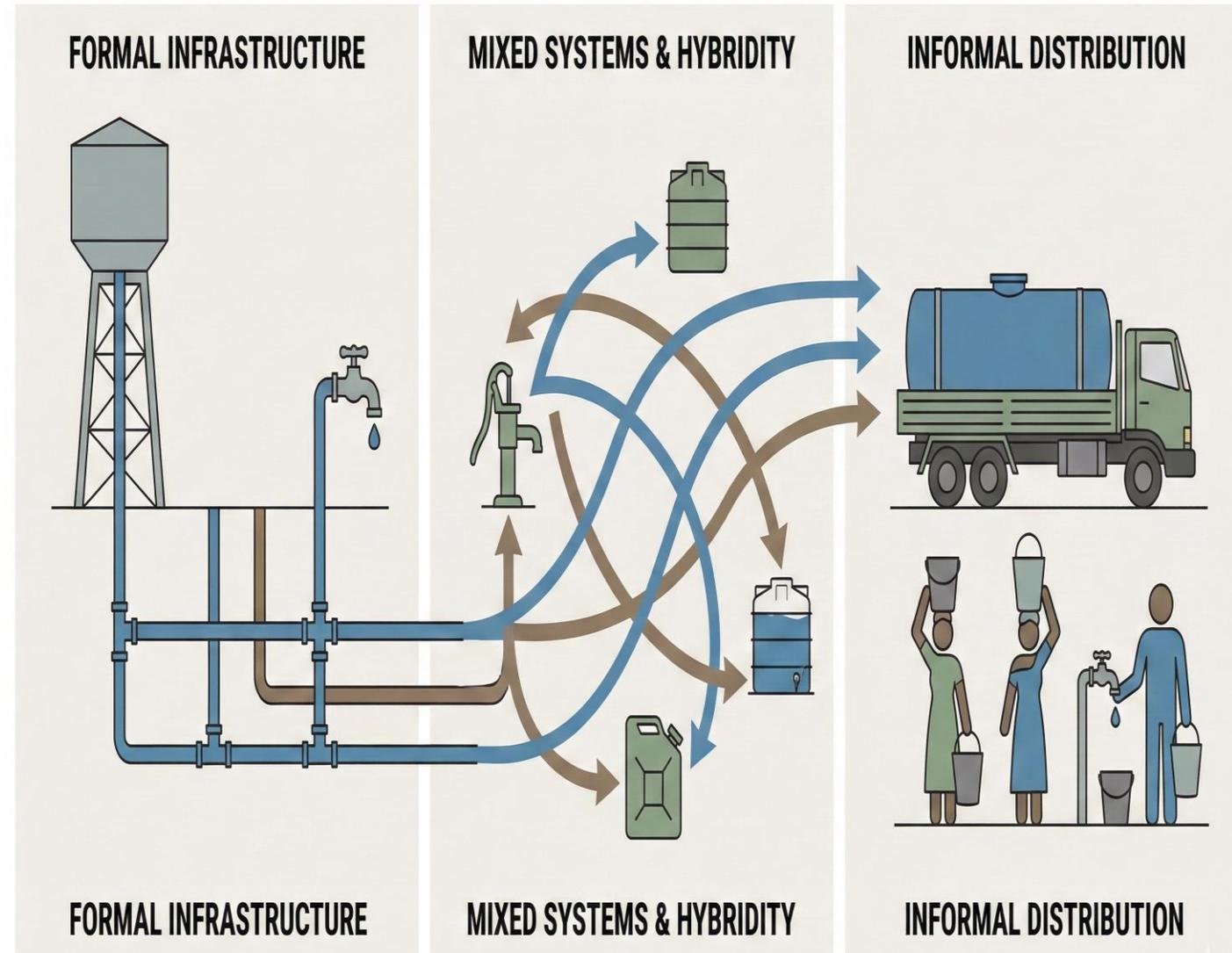
# Introduction: The Urban Hydrological Crisis in the Global South

- Sub-Saharan Africa is undergoing a rapid demographic shift with over 60% of the population projected to live in cities by 2050. This urbanization coincides with a changing climate regime characterized by higher intensity rainfall and longer dry spells
- Conventional predict-and-provide infrastructure designed for stationary climate norms is failing. Cities like Kumasi and Accra face a compounded risk regime of pluvial flooding and seasonal scarcity that disproportionately affects low-income populations
- This research moves beyond technical engineering assessments to examine how marginalized residents adapt to these failures and proposes a framework that integrates these adaptations into formal planning

# The Reality of African Urban Waterscapes

FIGURE 1: AFRICAN URBAN WATERSCAPE CONCEPTUAL MODEL

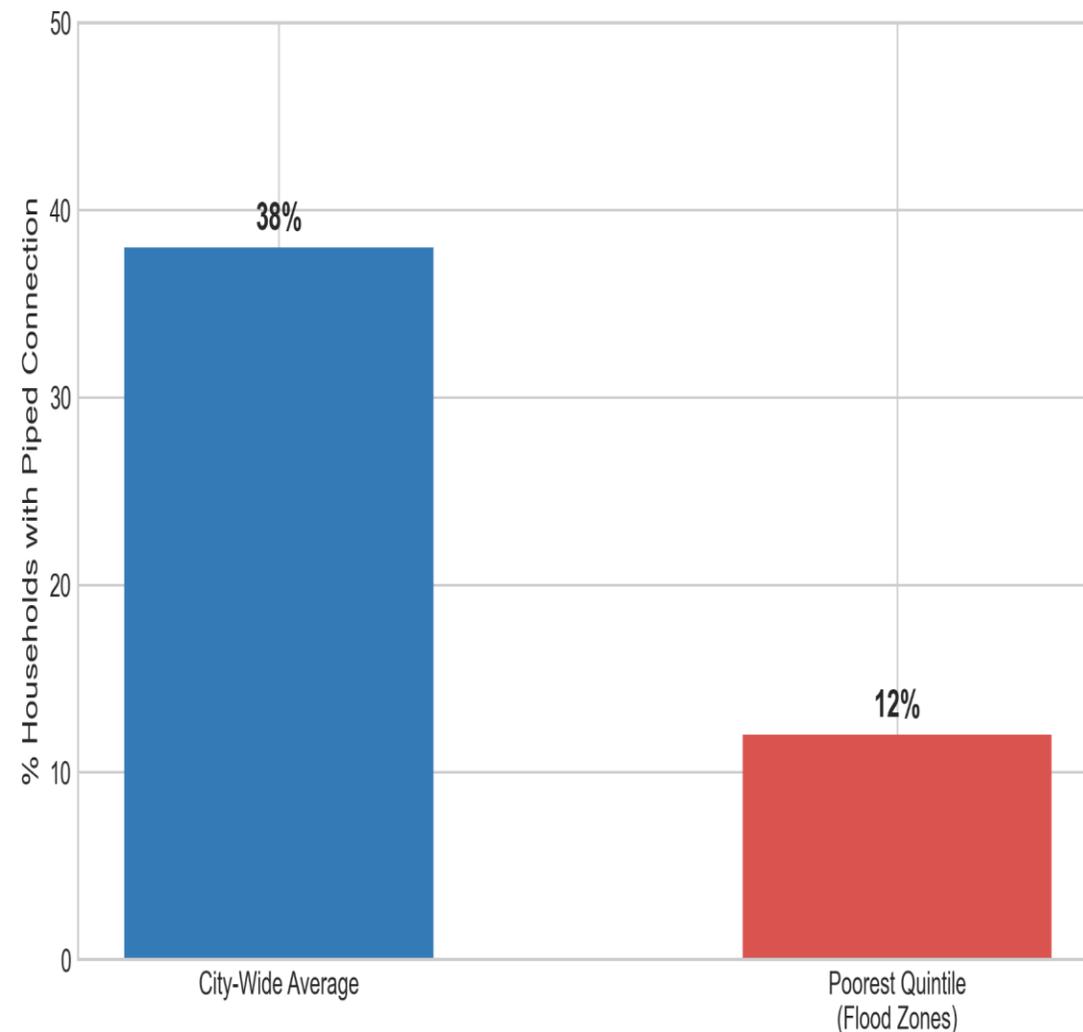
- The contemporary African urban waterscape is a hybrid system where piped networks coexist with decentralized, often informal, distribution mechanisms
- this hybridity is critical because informal systems are not merely transitional but are the constitutive infrastructure for the majority of the urban population.



# Quantifying the Infrastructure Gap

- The hybrid system is defined by exclusion. Our spatial analysis reveals that while the city-wide average for piped water access is 38%, this coverage drops to 12% for households in the poorest quintile
- There is a strong correlation ( $r = 0.81$ ) between residence in high flood-risk zones and the absence of formal water infrastructure. This confirms that infrastructure deficits are spatially concentrated in the most vulnerable areas

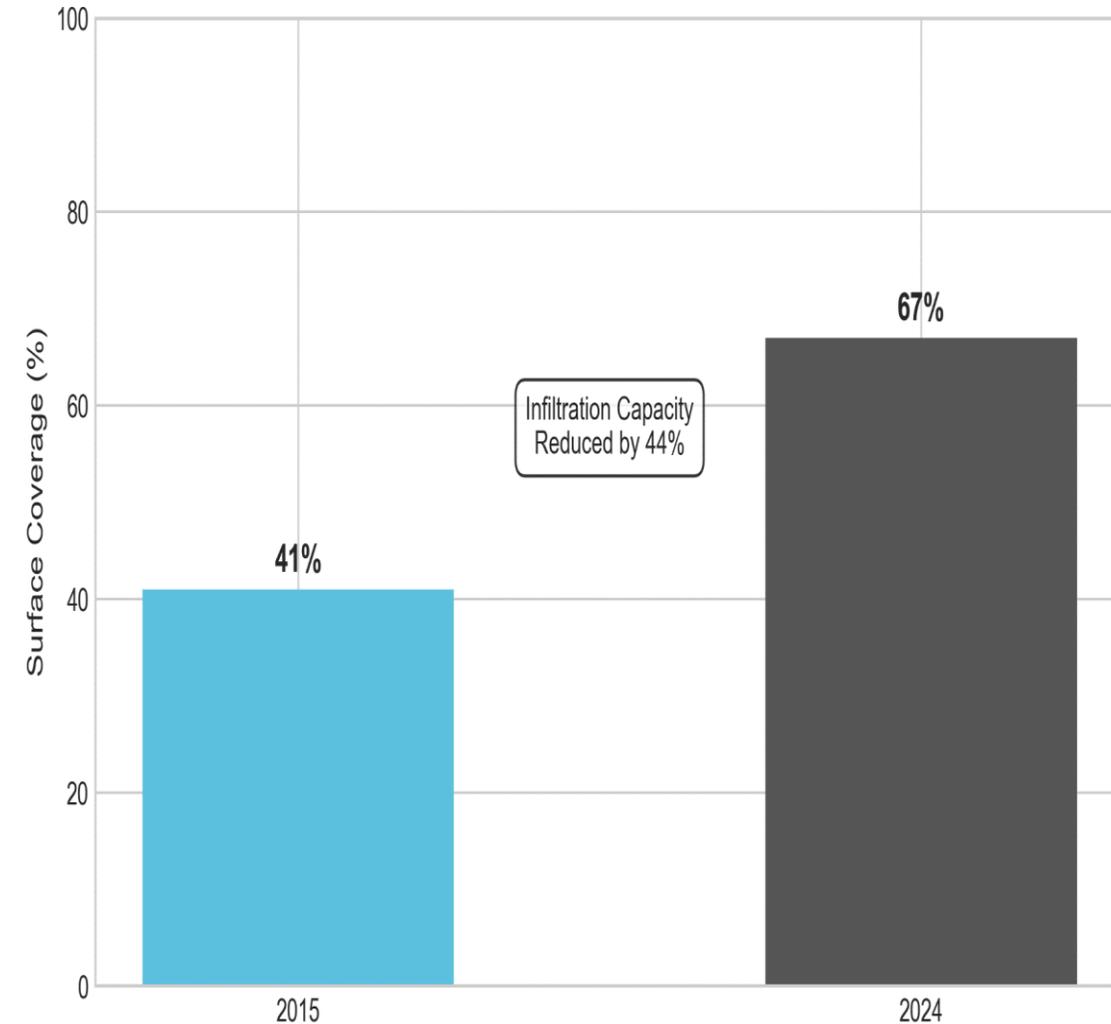
The Infrastructure Gap: Access to Piped Water



# Hydrological Drivers of Risk

- Rapid urbanization has fundamentally altered the city's hydrology. Between 2015 and 2024, impervious surface cover in the study area increased from 41% to 67%
- This surface hardening has reduced the natural infiltration capacity of the catchment by approximately 44%. The result is a significant increase in surface runoff and pluvial flood risk during the intensified rainfall events associated with climate change.

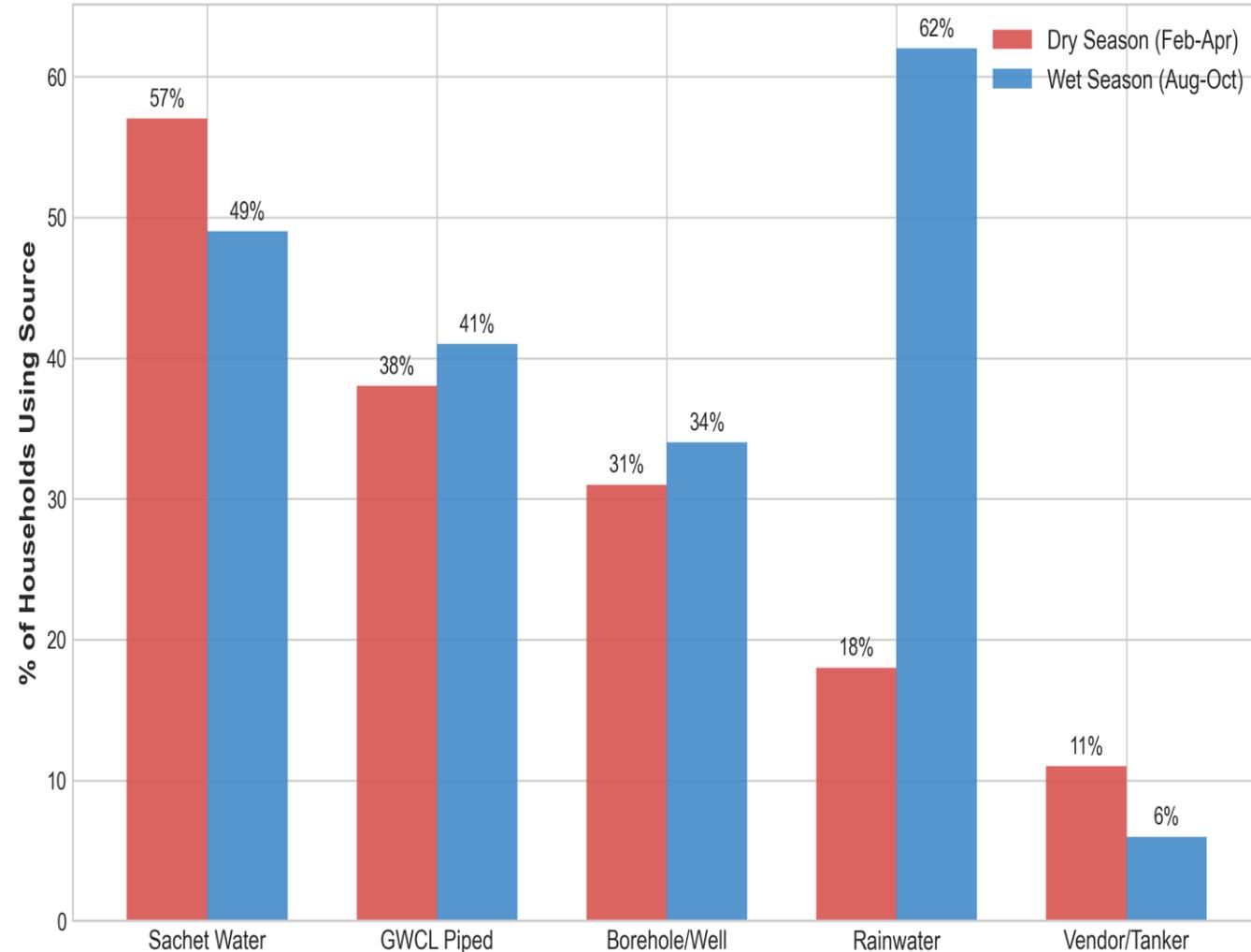
Urban Expansion: Growth of Impervious Surfaces



# Seasonal Adaptation and Agency

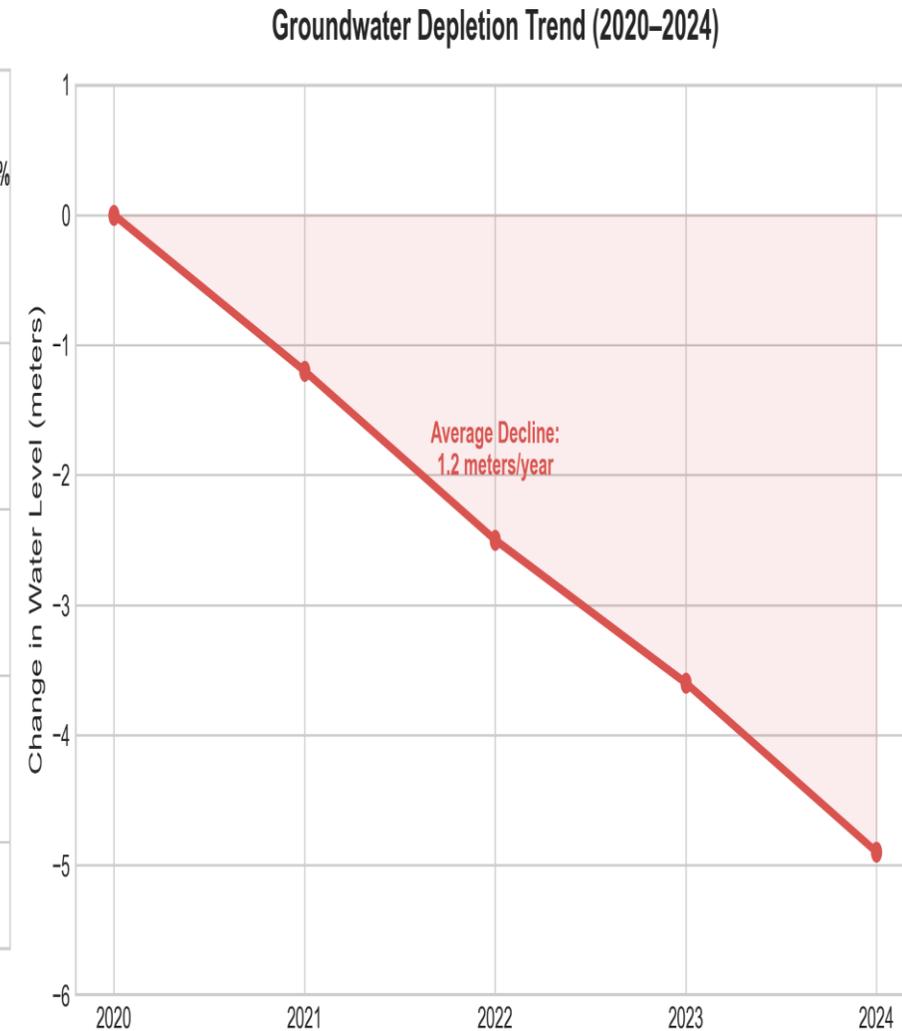
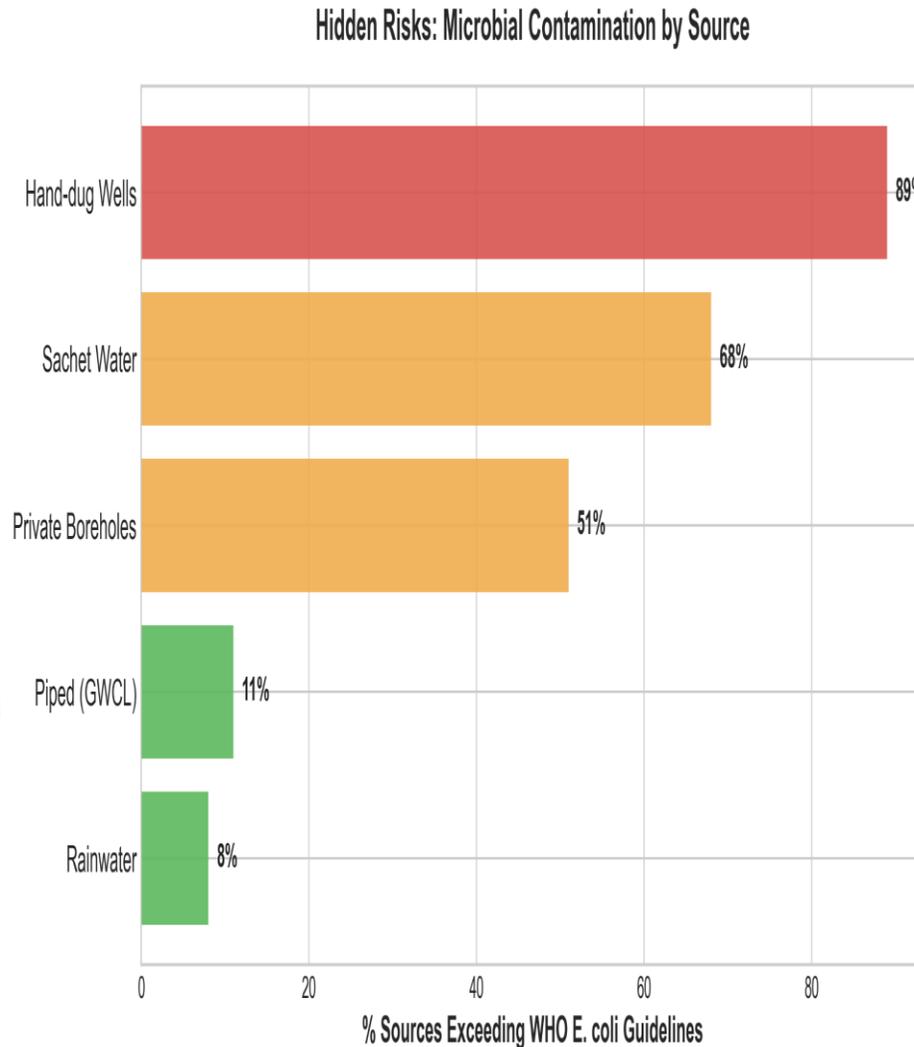
The Adaptation Shift: Seasonal Water Source Reliance

- Residents demonstrate significant agency in navigating these risks. We observed a marked seasonal shift where reliance on rainwater harvesting increases from 18% in the dry season to 62% in the wet season
- This hyper-diversification of sources is a necessary coping strategy but indicates high instability in water security. It shifts the burden of water management onto the household level

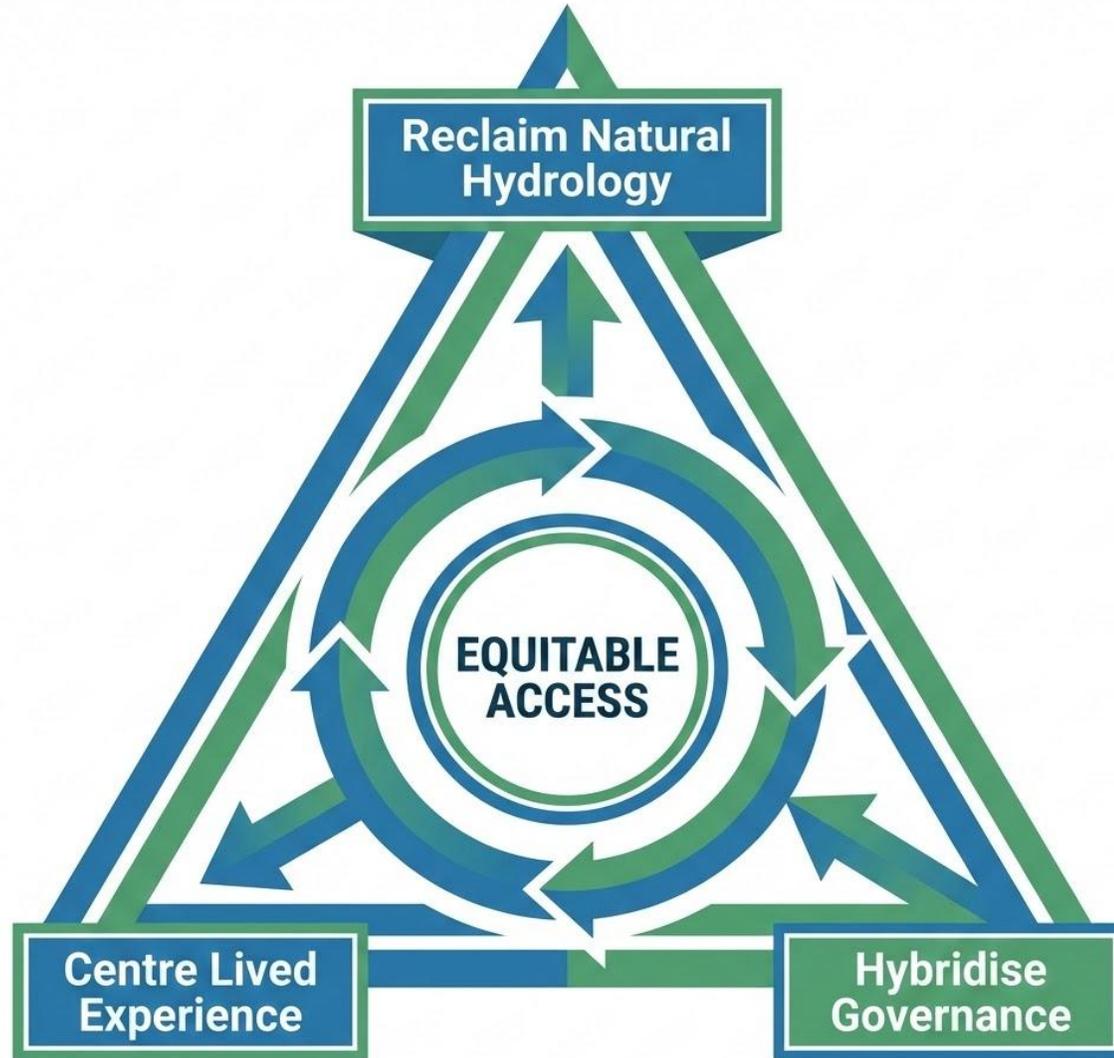


# The Hidden Costs of Informal Adaptation

- Public Health Risk: These adaptive strategies compromise health. Our testing showed that 89% of hand-dug wells and 68% of sachet water samples exceeded WHO guidelines for *E. coli*
- The reliance on private boreholes has created a tragedy of the commons scenario. Monitoring data indicates an average groundwater depletion rate of 1.2 meters per year due to unregulated abstraction



# The Climate-Resilient Urban Waterscape Framework



- We propose a framework rooted in three pillars: reclaiming natural hydrology, hybridizing governance, and centering lived experience
- This framework moves beyond engineering efficiency to include social justice as a functional component of hydrological planning.

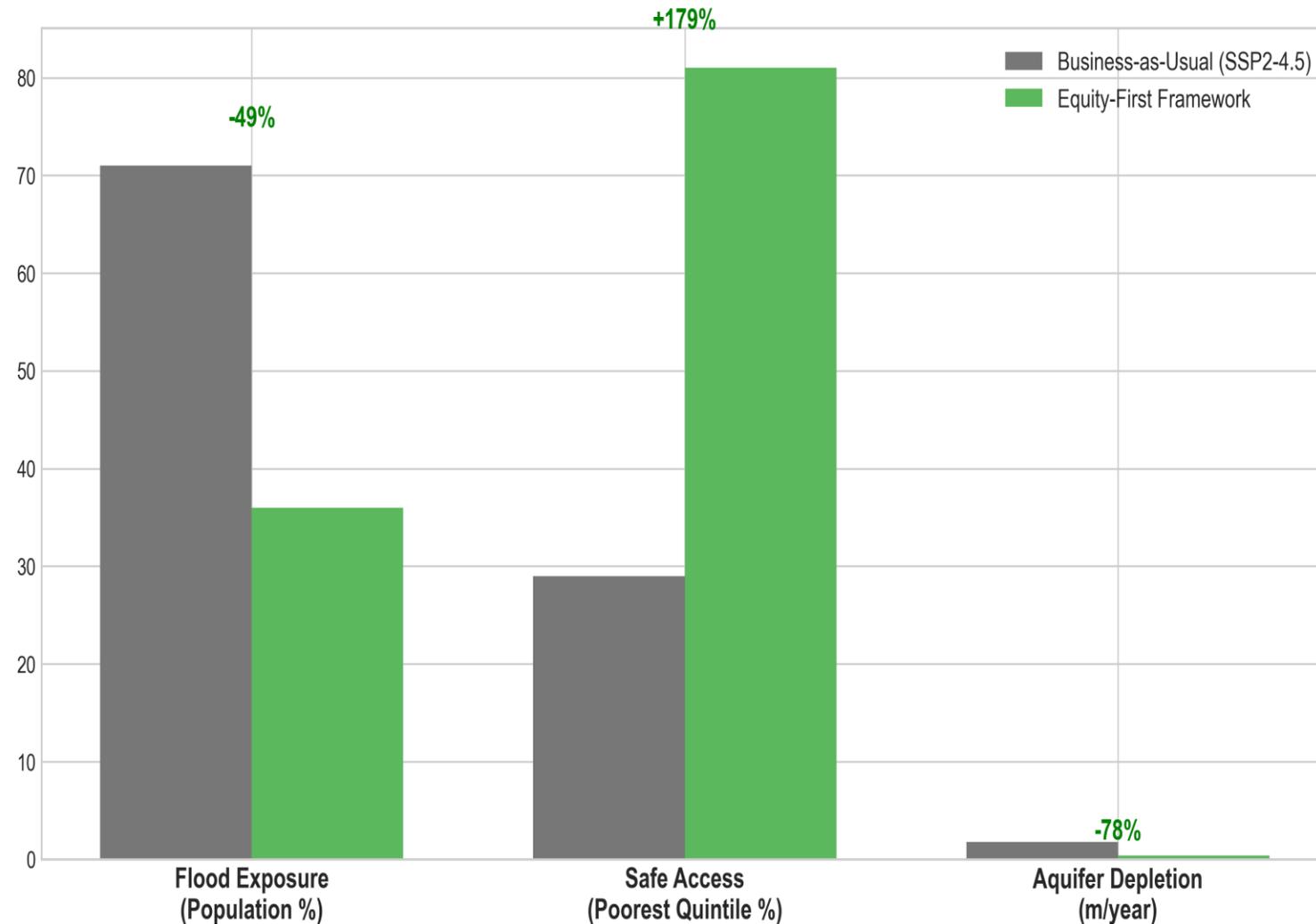
# Equity vs. Business-as-Usual

- We modeled two scenarios to 2050 under SSP2-4.5 and SSP5-8.5 climate pathways:

Business-as-Usual approach (expanding pipes) and an equity-first approach which prioritizes nature-based solutions in poor areas.

- The equity-first approach reduced the population exposed to flood depths greater than 0.5 meters by 49% compared to the baseline

Modeled Outcomes: Equity-First vs. Business-as-Usual (2050)



# The 49% Reduction

- The 49% reduction relies on the assumption that restoring active storage in upstream low-income settlements—through wetlands and retention ponds—attenuates peak flow for the entire catchment
- The model assumes a reduction in impervious surface growth rates due to land-use controls. Sensitivity analysis indicates these outcomes are robust provided that riparian buffer zones are protected from encroachment
- This means if we protect the most vulnerable areas, it provides the highest aggregate flood reduction benefit for the city

# Regulating the Commons: Groundwater and Equity

In addressing the 1.2m/year depletion rate without cutting off access for the poor, we have to;

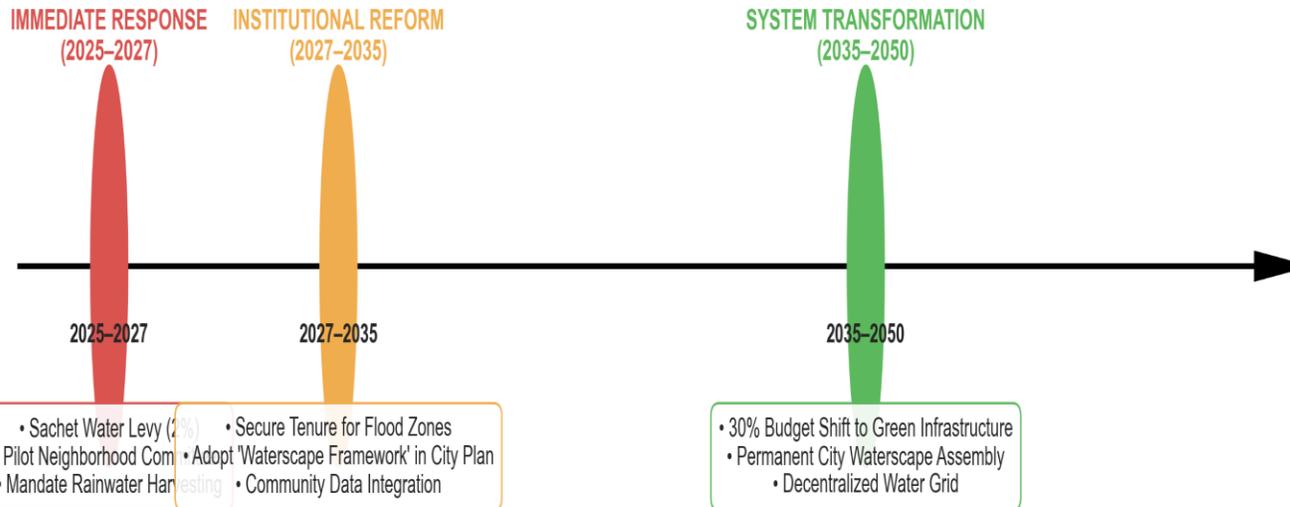
- Instead of top-down bans which criminalize survival, we propose neighborhood water committees with legal usufruct rights
- These committees manage abstraction quotas and coordinate collective boreholes. This shifts regulation from a punitive state action to a community-managed resource agreement, ensuring preservation does not come at the expense of access

# The Role of Community-Led Monitoring

- We propose transitioning from ad-hoc adaptation to formal integration via Community Water Quality Observatories
  - This is done by equipping residents with simple testing kits (CBT) and mobile reporting tools, the agency already evident in sourcing water is redirected toward quality assurance.
- : This generates real-time data for the utility while empowering communities to demand accountability, bridging the gap between informal providers and formal regulation.

# Implementation Roadmap and Gender Justice

Policy Implementation Roadmap: Kumasi 2025–2050



- The roadmap moves from immediate levies on sachet water to long-term institutional reform
- Recognizing that women currently bear the burden of water collection and management, the framework mandates 50% female representation in water committees.
- Tenure security in flood zones is prioritized not just for infrastructure protection, but to validate the women-led household investments in green infrastructure

# Urban Hydrology as Climate Justice

- In Kumasi, technical solutions that ignore social equity are hydrologically inefficient. The equity-first model demonstrates that prioritizing the vulnerable enhances resilience for the entire city
- True climate resilience requires reframing urban hydrology. It is not just about moving water but about redistributing power and legitimizing the local knowledge of those who have been adapting to the crisis for decades
- We must design systems where the technical and governance structures adapt to the lived realities of the poor, rather than forcing the poor to adapt to failing systems

# Thank You

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