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Session 1. « City resillience to climate change »
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IMPACTS OF FLOODS IN CITIES WITH FORMAL AND INFORMAL HOUSING: ANALYSIS FOR THE CITY OF CAPE TOWN

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Outline

1. **Urban land-use simulation models**

2. **The NEDUM-2D model applied to Cape Town**
   - ➢ Specificities of the Cape-Town model
   - ➢ Introducing flood risks in the model

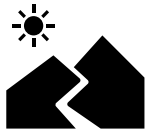
3. **Simulations**
   - ➢ Comparing with and without anticipation of flood risks
   - ➢ Climate change (under anticipation of flood risks)

4. **Conclusion**

1. Urban land-use simulation models

The city structure as a spatial equilibrium

The context



Geography
(amenities & constraints)

Institutions
(regulations)

Infrastructure
(transport network)

Agents

Households

Firms

"Developers"

Choices

Construction

Location

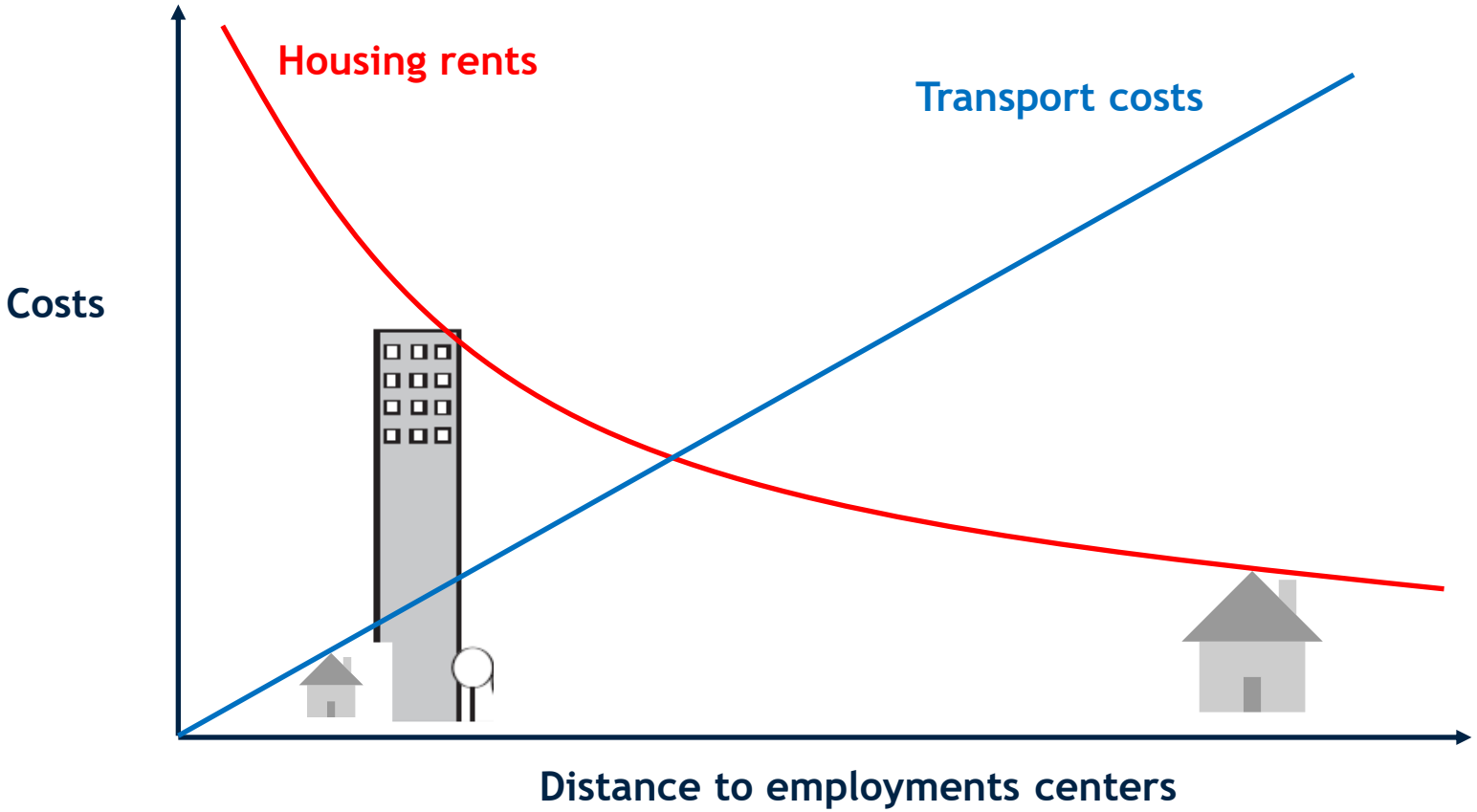
Transport

Land and housing markets

Supply & demand ⟹ **Prices** ⟹ **City patterns** = **Where people live, work, and travel**

The fundamental trade-off in urban models (location choice)

Based on classic urban economics theory (AMM, see Fujita, 1989)



- Spending more on transport costs is compensated by lower rents
- Developers use land more intensively where rents are high
- Other forces can influence the spatial structure (e.g., local amenities)

Why do we need urban simulation models?

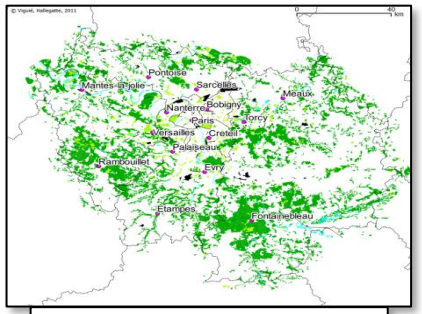
- **Understand the spatial equilibrium**
  - Drivers of city structure
  - Economic outcomes (ultimately: welfare of households)

- **Simulate systemic impacts**
  - Shocks (population, climate, etc.)
  - Policies/planning (zoning, transport investment & subsidies, housing, UGB, etc.)

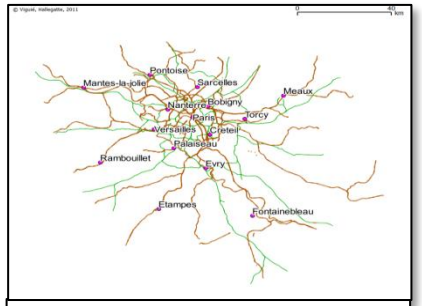
- **Other urban land-use simulation models**
  - TRANUS (de la Barra, 1989)
  - UrbanSim (Wadell, 2000)
  - RELU-TRAN (Anas and Liu, 2007)
  - Urban Energy Footprint Model (Larson et al., 2012)
  - “Quantitative Urban Model” (Ahlfedlt et al. 2015)

NEDUM-2D model

- Standard urban economics (monocentric or polycentric)
- A 2D representation on a plane/grid
- Multiple modes of transport
- Static and dynamic versions of the model

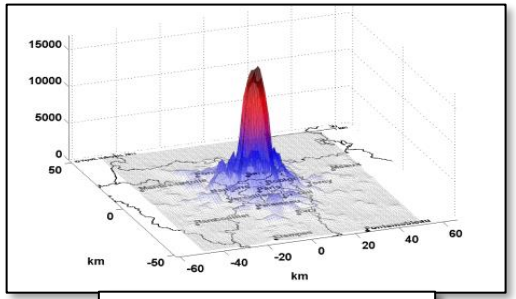


Land-use constraints

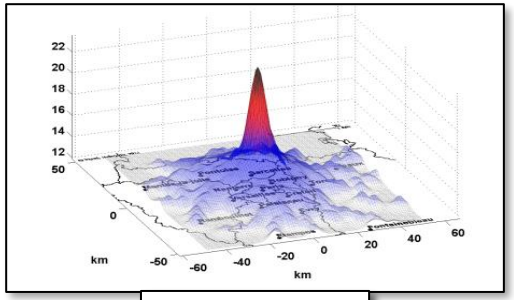


Transport times and costs

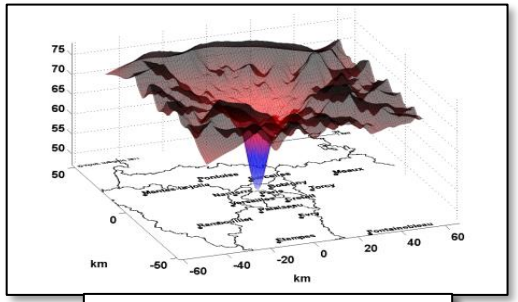
- Total population
- Construction costs
- Average household income



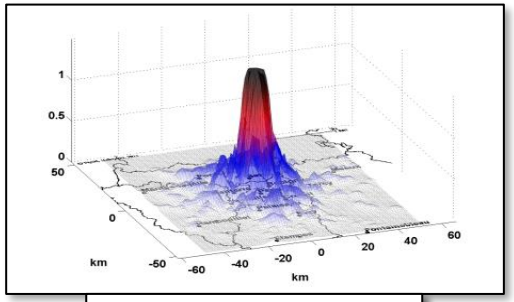
Population density



Rents



Average dwelling size



Floor-area ratio

Applications to: Paris, Buenos Aires, Toulouse, Wuhan, London

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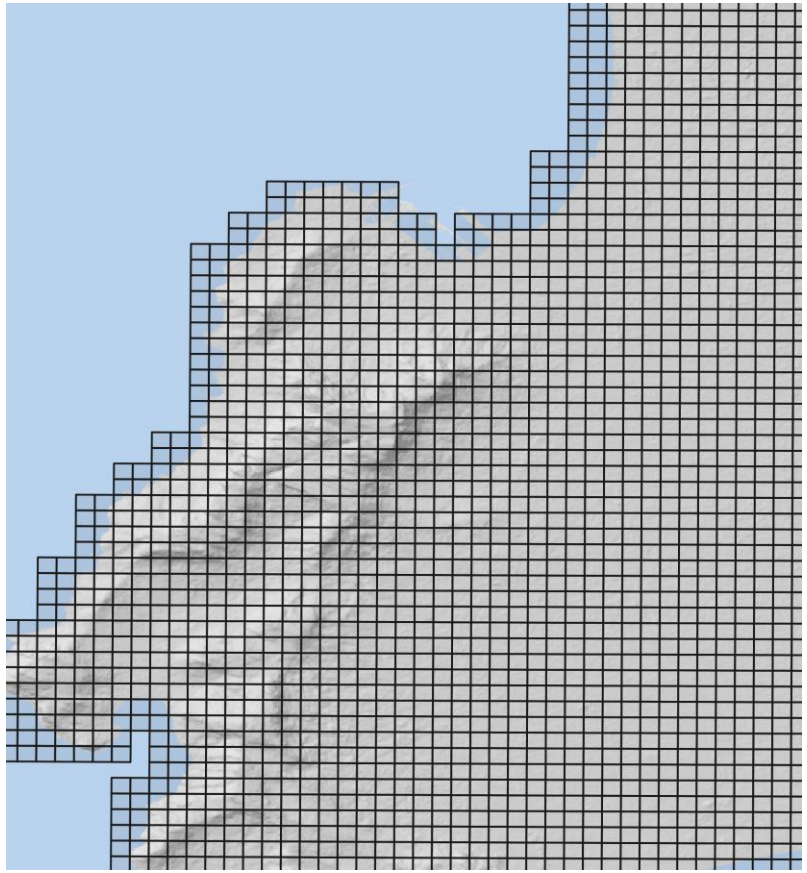
2. The NEDUM-2D model applied to Cape Town

Specificities of the Cape Town model

The City of Cape Town grid (500m x 500m)



For each cell, we consider:

- available land area
- zoning restrictions
- amenity score
- accessibility score (travelling to jobs)
- number of RDP/BNG houses
- informal settlement zones

5 transportation modes

Private car

Minibus / taxi

Walking

Bus

Train

 Source: Shutterstock

4 housing sub-markets

Formal, market-led housing (~ >80m² dwellings on >300m² plots)

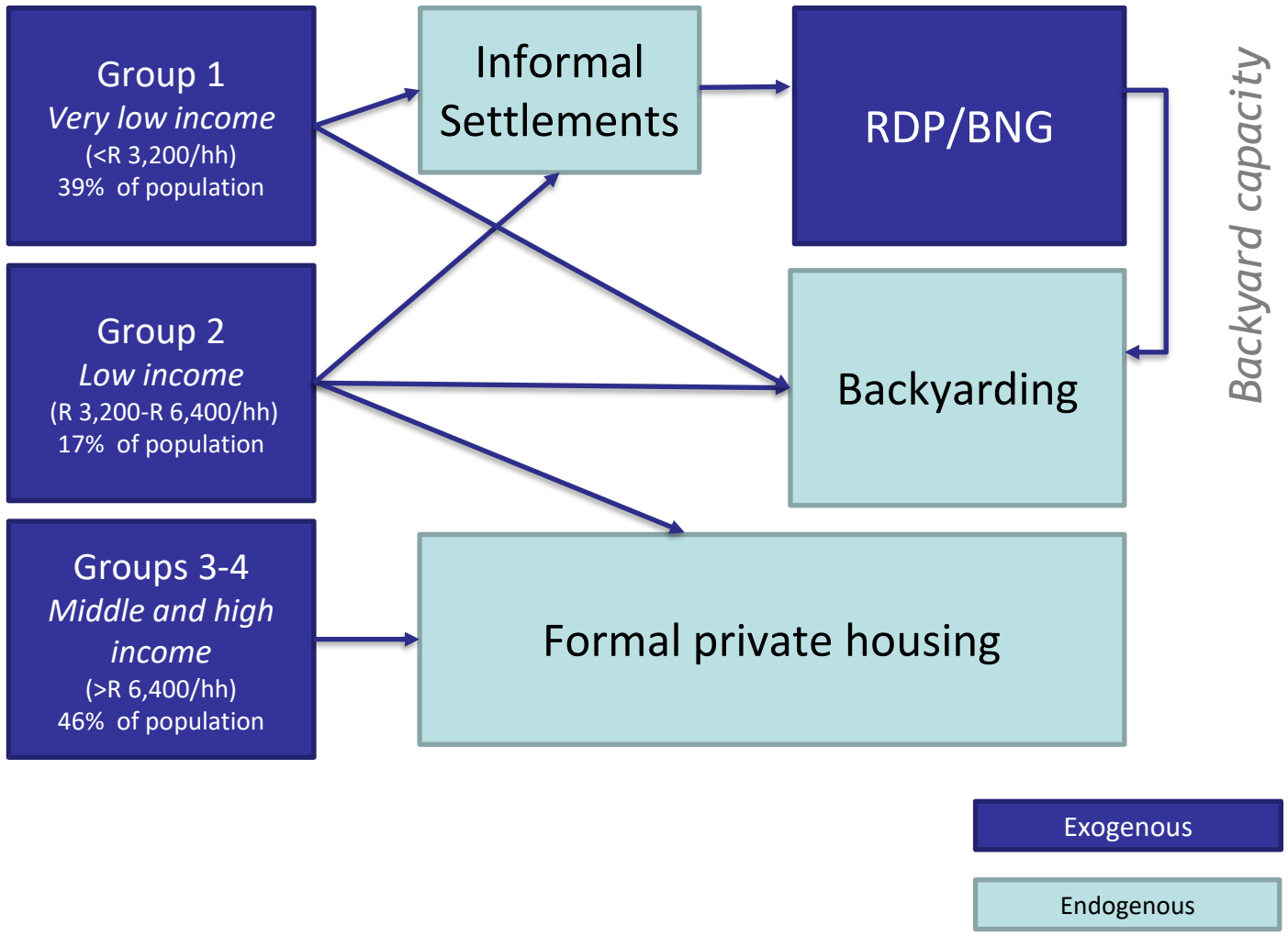
Dwellings built without building approval in the backyard of formal dwelling plots (~ 5-20m²)

Formal, free-standing state-assisted housing (~ 40-60m² dwellings on ~ 150-300m² plots)

Dwellings informally built in informal settlements (~ 10-30m² dwellings w/o title deed)

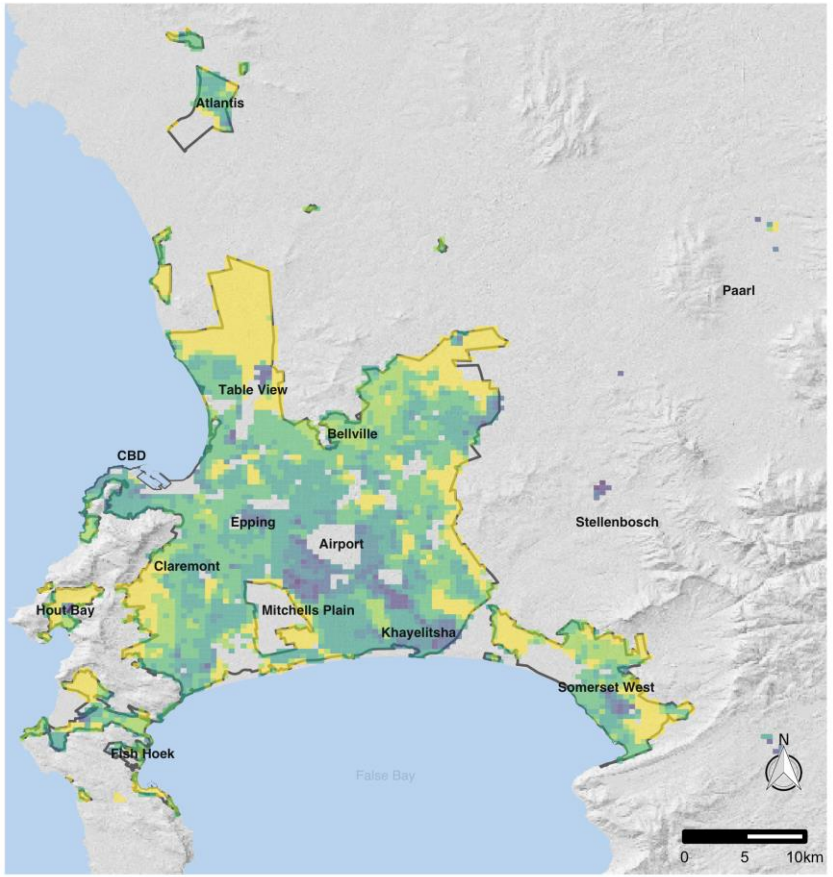
Sources: Lemanski (2009), others

Sorting into housing submarkets

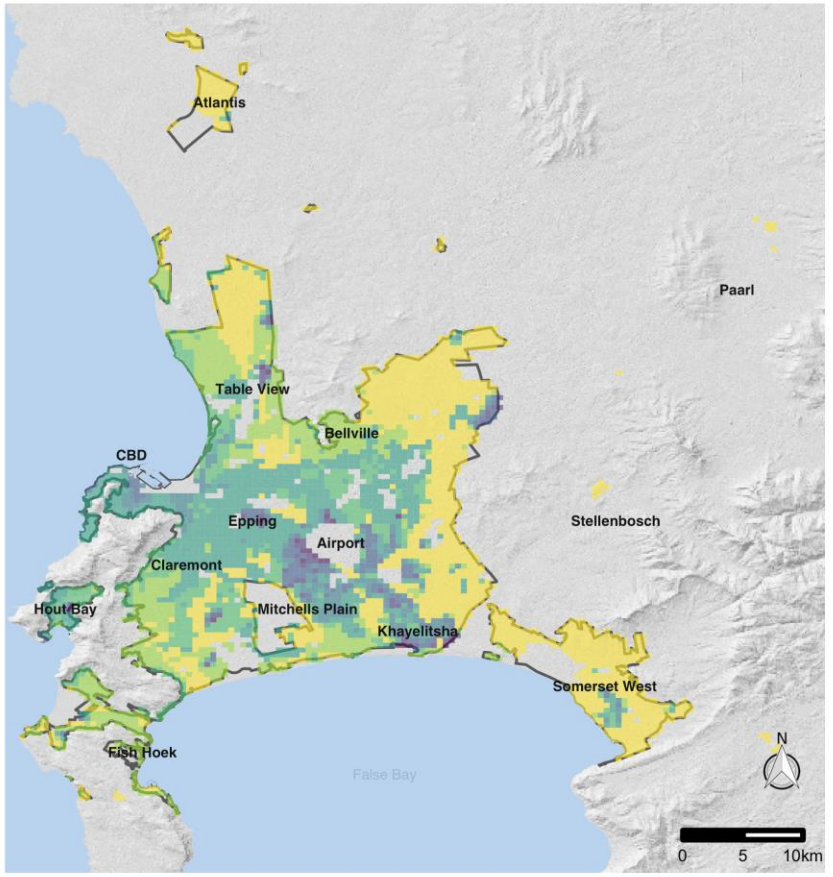


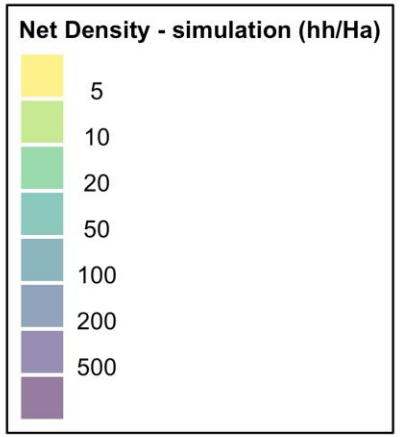
Model fit (2011)

Household density (actual data)



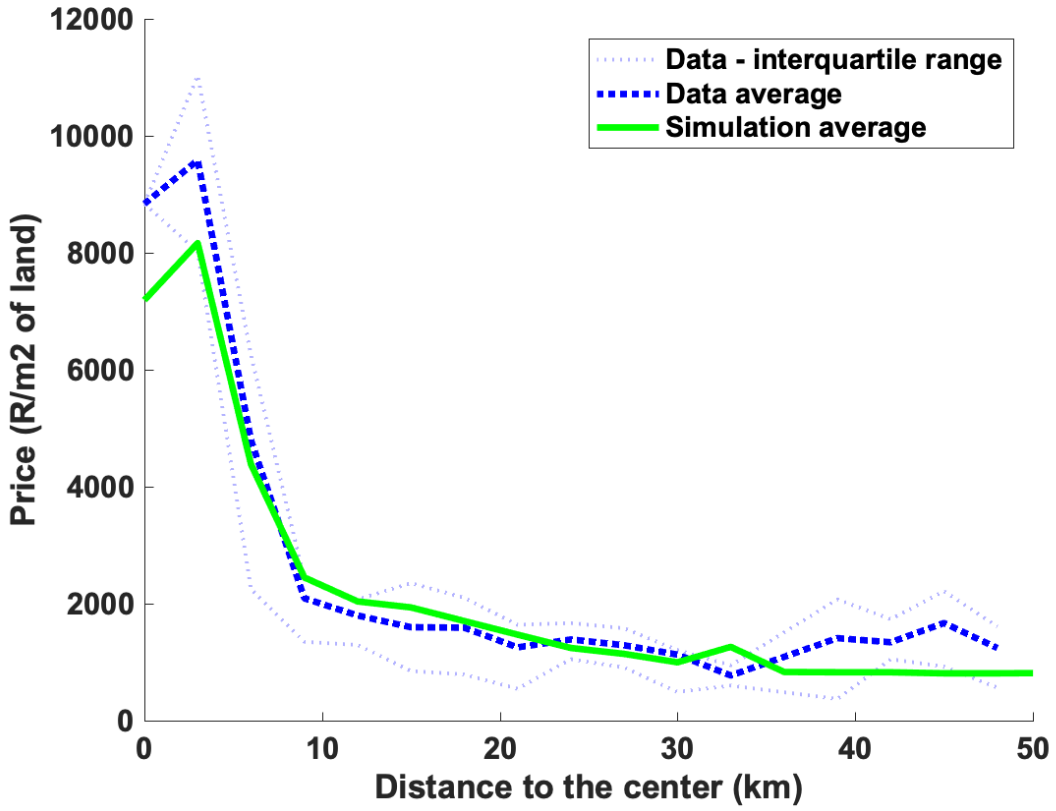
Household density (simulation)



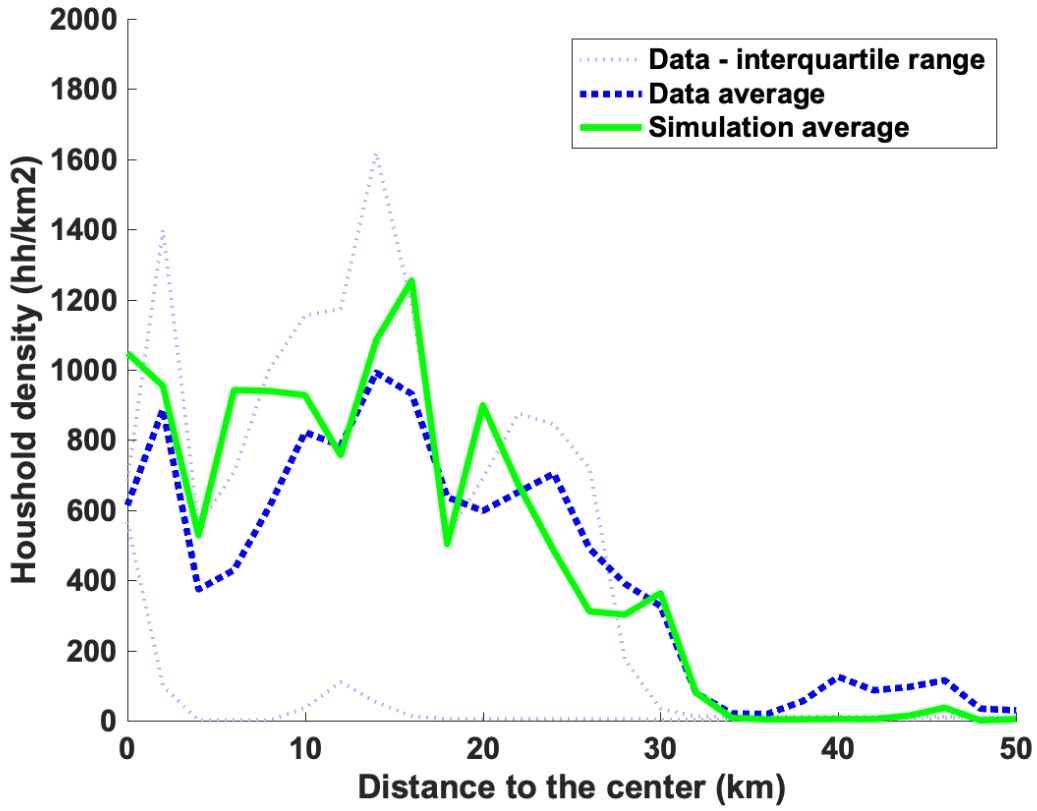


Model fit (2011)

Formal housing prices



Household density



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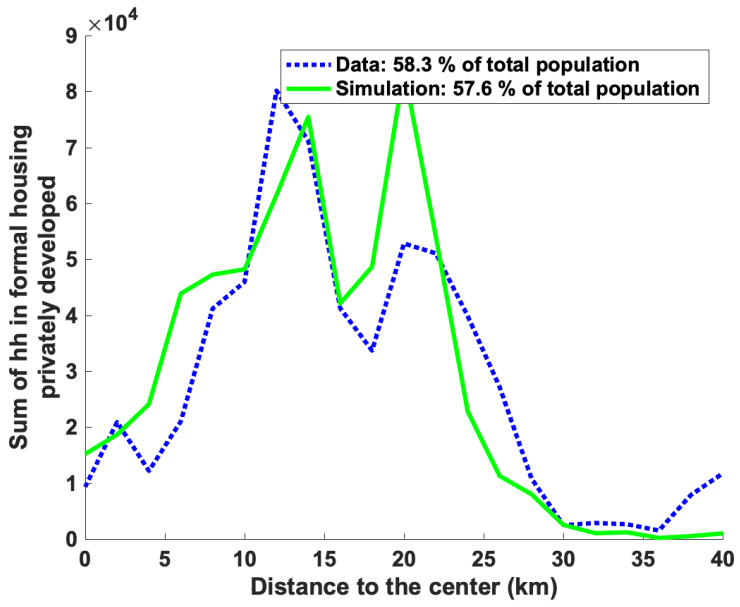
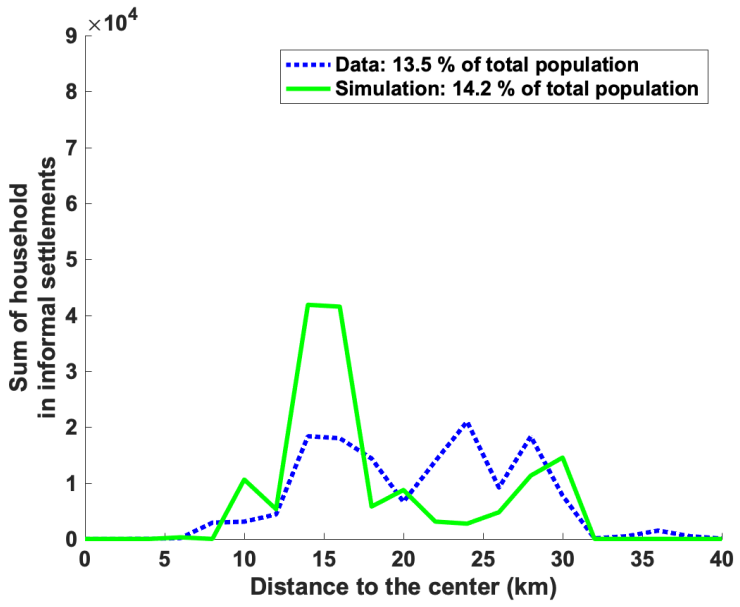
Model fit (2011)

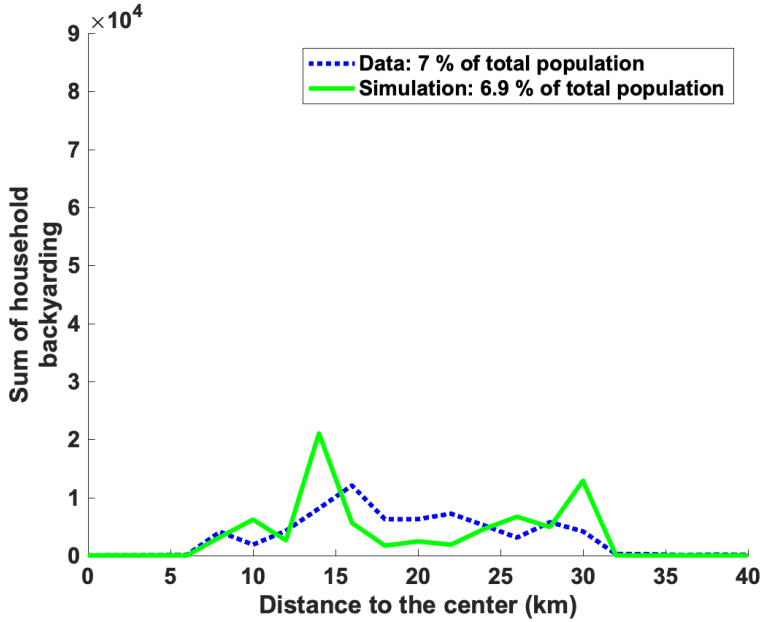
Population in formal private housing



Population in informal settlements



Population in backyards



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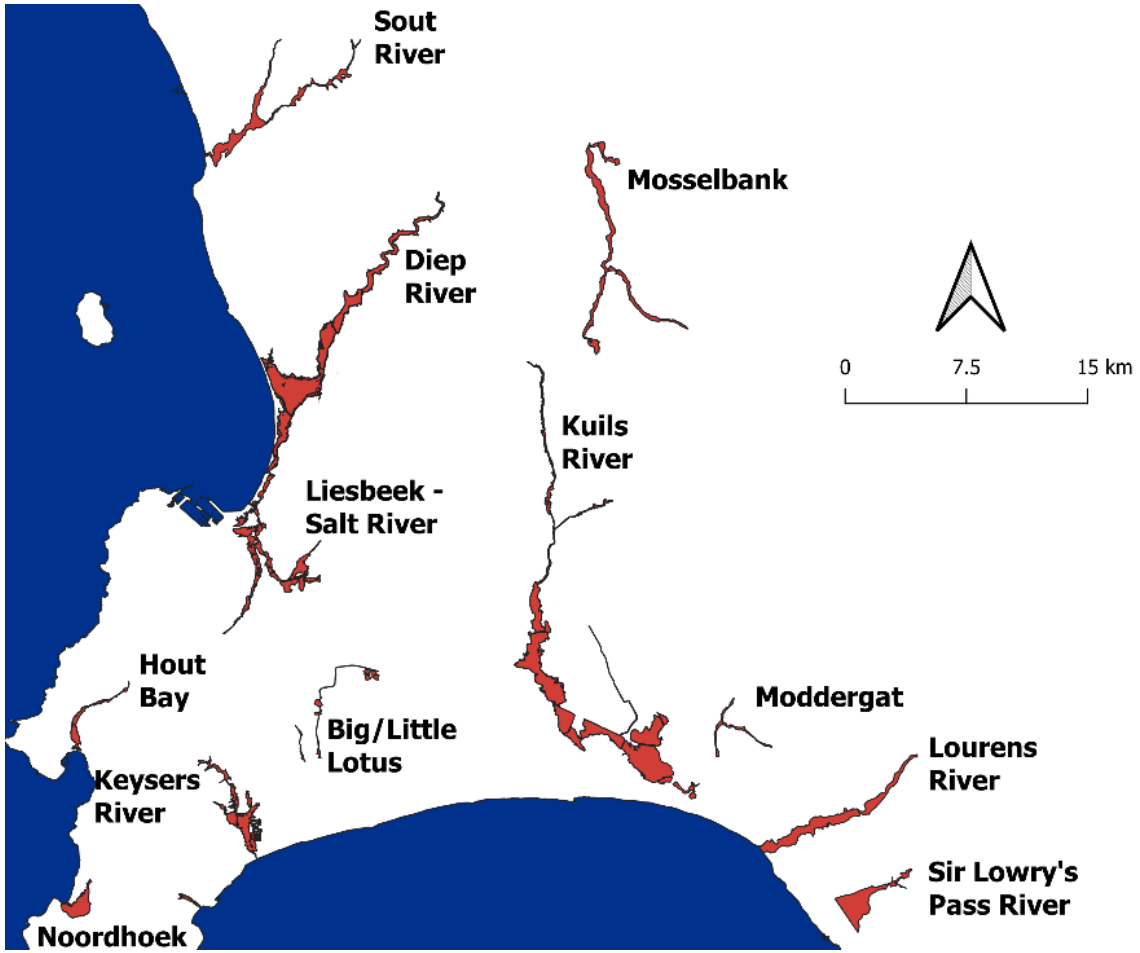
Introducing floods risks in the model



Cape Town's major flood plain

3 sources of floods

- **Fluvial** and **pluvial** using FATHOM flood maps
- **Coastal** using DELTARES flood maps

These maps provide information on:

- Flood prone areas (coasts, waterways, depression areas)
- Probability of flood occurrence
- Flood depth

2 possible impacts

- **Structural damages**: building depreciation caused by floods
- **Contents damages**: destruction of part of households' belongings due to floods

3. Simulations

Simulation outputs

- **Urban patterns**
  - sorting across the city, into housing types
- **Exposure to floods**
  - by housing types
  - by income group
- **Damages**
  - contents
  - structures (different damage functions by housing type)

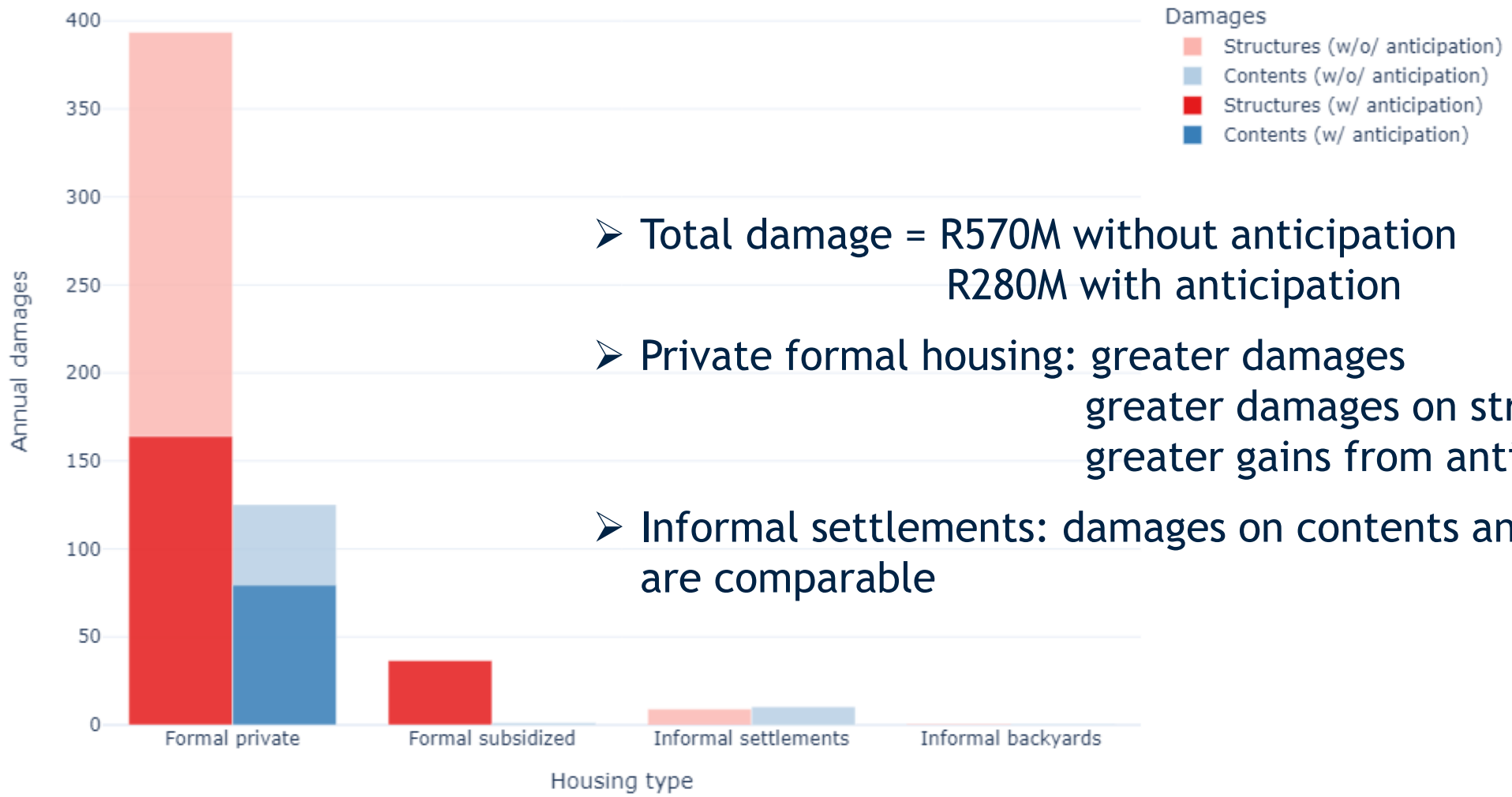
Comparing with and without anticipation of flood risks

- **Anticipation**: Households know about the frequency of floods and flood depths
  - Location decisions ("extensive margin")
  - Housing choices ("intensive margin")

- **No anticipation**: Households have no information
  - Their choices do not account for flood risks

- We focus on the difference in outcomes:
  - Outcomes without anticipation minus outcomes with anticipation

Annual damages from fluvial floods (in million Rands, 2011)



- Total damage = R570M without anticipation
  R280M with anticipation
- Private formal housing: greater damages
  greater damages on structures
  greater gains from anticipation
- Informal settlements: damages on contents and structures are comparable

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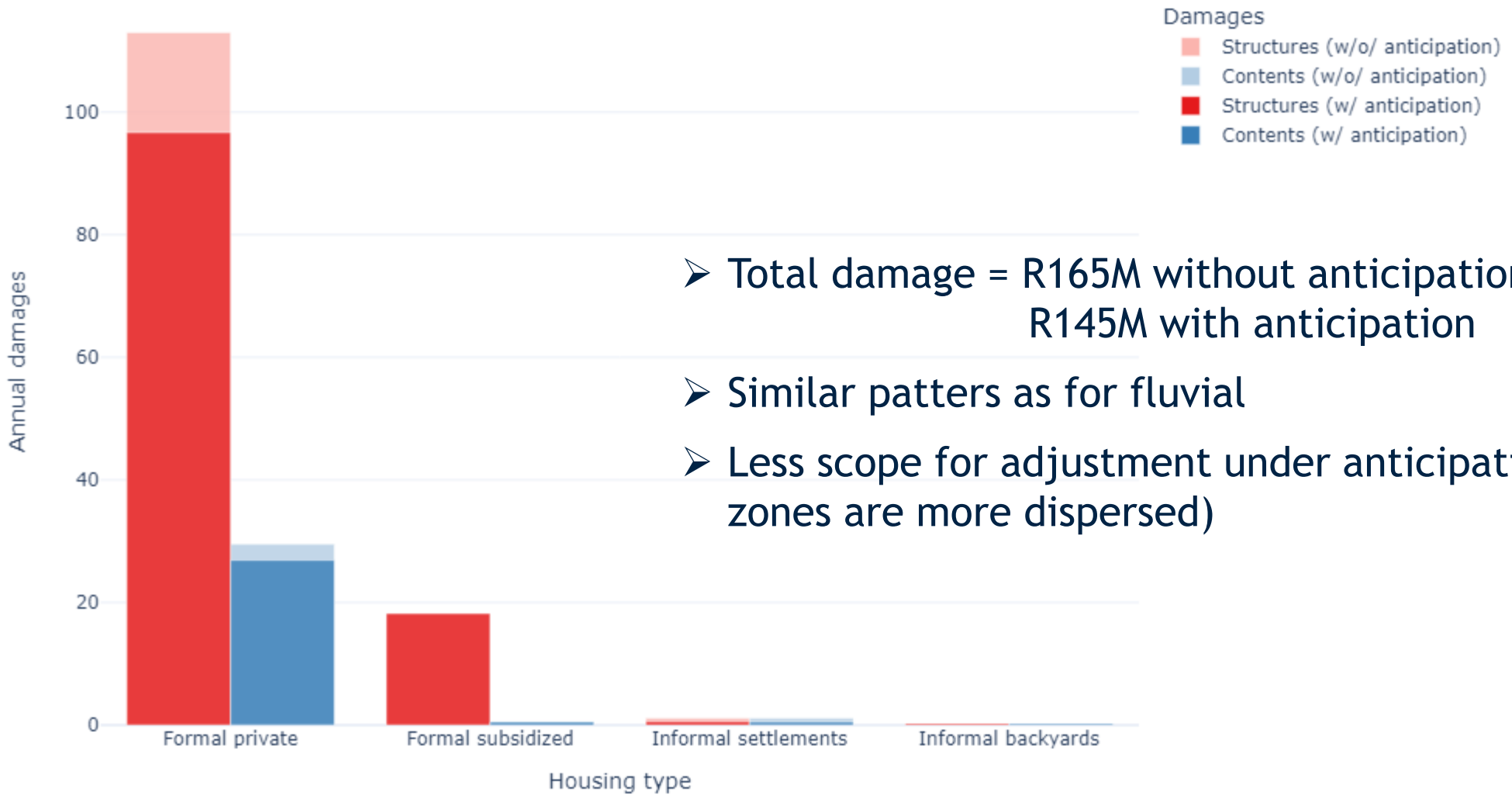
Annual damages from pluvial floods (in million Rands, 2011)



- Total damage = R165M without anticipation
  R145M with anticipation
- Similar patters as for fluvial
- Less scope for adjustment under anticipation (pluvial zones are more dispersed)

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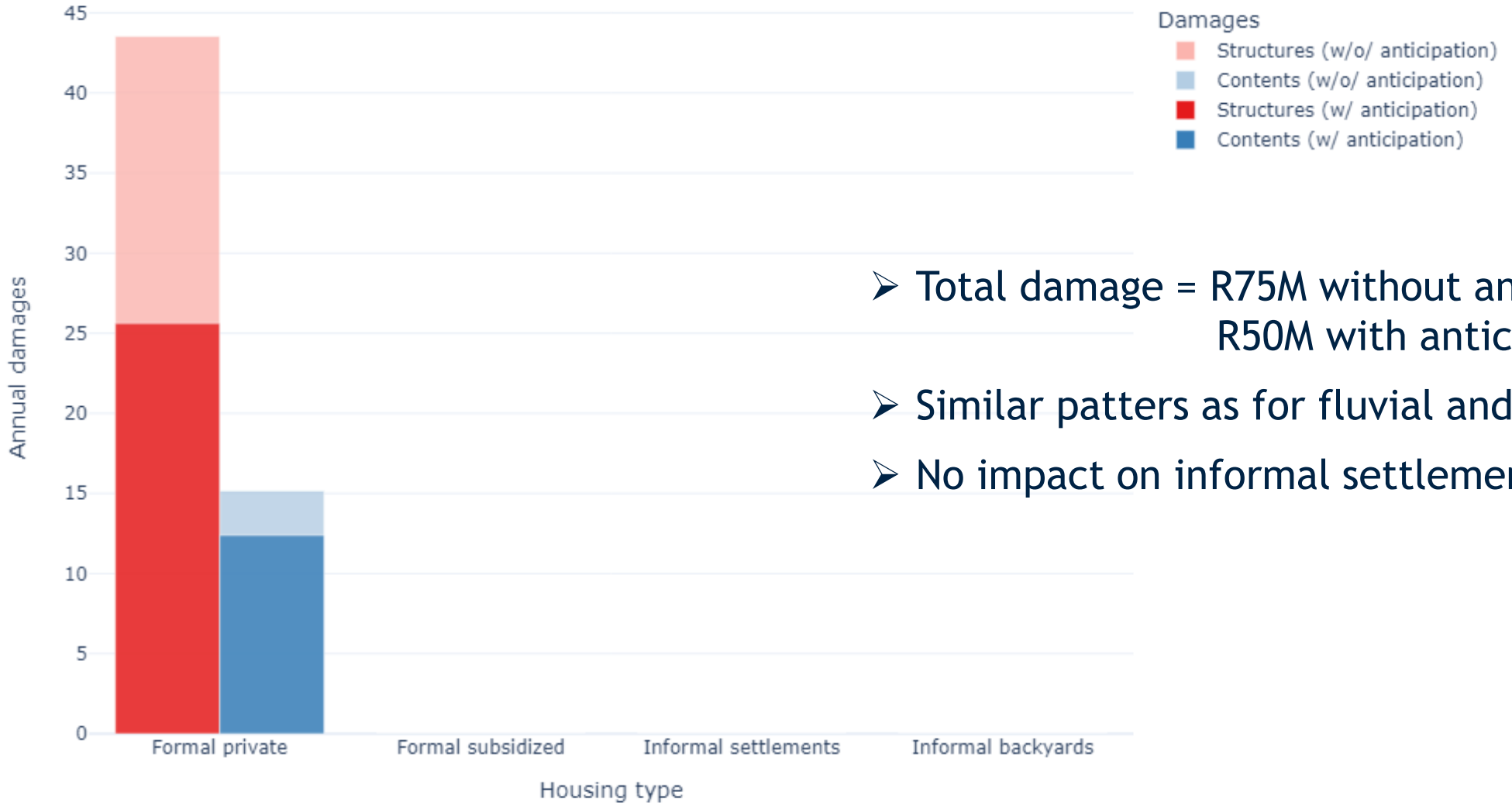
Annual damages from coastal floods (in million Rands, 2011)



- Total damage = R75M without anticipation
  R50M with anticipation
- Similar patters as for fluvial and pluvial
- No impact on informal settlements (inland)

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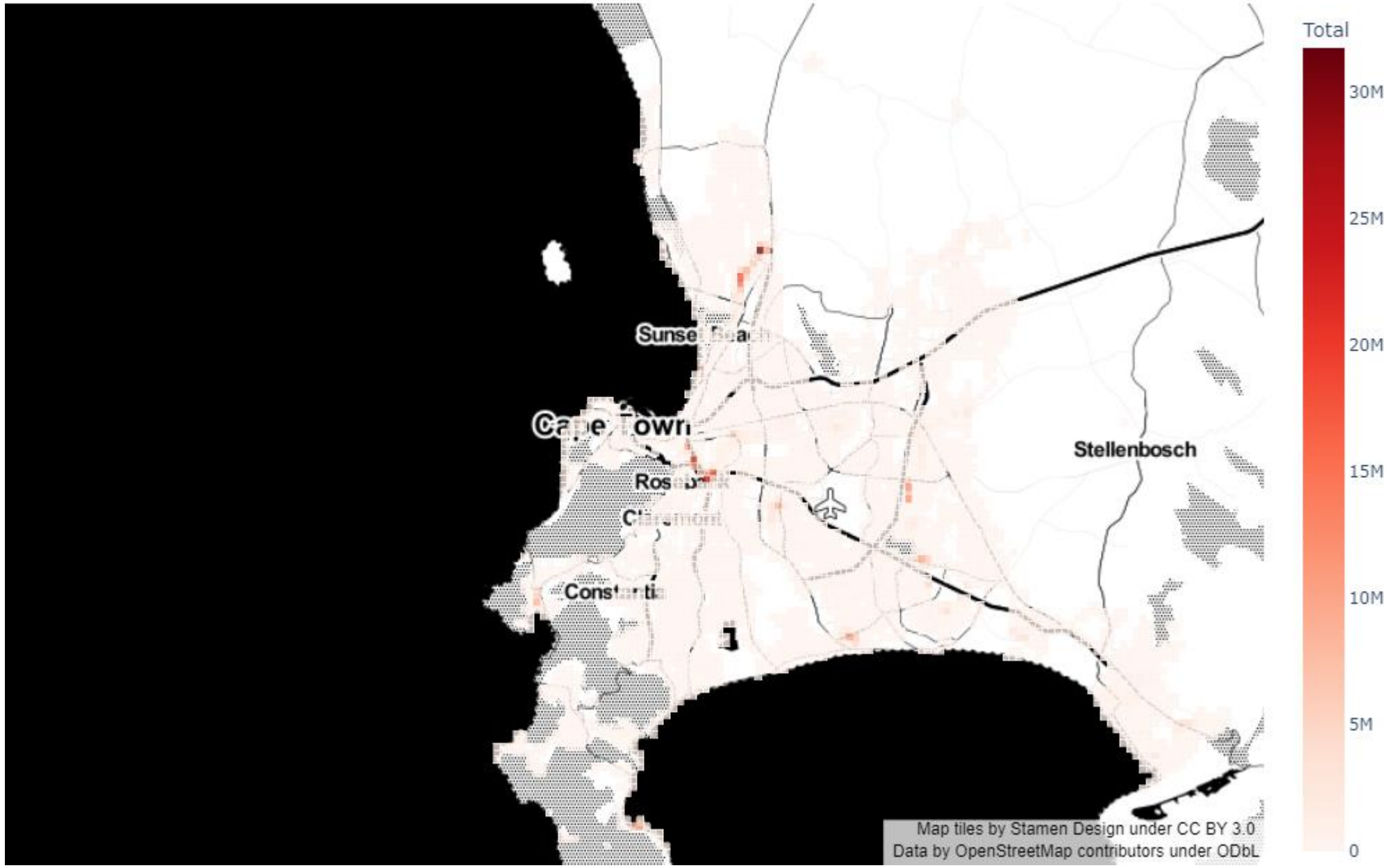
Aggregate flood damages without anticipation (in m Rands, 2011)



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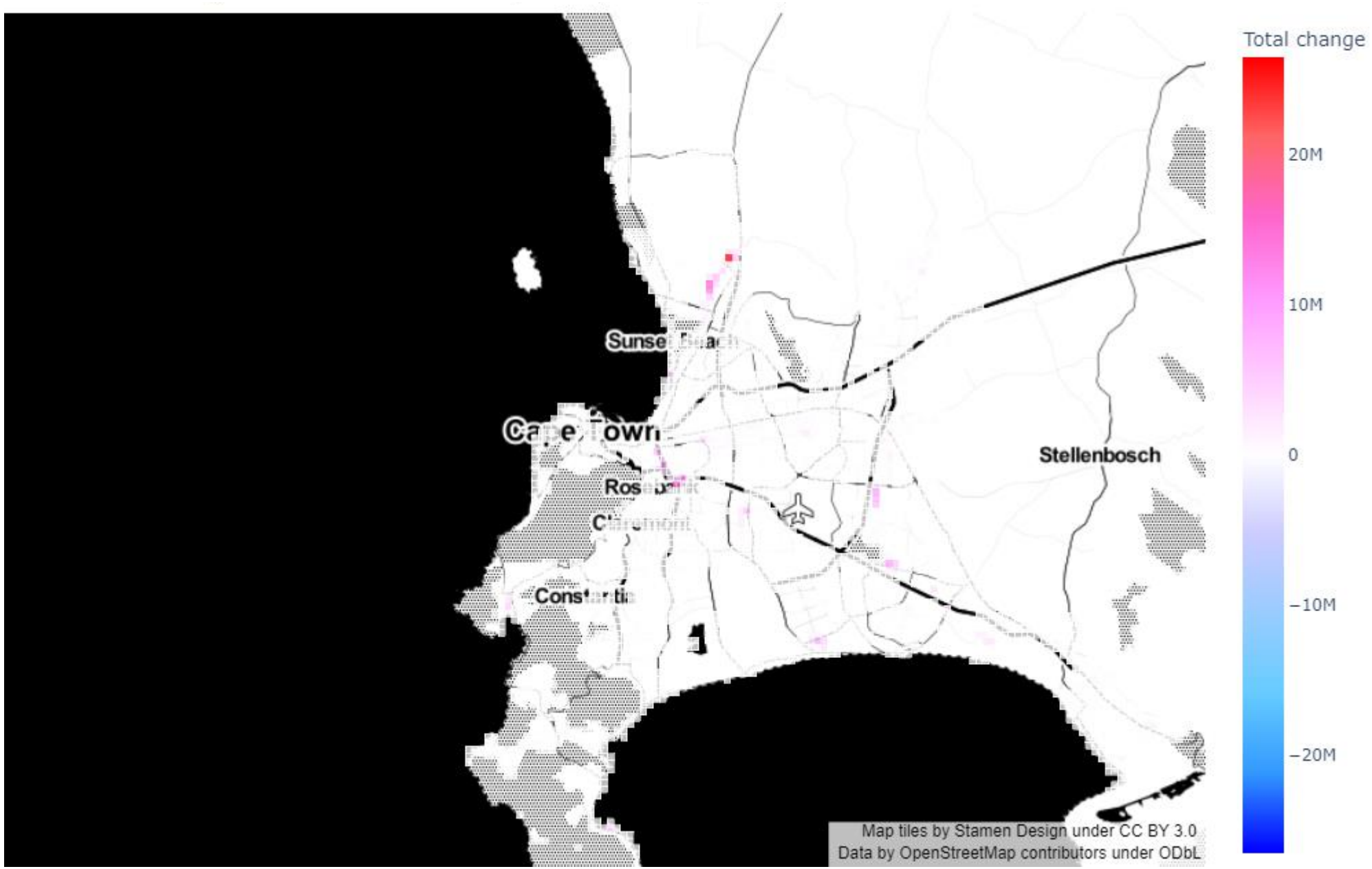
∆ Aggregate flood damages due to lack of anticipation (in m Rands, 2011)



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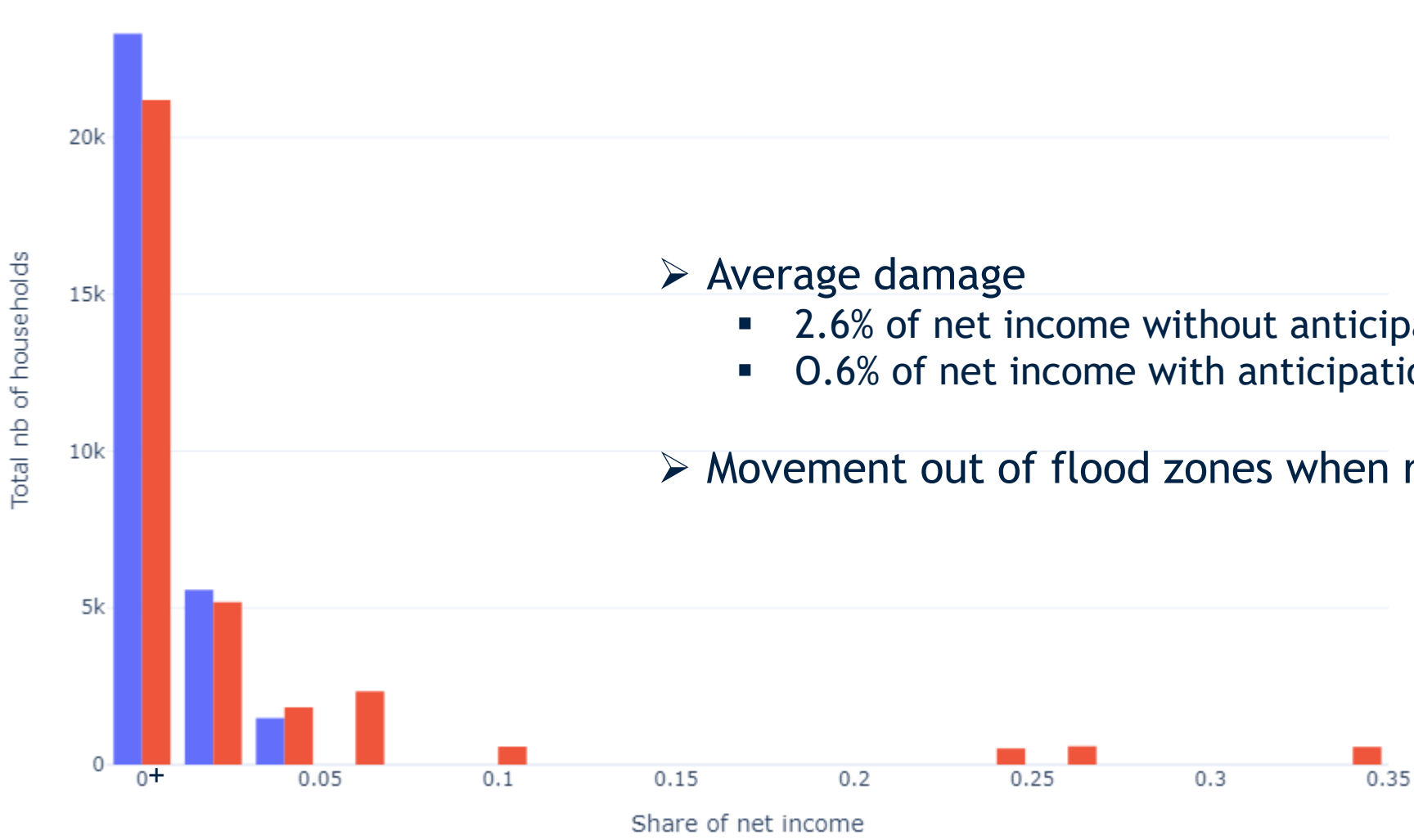
Distribution of fluvial flood damages among poor households (income group 2) living in flood zones as share of net income (in million Rands, 2011)



- Average damage
  - 2.6% of net income without anticipation (33,000 HH)
  - 0.6% of net income with anticipation (30,000 HH)
- Movement out of flood zones when risks are anticipated

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Δ # of households when there are no anticipation of aggregate flood risks

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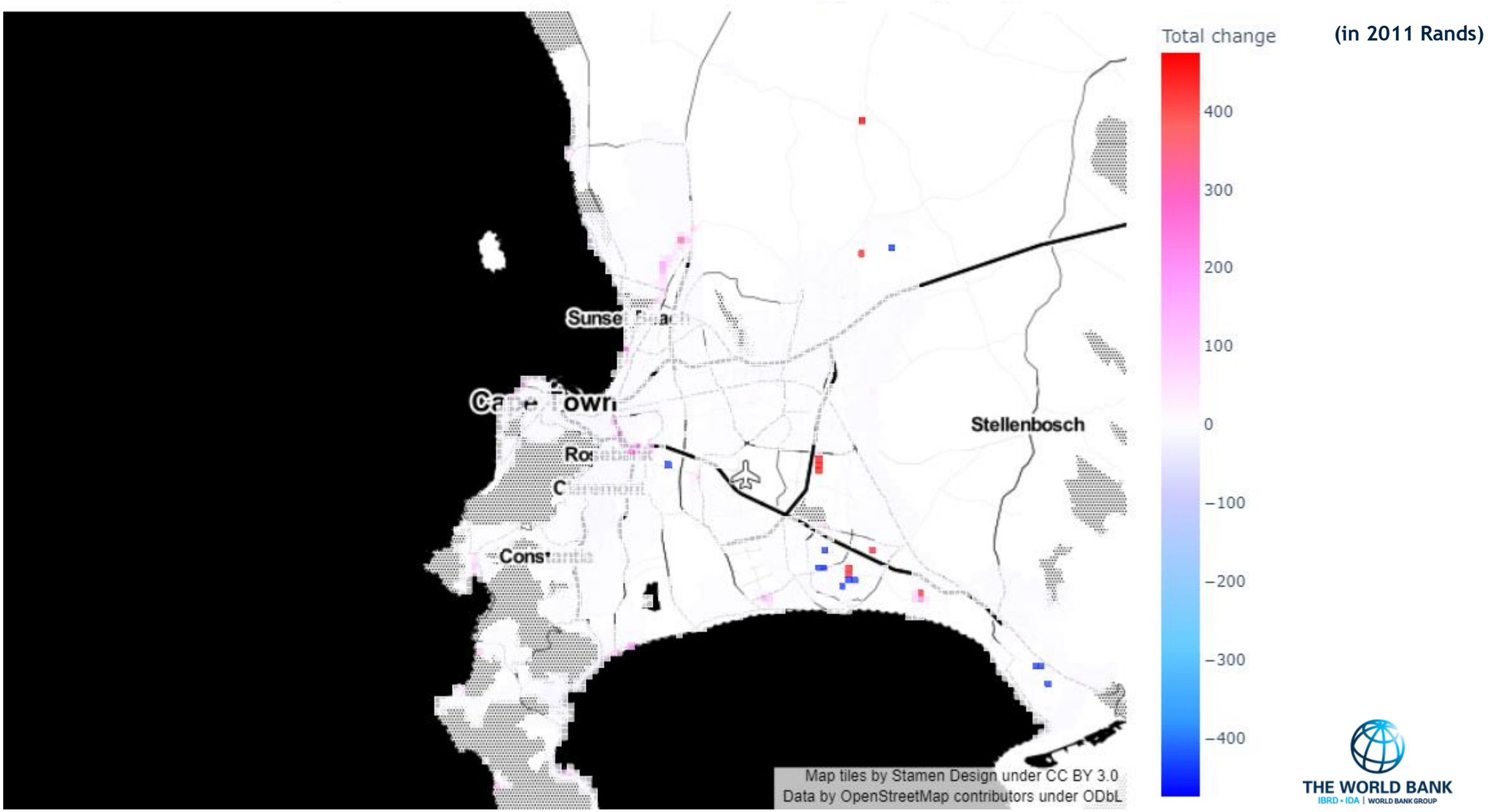
∆ annual rent / m2 in formal housing without anticipation of aggregate flood risks



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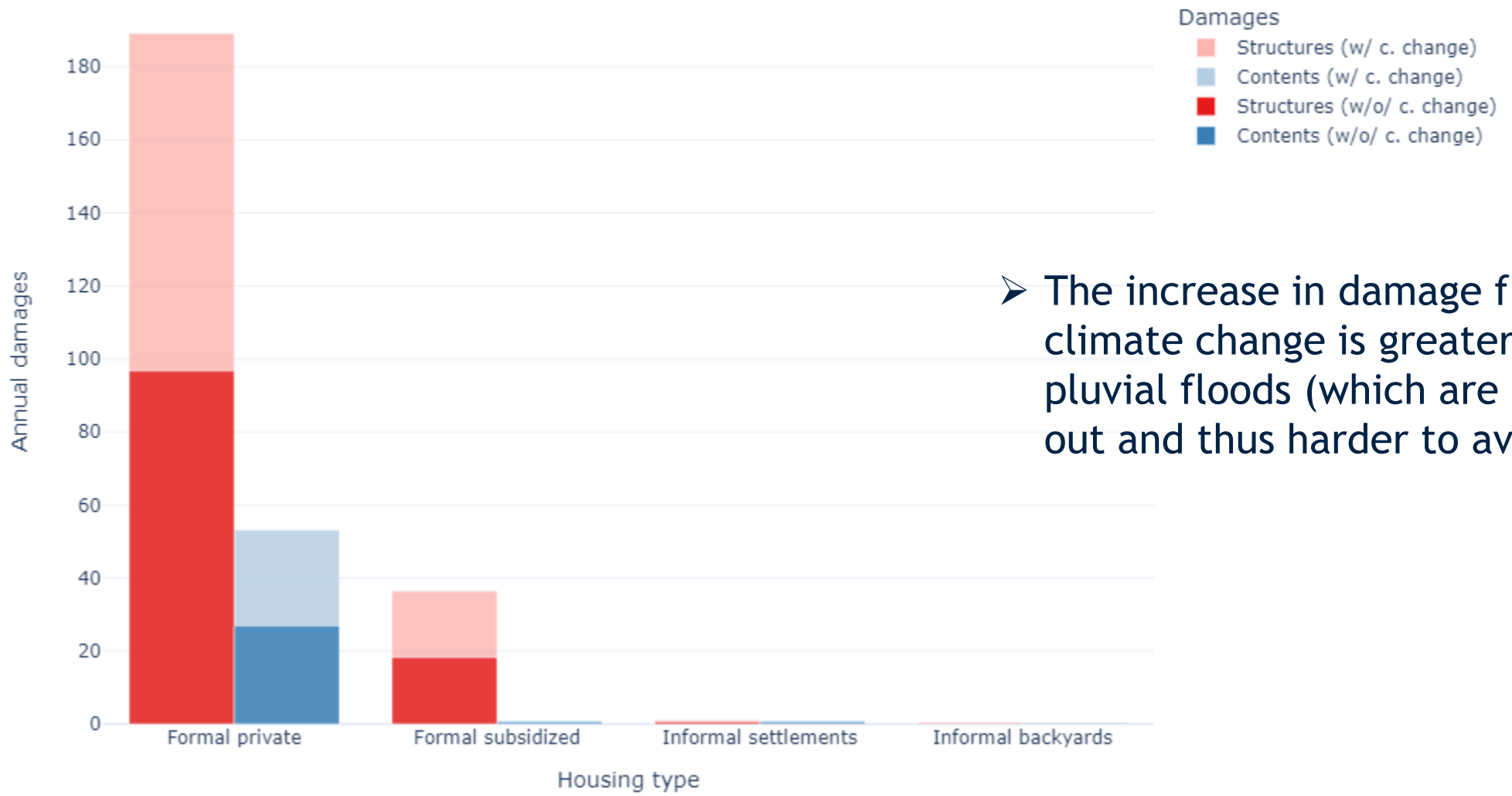
Climate change scenario (under anticipation of flood risks)

Climate change scenario

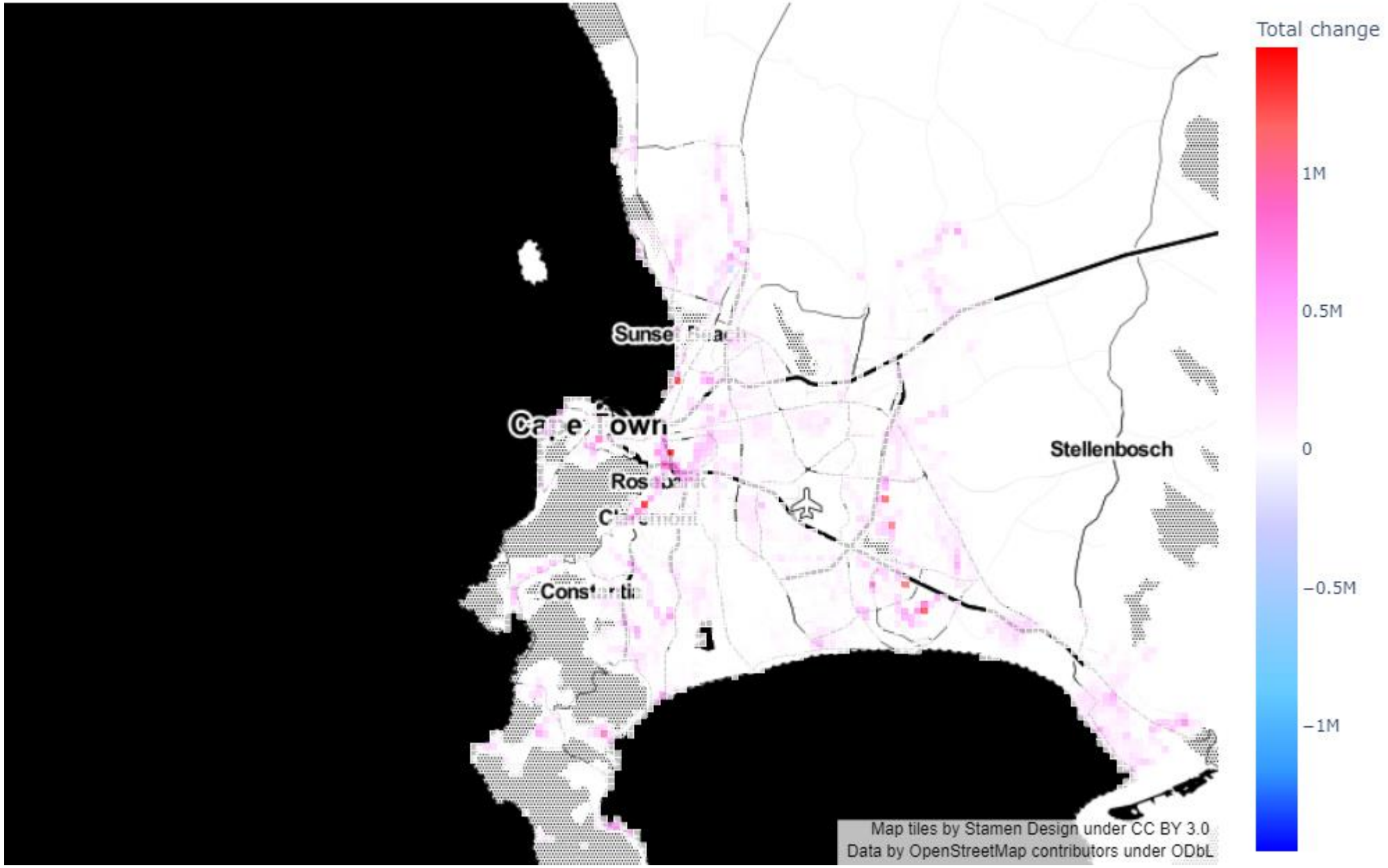
- **Coastal flood risks**
  - DELTARES flood maps (IPCC's RCP 8.5 scenario)
- **Fluvial and pluvial risks**
  - Frequency of shocks x2
- We focus on the difference in outcomes:
  - Outcomes with climate change minus outcomes without climate change

Annual damages from pluvial floods (in million Rands, 2011)



- The increase in damage from climate change is greater for pluvial floods (which are spread out and thus harder to avoid)

Aggregate flood damage increase with climate change (in M Rands. 2011)



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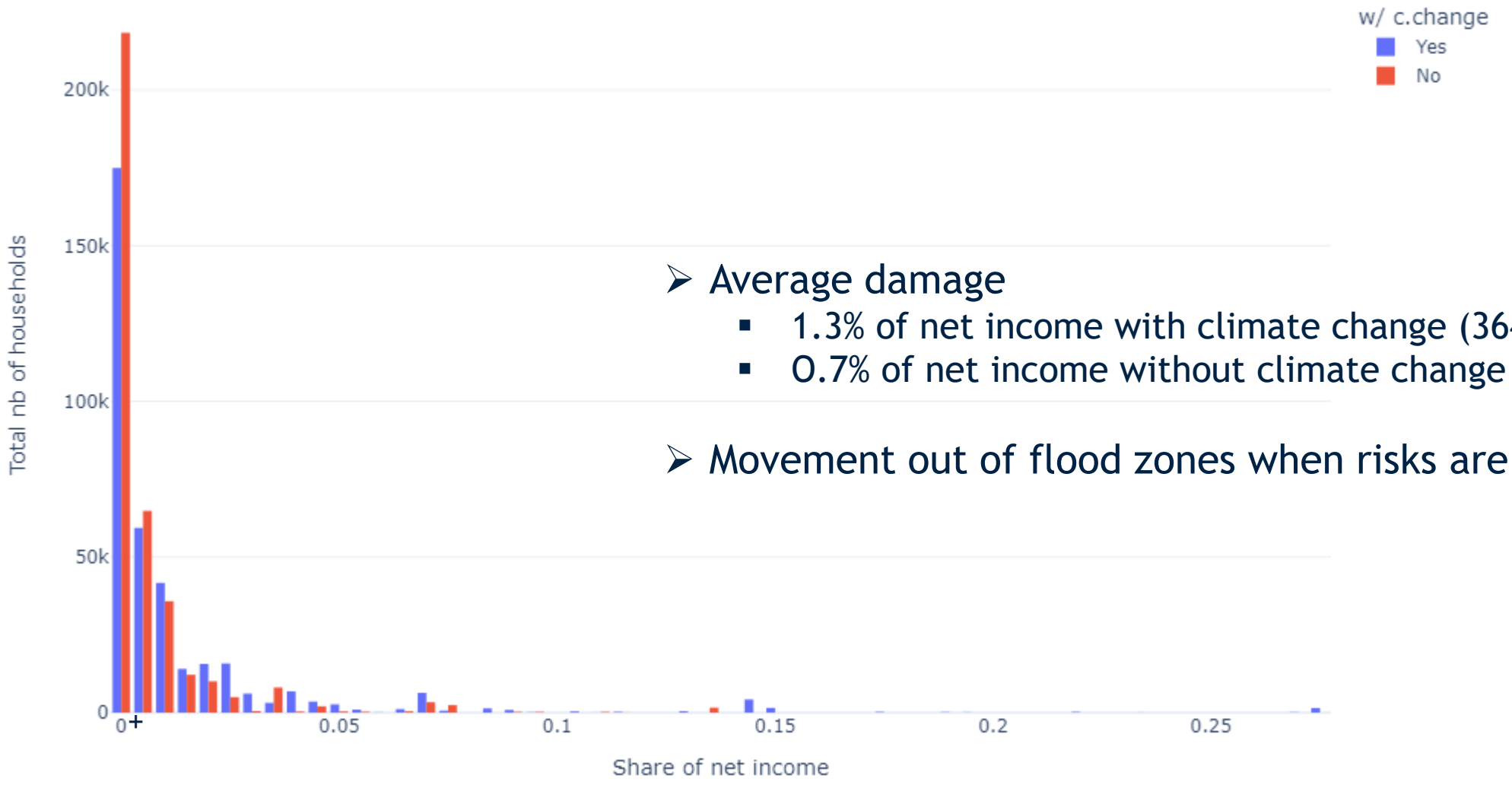
Distribution of damages from pluvial floods among the poor (income group 1) as share of net income



- Average damage
  - 1.3% of net income with climate change (364,000 HH)
  - 0.7% of net income without climate change (366,000 HH)
- Movement out of flood zones when risks are anticipated

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Change in the number of households with climate change

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Change in annual rent/m2 under climate change in formal housing (in Rands. 2011)

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4. Conclusion

Conclusion

- **Assessing climate impacts requires a model because city structure is not invariant**
- **Quantitative tool (based on urban economic theory)**
  - Simple, tractable, adaptable, open-source model
  - Can be used by local governments
- **Unequal impacts of floods in Cape Town**
  - Absolute: the rich, relative: the poor
- **Next steps and possible improvements**
  - Other costs (health, missed work)
  - Protection investments (self, public)
  - Benefit/cost analysis of flood protection investments

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