Remote Sensing of Resistance and Recovery in Beira following Cyclone Idai

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Introduction

- Cyclone Idai made landfall near Beira on night between March 14 and 15, 2019. In the Southern Hemisphere Idai ranks as the second-deadliest tropical cyclone on record with high wind speeds and subsequent large-scale floods.

- While the frequency of tropical cyclones in Eastern Africa is expected to increase as a consequence of climate change, it becomes more an more urgent to study local resilience to weather-related disasters.

- Hopefully, more knowledge about factors influencing resistance and recovery can help both first-responders and longer-term social policy makers improve targeting of assistance.

Research questions

- What are the pros and cons of using remote sensing data to measure both the impact of a cyclone and the process of reconstruction?
- Which factors affect the impact of – and recovery from - a large tropical cyclone?
- Can this knowledge be used to improve targeting of disaster relief?

Resilience concepts: resistance and recovery

- Resilience can be defined as:
- "*the ability of a system and its component parts to anticipate, **absorb**, **accommodate** or **recover** from the effects of a hazardous event in a timely and efficient manner*"

  - Resistance: how deep is the dip?
  - Recovery: how much and how fast?

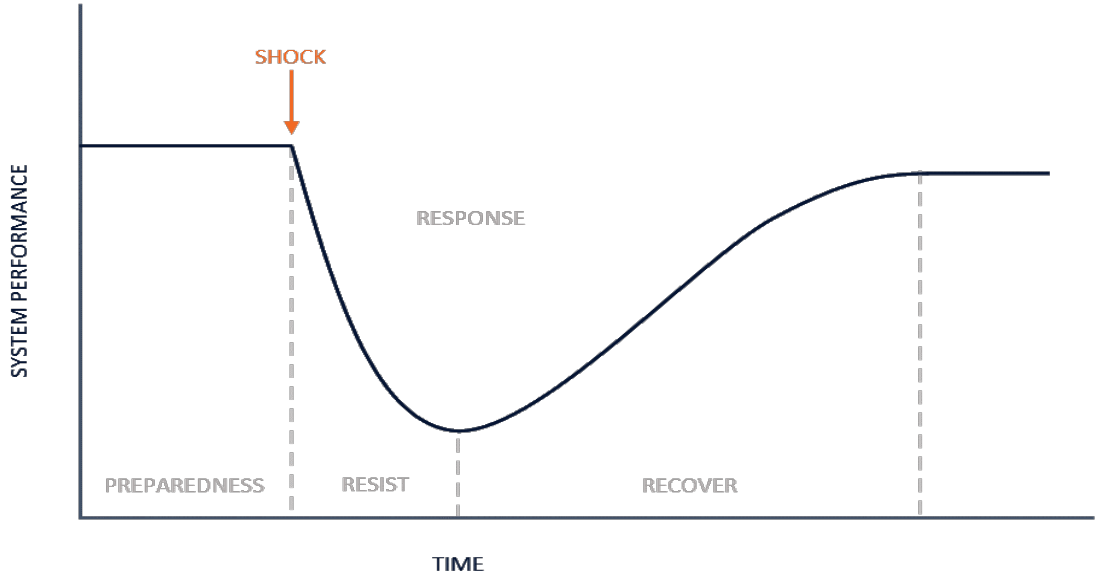


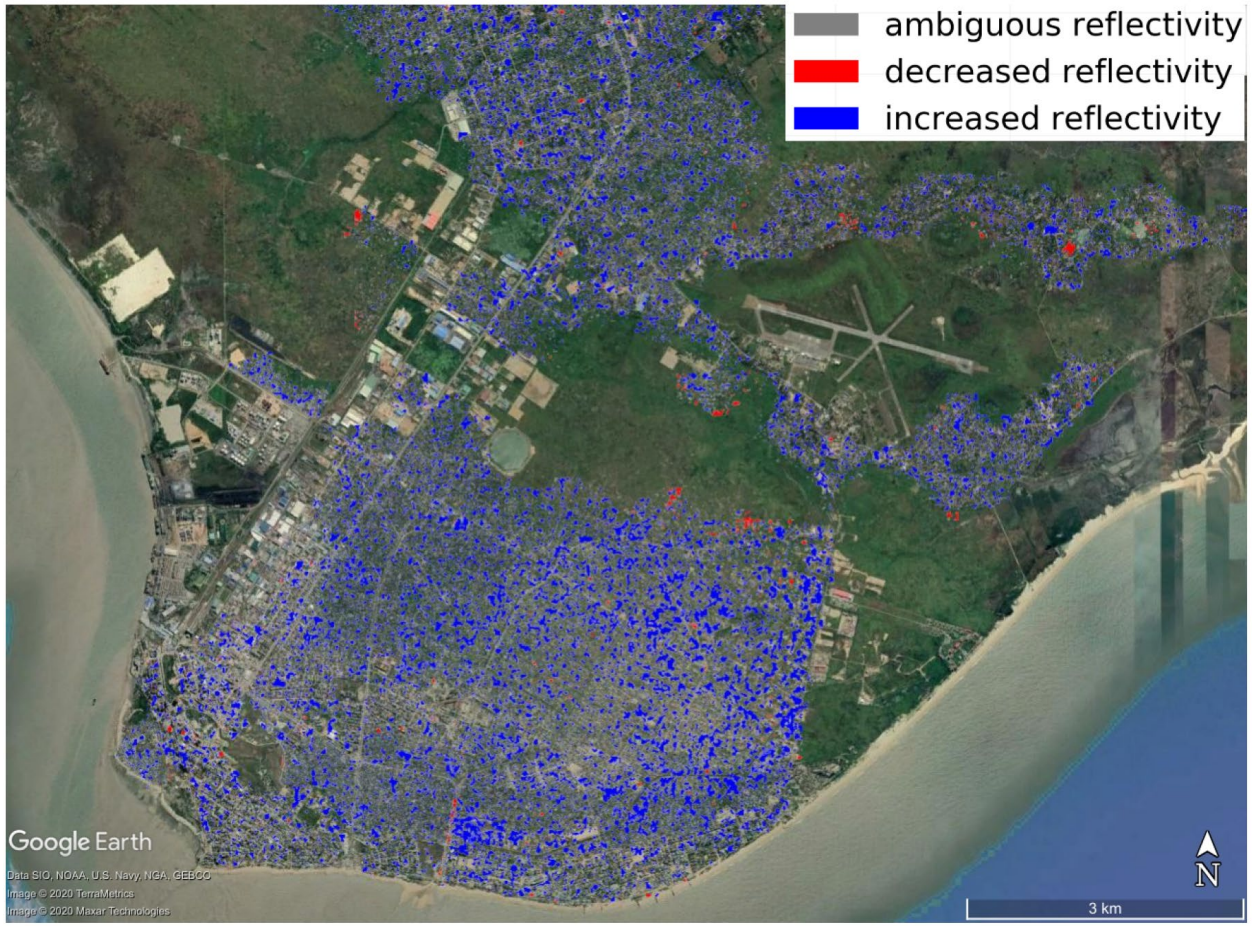
Image source: https://www.shoalgroup.com/uncategorised/understanding-resilience-in-systems/

Data sources

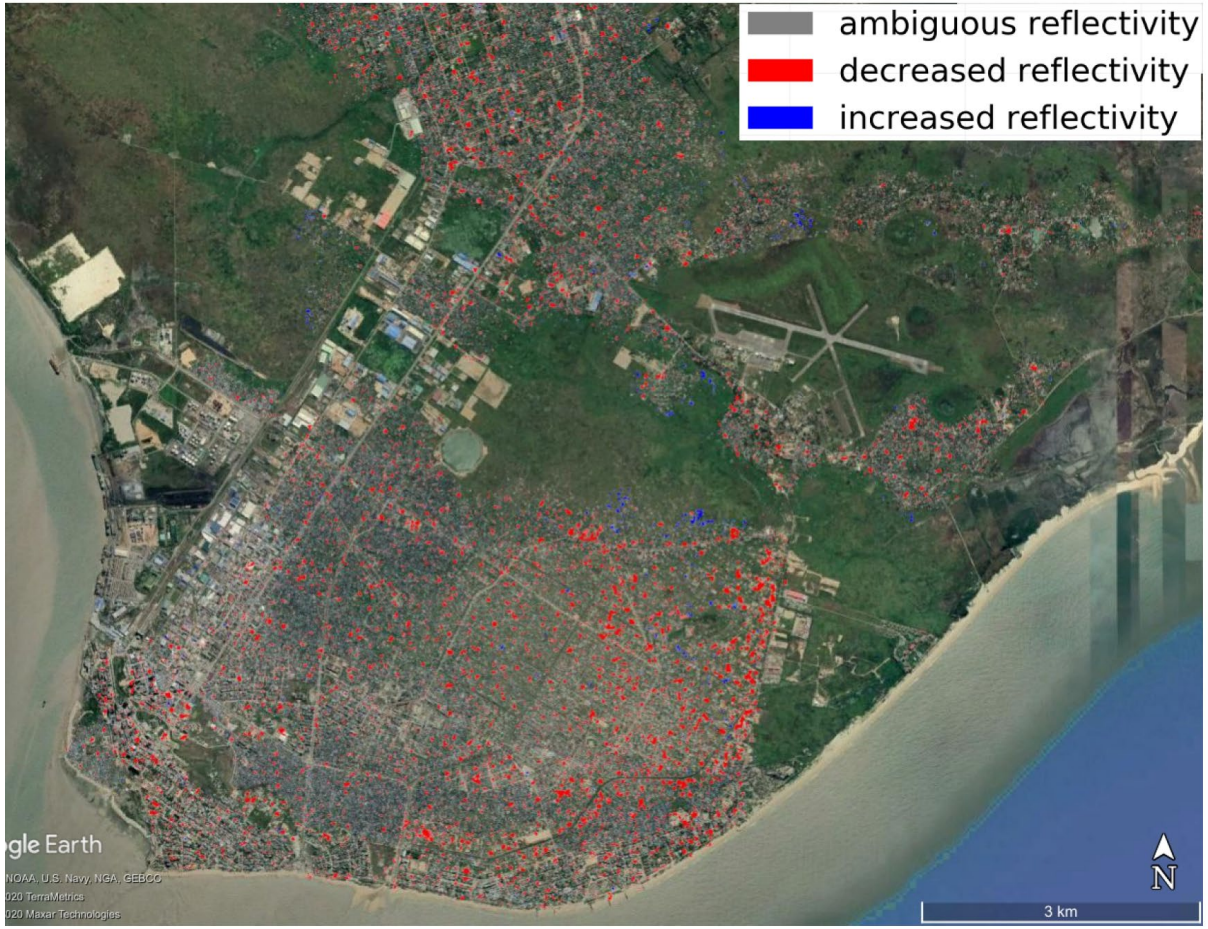
- Three sources:
  1. Radar change detections of cyclone impact
  2. New images, training, model: house detections and classifications
  3. Cell-level spatial data including construction density, initial wealth, and distances

- Unit of analysis: cells of 115m * 115m (~6,000 obs)
- Time dimensions:
  - 14-20 or 14-26 March 2019 (resistance)
  - June 2019 – Jan 2020 (reconstruction)

Data – Radar change detections



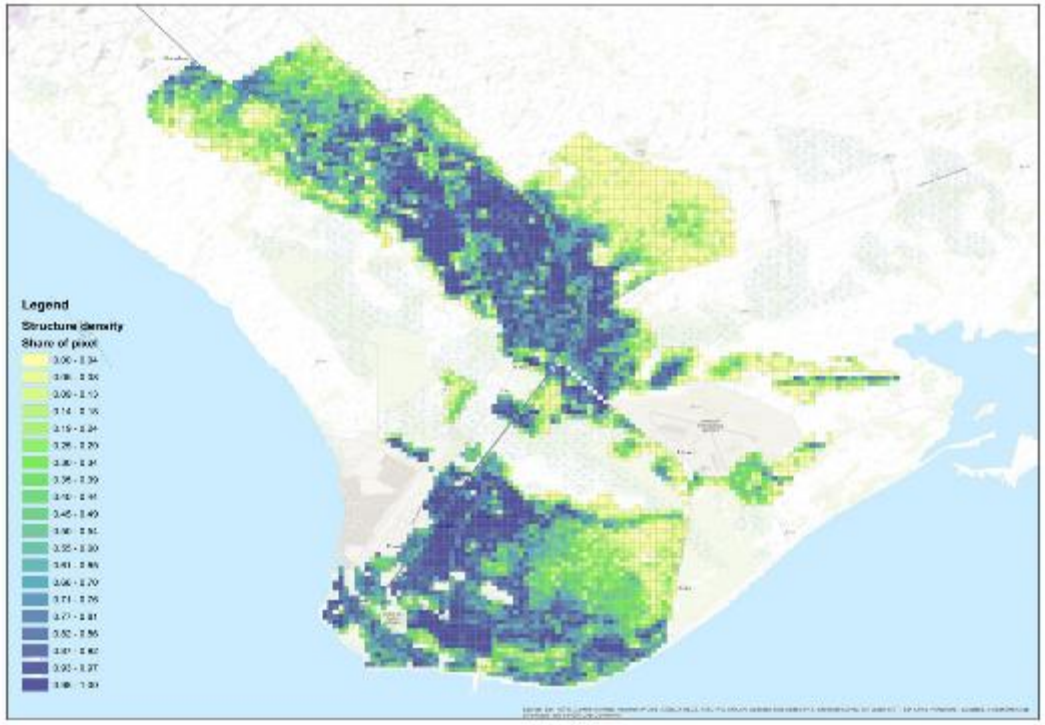
(**b**) 14 March–20 March

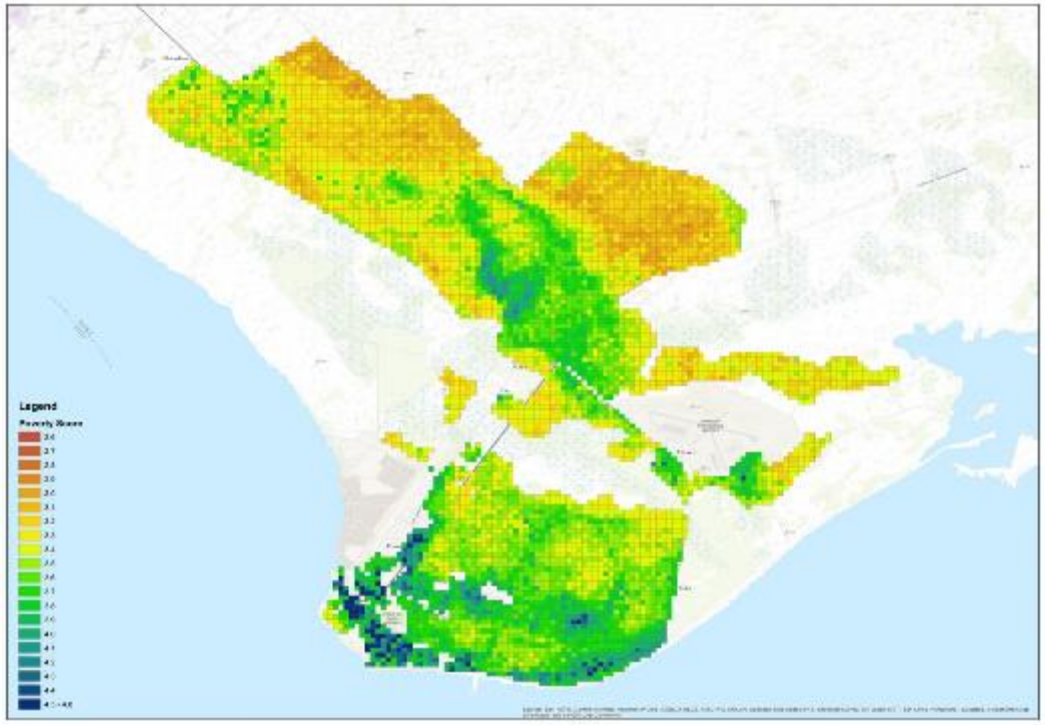


(**c**) 20 March–26 March

Data – new images, detections, classifications

Data – Poverty, infrastructure, distances





Outcome variables:

- Resistance (before-after cyclone):
  - Radar change detections (increased reflectivity) **14-20 and 14-26 March 2019**
  - Alternative: Manually damage tags **13-26 March 2019**

- Reconstruction (3-10 months after cyclone):
  - Change in share of painted roofs **June 2019 – Jan 2020**
  - Change in share of houses under construction **June 2019 – Jan 2020**

Explanatory variables

- Cyclone exposure:
  - Distance to coast
  - Radar changes March 14-20
- Initial wealth:
  - Estimated PMT score (2018)
- Access to services:
  - Distance to city centre
  - Distance to primary road (from OSM)
  - PASP coverage (from WB/INAS)
- Neighborhood fixed effects

Hypotheses

- Resistance:
  - Indicators: Radar change detections before-after cyclone, manual damage tags
  - Degree of destruction depends on **initial wealth** (better houses more resistant), **construction density** and **exposure to hazard**
- Recovery:
  - Indicators: a positive change in share of painted roofs, buildings under construction
  - Process of recovery depends on **scale of destruction, initial wealth,** and **access to services (schools, roads, social protection, manufacturers)**

Estimation models

For all units of analysis, i.e. cells falling within the city limits, resistance to the immediate cyclone impact can be assessed by estimating the following:

$$Impact = \beta_1 PMT + \beta_2 density + \beta_3 dist.coast + \epsilon \quad (1)$$

In a similar fashion, the process of reconstruction can be analysed in a regression set-up:

$$Recon = \beta_1 PMT + \beta_2 Impact + \beta_3 density + \beta_4 dist + \beta_5 SP + \gamma + \epsilon \quad (2)$$

Results

Table 1: Resistance

	(1)	(2)	(3)	(4)	(5)	(6)
Initial wealth	0.01	0.02	-0.05***	-0.08***	-0.11***	-0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Density	0.15***	0.15***	-0.12***	-0.13***	0.03***	0.04***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Dist. coast		0.01*		-0.01***		0.02***
		(0.00)		(0.00)		(0.00)
Constant	0.61***	0.53***	0.66***	0.88***	0.53***	0.29***
	(0.04)	(0.06)	(0.03)	(0.06)	(0.02)	(0.03)
N	5650	5650	5650	5650	5003	5003
r2	0.02	0.02	0.02	0.03	0.06	0.08

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Column 1-2: share of building pixels with increase in reflectivity March 14-20. Column 3-4: share of building pixels with increase in reflectivity March 14-26. Column 5-6: Number of manual tags divided by number of building pixels 14-20

Results

Table 2: Reconstruction

	(1)	(2)	(3)	(4)	(5)	(6)
Initial wealth	0.10***	0.06***	0.05***	0.10***	0.11***	0.12***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Cyclone impact	-0.01	-0.01	-0.01	0.02*	0.01	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Dist. city centre		-0.65***	-1.87***		0.25***	0.78**
		(0.06)	(0.24)		(0.08)	(0.31)
Dist. prim. road		-0.61***	-0.74***		1.72***	0.29
		(0.12)	(0.27)		(0.15)	(0.36)
SP coverage		0.00	0.00		-0.03***	-0.02***
		(0.00)	(0.00)		(0.01)	(0.01)
Constant	-0.32***	-0.12***	-0.08**	-0.32***	-0.40***	-0.41***
	(0.02)	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)
N	5473	5473	5473	5473	5473	5473
r2	0.06	0.08	0.11	0.03	0.06	0.10

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Column 1-3: change in share of painted roofs, column 4-6: change in share of buildings under construction. Column 3 and 6 include neighborhood fixed effects

Preliminary conclusions

- Remote sensing data is useful for measuring both cyclone impacts and process of reconstruction – with caution! If data extracted from satellite images and radar change detections is valid, the following messages emerge:

- Richer, and denser neighbourhoods faced a lower immediate cyclone impact (measured as share of built-up area damaged – after first clean-up)

- Reconstruction process is largely unaffected by initial degree of damages, but more pronounced in richer areas for both the change in the share of high-quality roofs and buildings under construction.
- The former more so closer to the city centre and primary roads while the relation is opposite for the change in buildings under construction.
- Correlations robust to neighbourhood fixed effects.

Caveats

- Is it really cyclone damages that we are measuring?
  - Changes in the share of building pixels that show increased reflectivity filtered by building footprints
  - *Malmgren-Hansen et al. (2020)* discusses this in detail

- Is it really reconstruction that we are measuring?
  - Change in share of house detections that have a painted roof and change in share of house detections that seem to be buildings under construction, June 2019- Jan 2020
    - Can we trust the CNN estimates? See discussion in Fisker et al. (2020) (Ring Road paper)
    - Is it **re-**construction or just urban development?

- Is it really initial wealth that we are measuring?
  - See *Sohnesen et al. (2020)* for a better introduction to this