

Mozambique cholera risk from Cyclones Idai & Kenneth

Shiny app: <https://mahmud-ayesha.shinyapps.io/Cholera-MOZ/>

Methods Overview

We modeled cholera outbreak risk based on four measures:

1. Gravity model simulating human mobility
2. Previous cholera incidence
3. Flooding risk index (based on measured flooding from Cyclone Idai and projected flooding for Cyclone Kenneth)
4. El Niño sensitivity

Gravity model

- In the gravity (diffusion) model, we assume that travel from Beira occurs based on the population size of Beira, the population size of the receiving district and the geodesic distance between Beira and the receiving district.
- Formula:
$$\frac{\sqrt{population} * \sqrt{origin_population}}{distance}$$
 - Similar results obtained using different exponents
 - [Wesolowski et al. 2015](#)
- High resolution population data comes from [Facebook](#).

Previous Cholera Incidence

- This risk index is based on modeled annual cholera incidence, based on previous cholera outbreak data and ecological data, from [Lessler et al.](#)

Flood

- Cyclone Idai
 - The flooding index is based on the flood extent maps from [here](#).
 - This index is based on the proportion of area within each district that was affected by flooding following Cyclone Idai.
- Cyclone Kenneth
 - We assumed Tropical Cyclone Kenneth would follow the trajectory described here. and affect mainly the Cabo Delgado province. We assumed the impact would be highest in the districts closest to the storm trajectory (provided by NETHOPE on April 25th), with less impact in the districts further away (risk decays with distance). Only districts within the uncertainty zone were considered at risk.

El Niño sensitivity

- This risk index is based on comparisons of cholera incidence between El Niño and non El Niño years, from [Moore et al.](#).
- We only display sensitivity for districts that have higher incidence in El Niño years.

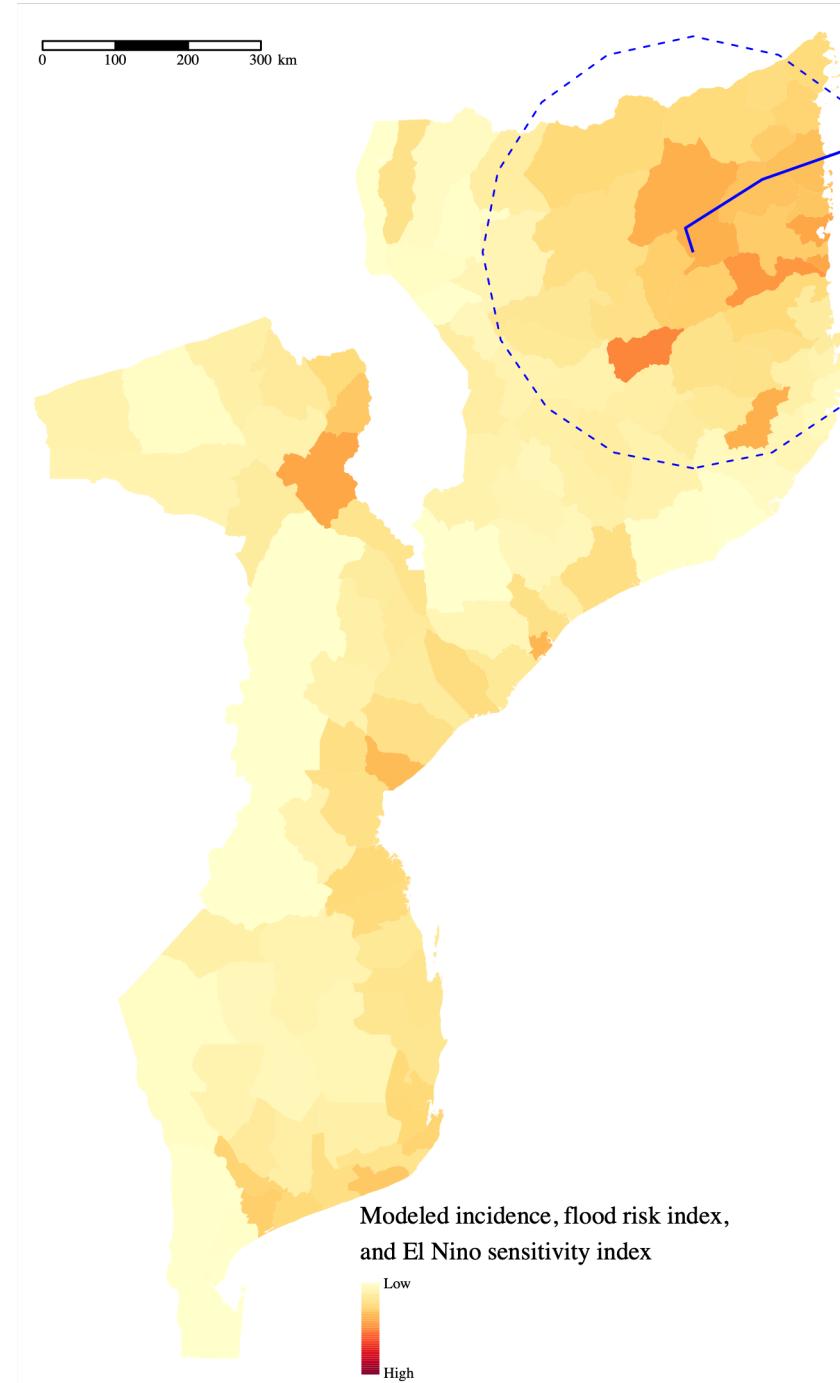
Combining risks

- We scaled all risk scores to be between zero and one. The maps display each risk score separately, as well as an average of the scores when multiple indices are selected.

Cyclone Kenneth: projected risk

- For Cyclone Kenneth, the projected risk is an average of the flooding index, El Niño sensitivity index and previous cholera incidence.
- The maps combining gravity model risk and Kenneth flood risk (see Appendix) still assume that the outbreak would be sparked from Beira, while the flood + El Niño sensitivity + incidence map provides an assessment of which districts may be most vulnerable.

**Previous Cholera
Incidence +
Kenneth Flood +
El Niño**



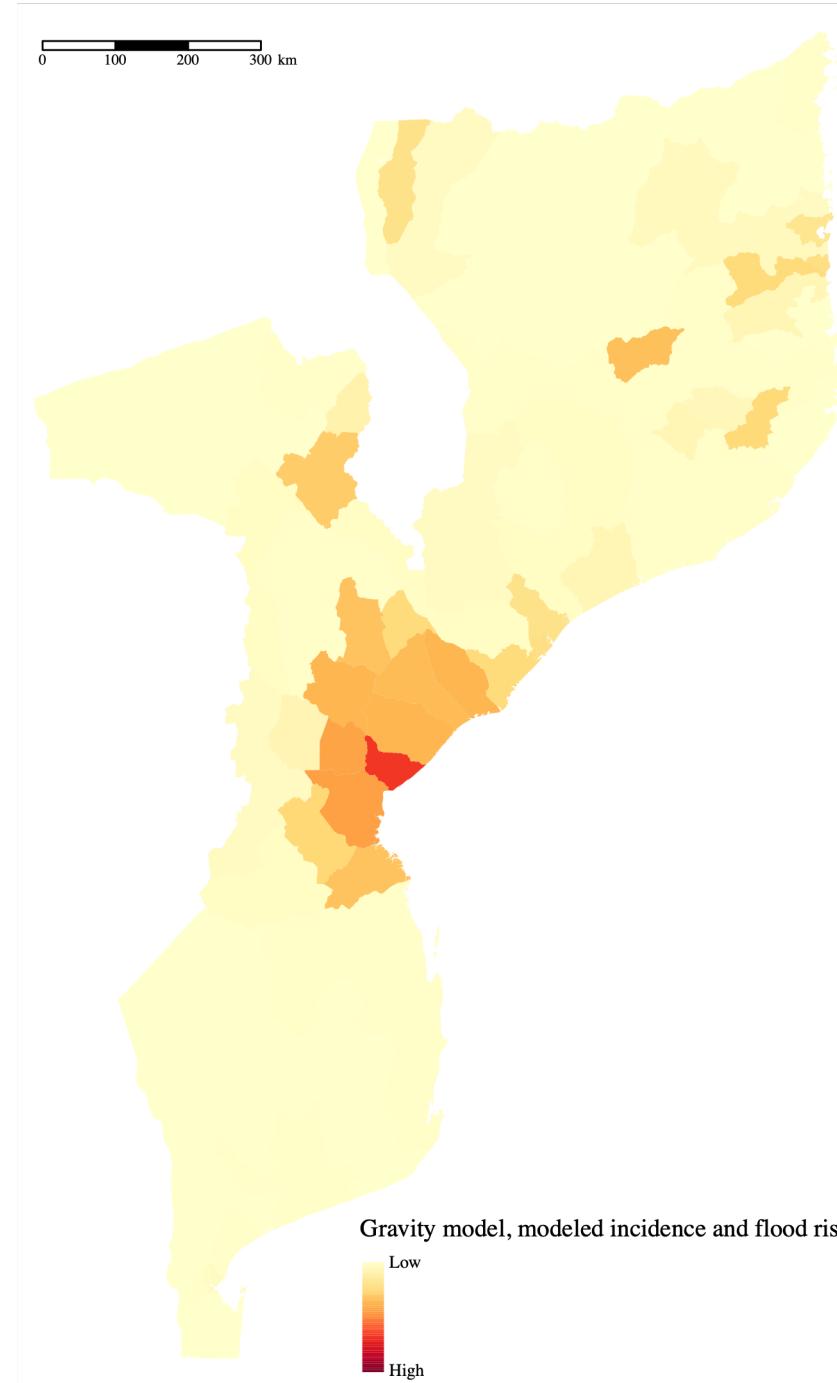
Highest Risk Areas

| Province | District | Population |
|--------------|------------|------------|
| Nampula | Lalaua | 98,397 |
| Cabo Delgado | Chiúre | 171,264 |
| Cabo Delgado | Pemba | 313,852 |
| Tete | Moatize | 416,709 |
| Cabo Delgado | Mecufi | 37,910 |
| Nampula | Meconta | 201,581 |
| Cabo Delgado | Montepuez | 256,119 |
| Zambezia | Inhassunge | 101,215 |
| Sofala | Dondo | 668,971 |
| Cabo Delgado | Macomia | 114,785 |
| Cabo Delgado | Meluco | 27,053 |
| Cabo Delgado | Quissanga | 38,764 |
| Tete | Tsangano | 263,386 |
| Inhambane | Zavala | 160,954 |
| Cabo Delgado | Muidumbe | 86,907 |
| Cabo Delgado | Ancuabe | 250,173 |
| Gaza | Bilene | 181,985 |
| Cabo Delgado | Balama | 160,182 |
| Cabo Delgado | Namuno | 237,520 |
| Inhambane | Jangamo | 195,231 |

Cyclone Idai: projected risk

- For Cyclone Idai, the projected risk is an average of the gravity model, flooding index and previous cholera incidence.

Gravity Model + Previous Cholera Incidence + Idai Flood

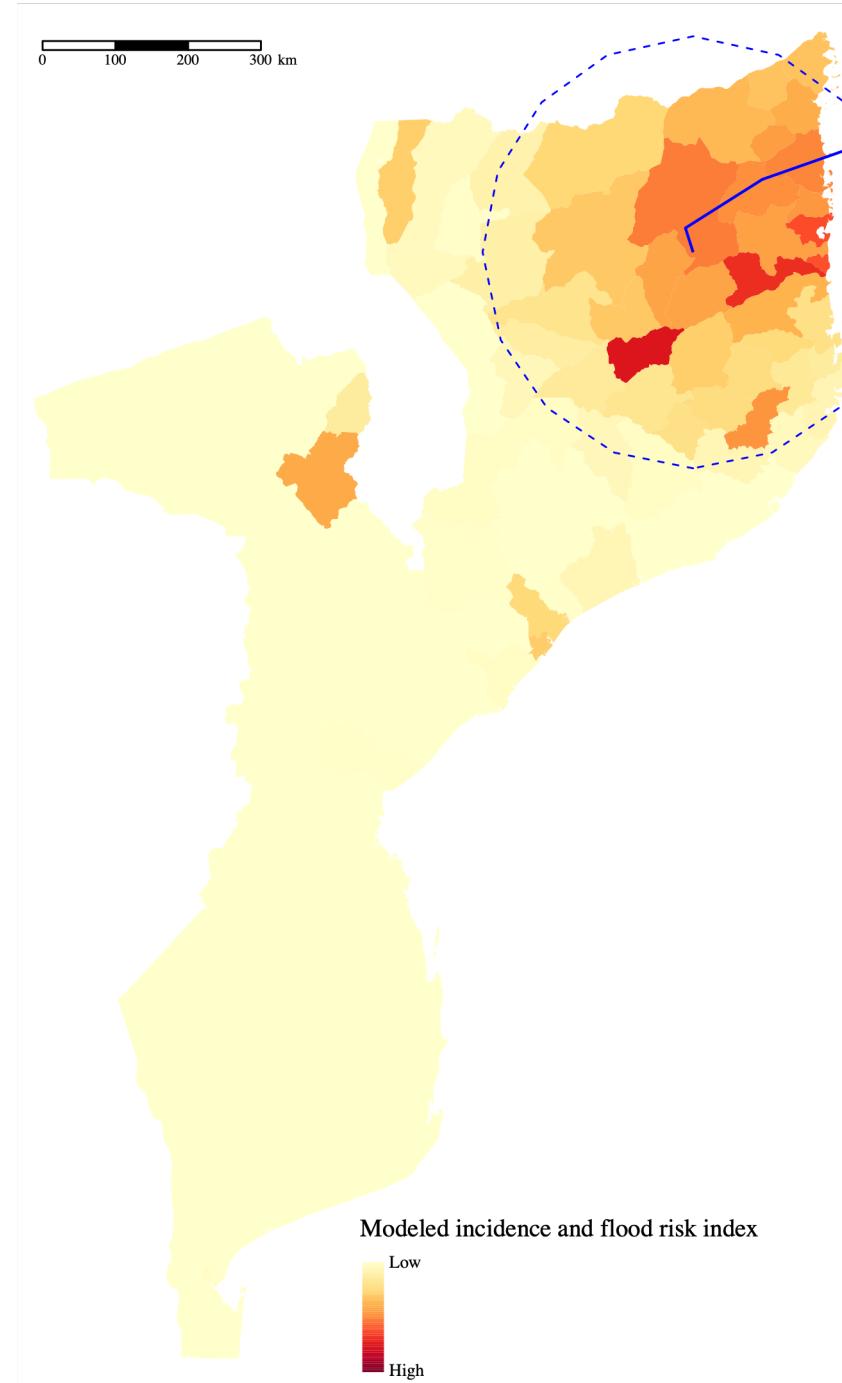


Highest Risk Areas

| Province | District | Population |
|--------------|------------|------------|
| Sofala | Dondo | 668,971 |
| Sofala | Buzi | 186,642 |
| Sofala | Nhamatanda | 313,569 |
| Sofala | Muanza | 41,681 |
| Sofala | Gorongosa | 174,101 |
| Sofala | Marromeu | 192,047 |
| Sofala | Cheringoma | 54,263 |
| Nampula | Lalaua | 98,397 |
| Sofala | Maringue | 101,841 |
| Sofala | Machanga | 51,643 |
| Tete | Moatize | 416,709 |
| Sofala | Chibabava | 145,198 |
| Nampula | Meconta | 201,581 |
| Cabo Delgado | Chiúre | 171,264 |
| Zambezia | Chinde | 121,703 |
| Sofala | Caia | 157,289 |
| Cabo Delgado | Mecufi | 37,910 |
| Zambezia | Inhassunge | 101,215 |
| Nassa | Lago | 122,921 |
| Zambezia | Nicoadala | 539,132 |

Appendix: additional risk maps

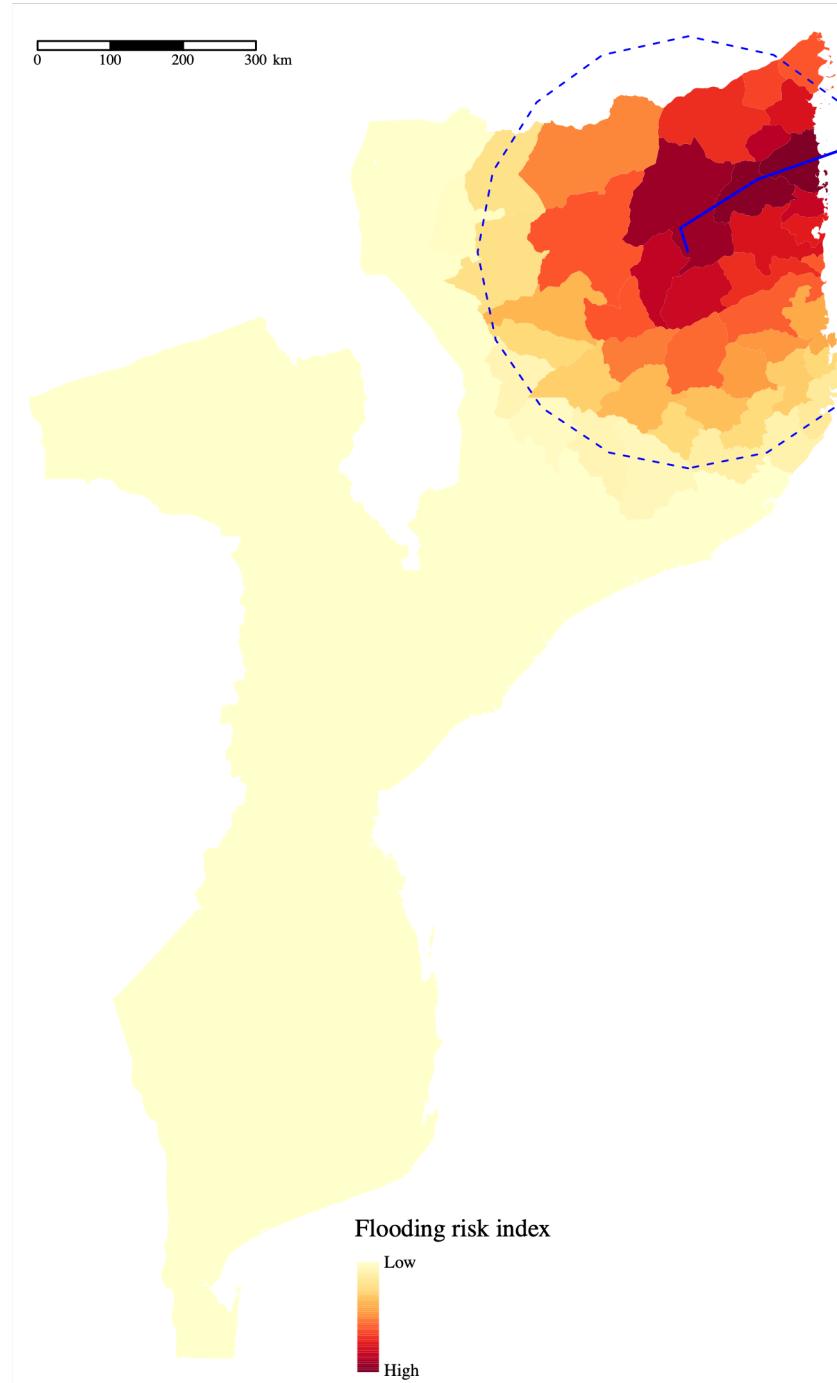
Previous Cholera Incidence + Kenneth Flood



Highest Risk Areas

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|--------------|-------------------|------------|
| Nampula | Lalaua | 98,397 |
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| Cabo Delgado | Balama | 160,182 |
| Cabo Delgado | Namuno | 237,520 |
| Tete | Moatize | 416,709 |
| Cabo Delgado | Mocimboa da Praia | 113,355 |
| Nampula | Namapa | 344,589 |
| Cabo Delgado | Mueda | 144,937 |
| Cabo Delgado | Palma | 58,502 |
| Cabo Delgado | Nangade | 81,299 |
| Nassa | Marrupa | 73,434 |

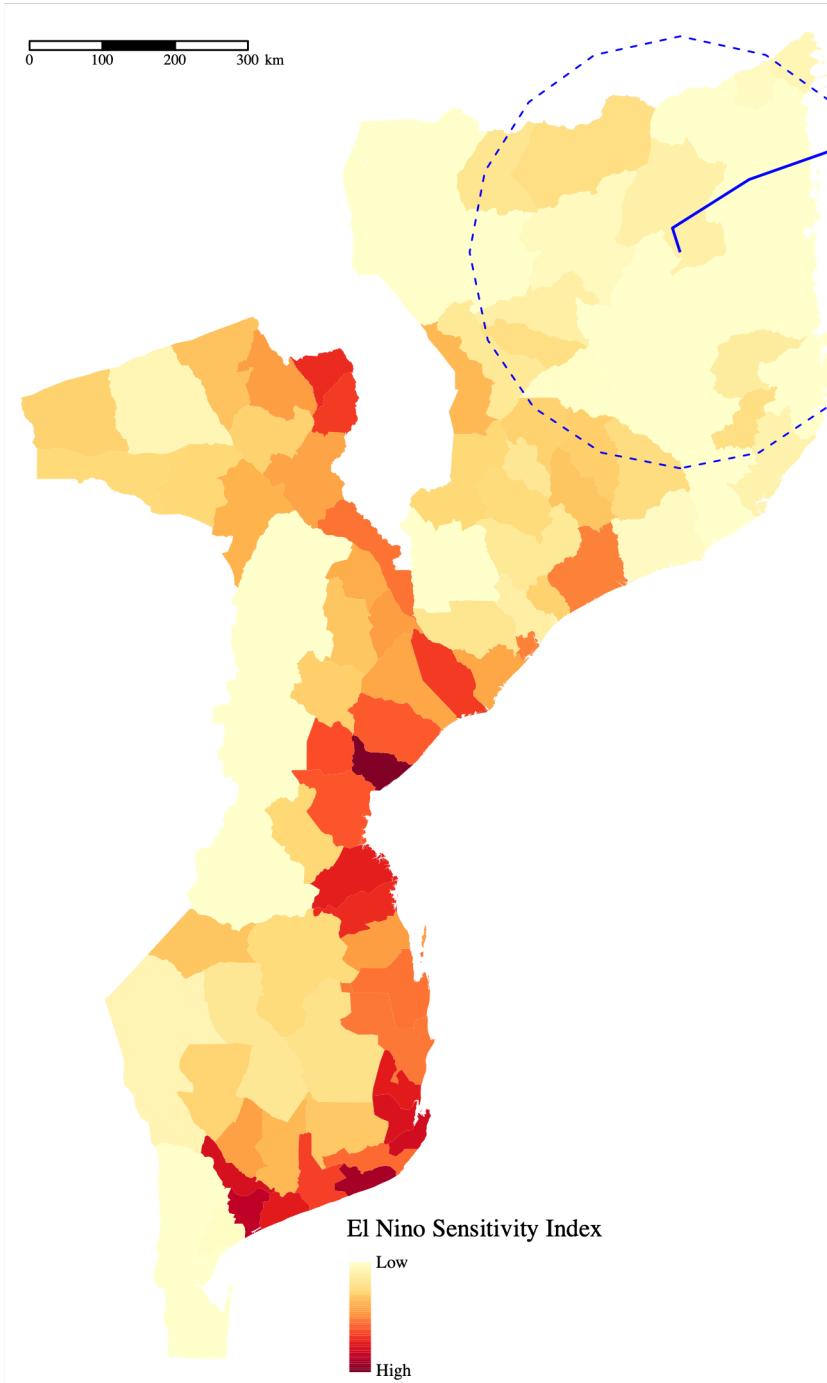
Kenneth Flood



Highest Risk Areas

| Province | District | Population |
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| Cabo Delgado | Macomia | 114,785 |
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| Cabo Delgado | Palma | 58,502 |
| Nassa | Nipepe | 36,591 |
| Cabo Delgado | Mecufi | 37,910 |
| Nampula | Namapa | 344,589 |
| Nampula | Mecuburi | 207,645 |
| Nampula | Lalaua | 98,397 |

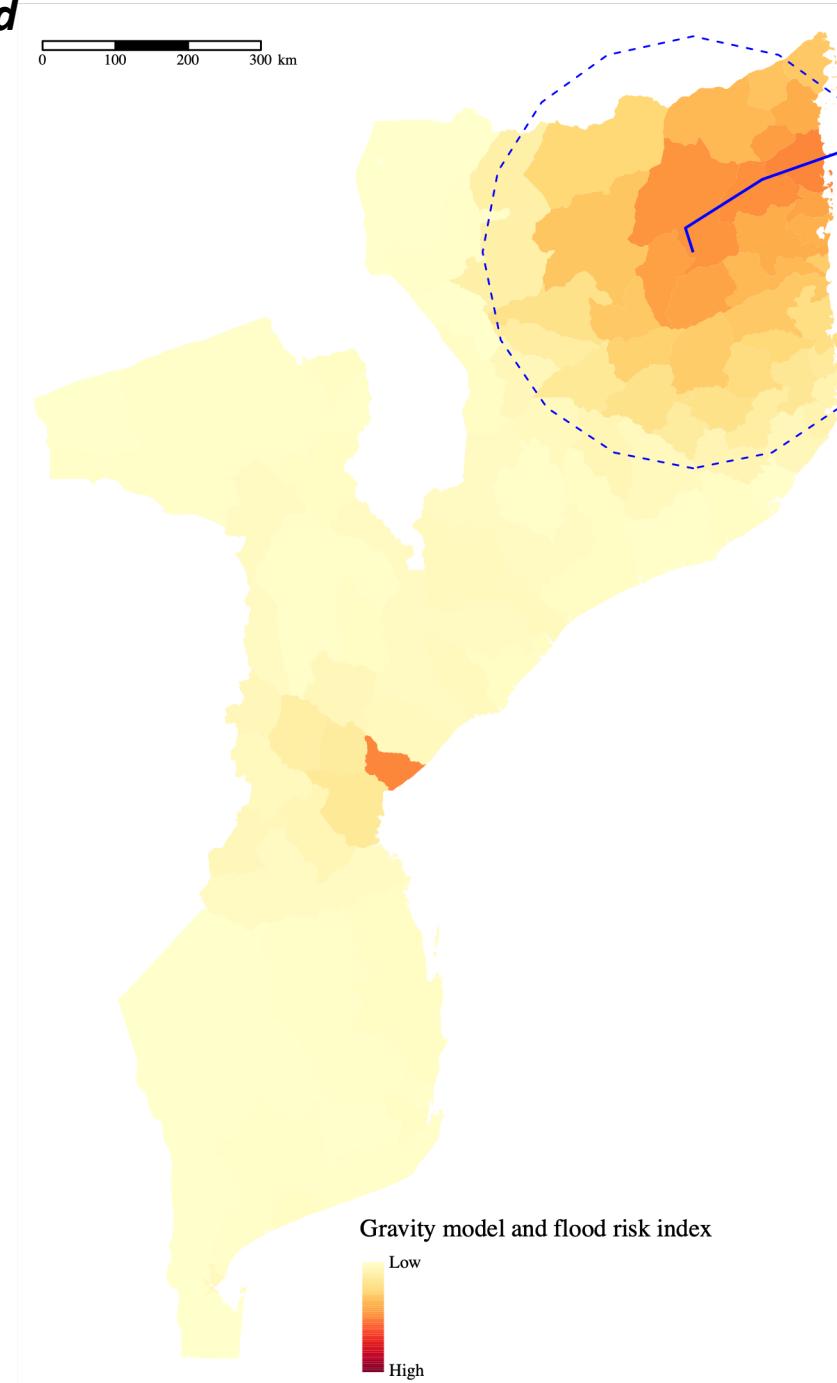
El Niño Sensitivity



Highest Risk Areas

| Province | District | Population |
|-----------|------------|------------|
| Sofala | Dondo | 668,971 |
| Inhambane | Zavala | 160,954 |
| Gaza | Bilene | 181,985 |
| Inhambane | Jangamo | 195,231 |
| Gaza | Chókwè | 206,109 |
| Inhambane | Homoine | 261,287 |
| Gaza | Xai-Xai | 414,296 |
| Inhambane | Morrumbene | 146,382 |
| Sofala | Machanga | 51,643 |
| Tete | Angónia | 373,215 |
| Inhambane | Govuro | 42,798 |
| Sofala | Marromeu | 192,047 |
| Tete | Tsangano | 263,386 |
| Gaza | Mandlakazi | 188,756 |
| Sofala | Nhamatanda | 313,569 |
| Sofala | Buzi | 186,642 |
| Sofala | Muanza | 41,681 |
| Inhambane | Inharrime | 128,144 |
| Tete | Mutarara | 351,987 |
| Inhambane | Vilanculos | 169,273 |

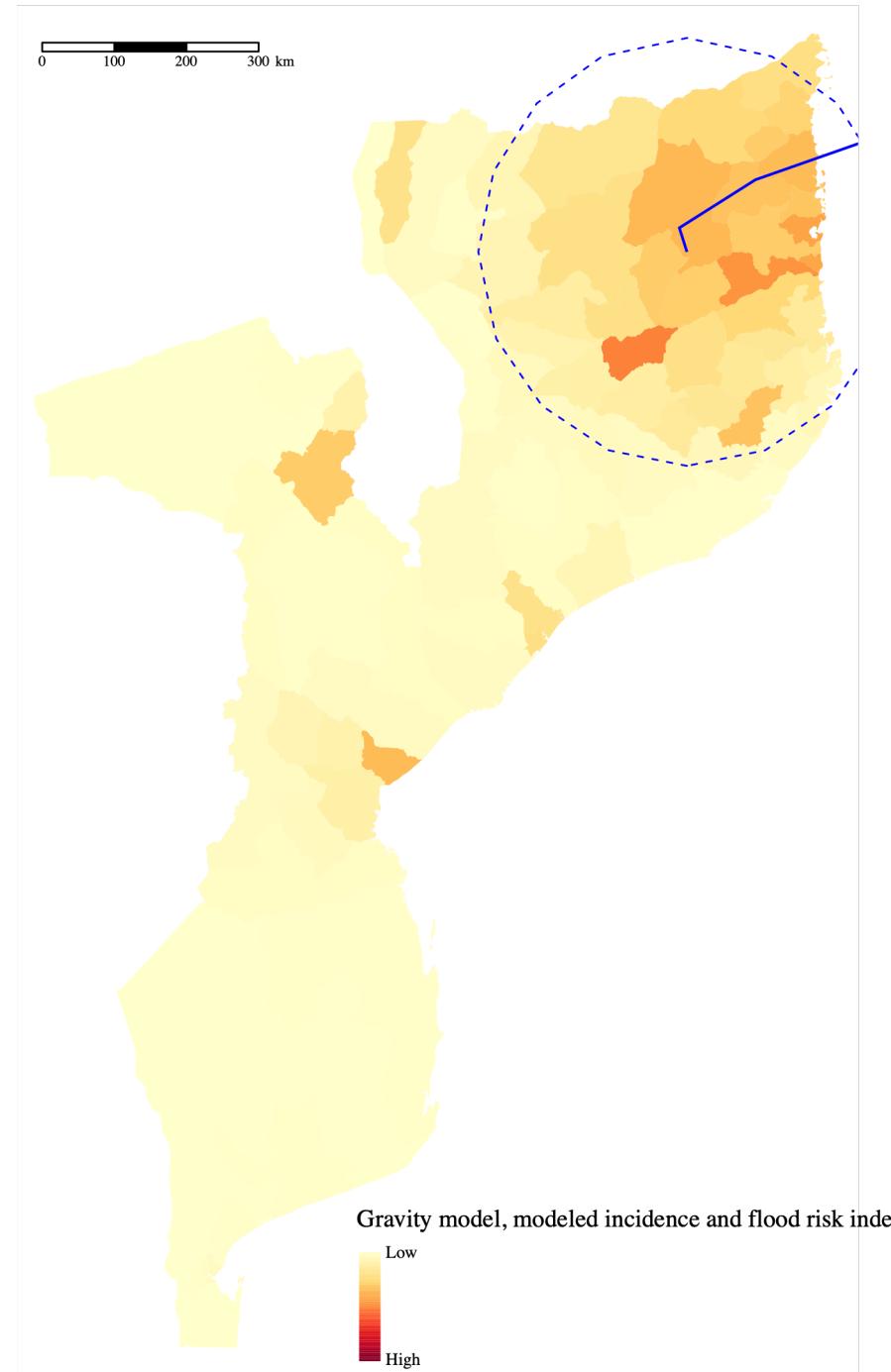
Gravity Model + Kenneth Flood



Highest Risk Areas

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| Nampula | Mecuburi | 207,645 |

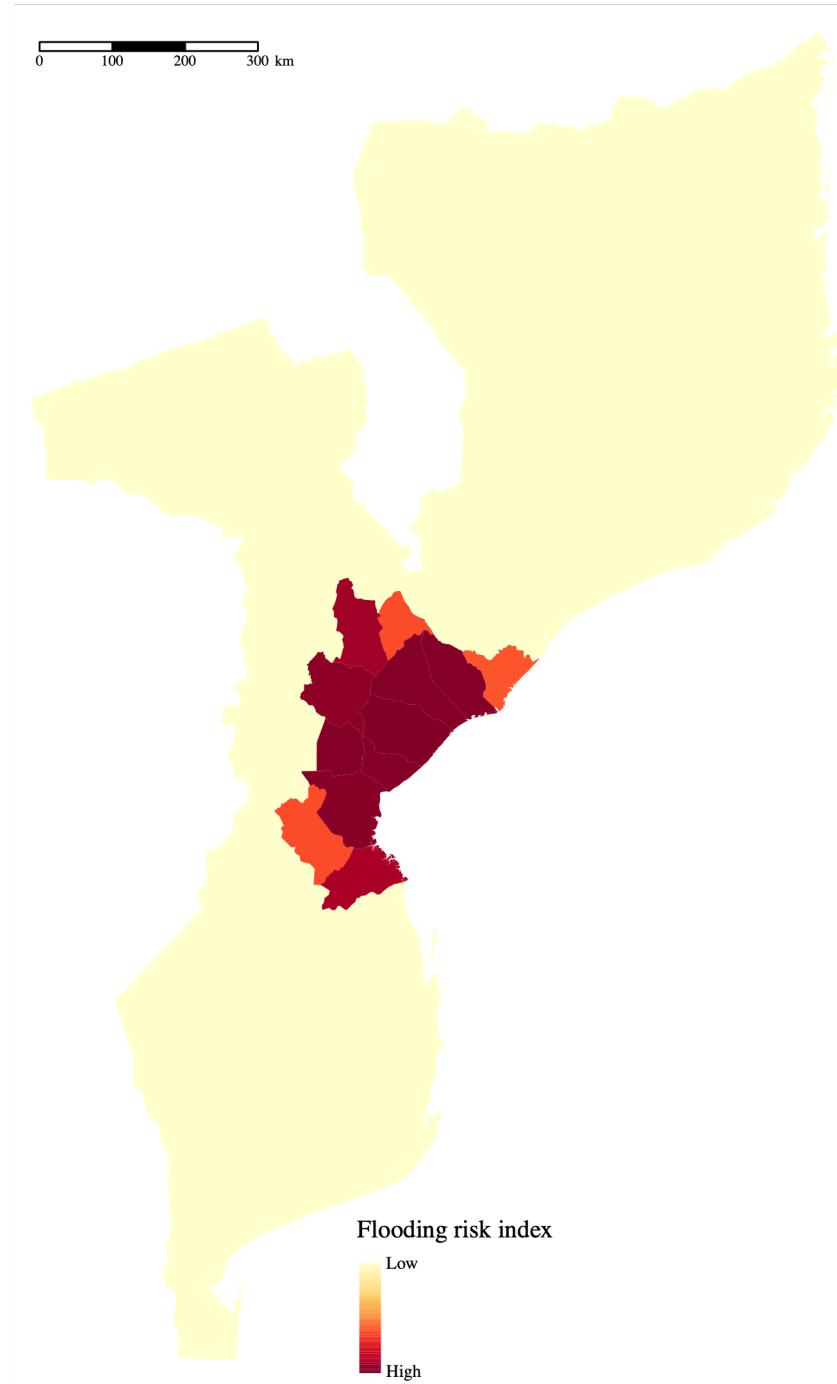
Gravity Model + Previous Cholera Incidence + Kenneth Flood



Highest Risk Areas

| Province | District | Population | Risk |
|-----------------|-------------------|-------------------|-------------|
| Nampula | Lalaua | 98,397 | |
| Cabo Delgado | Chiúre | 171,264 | |
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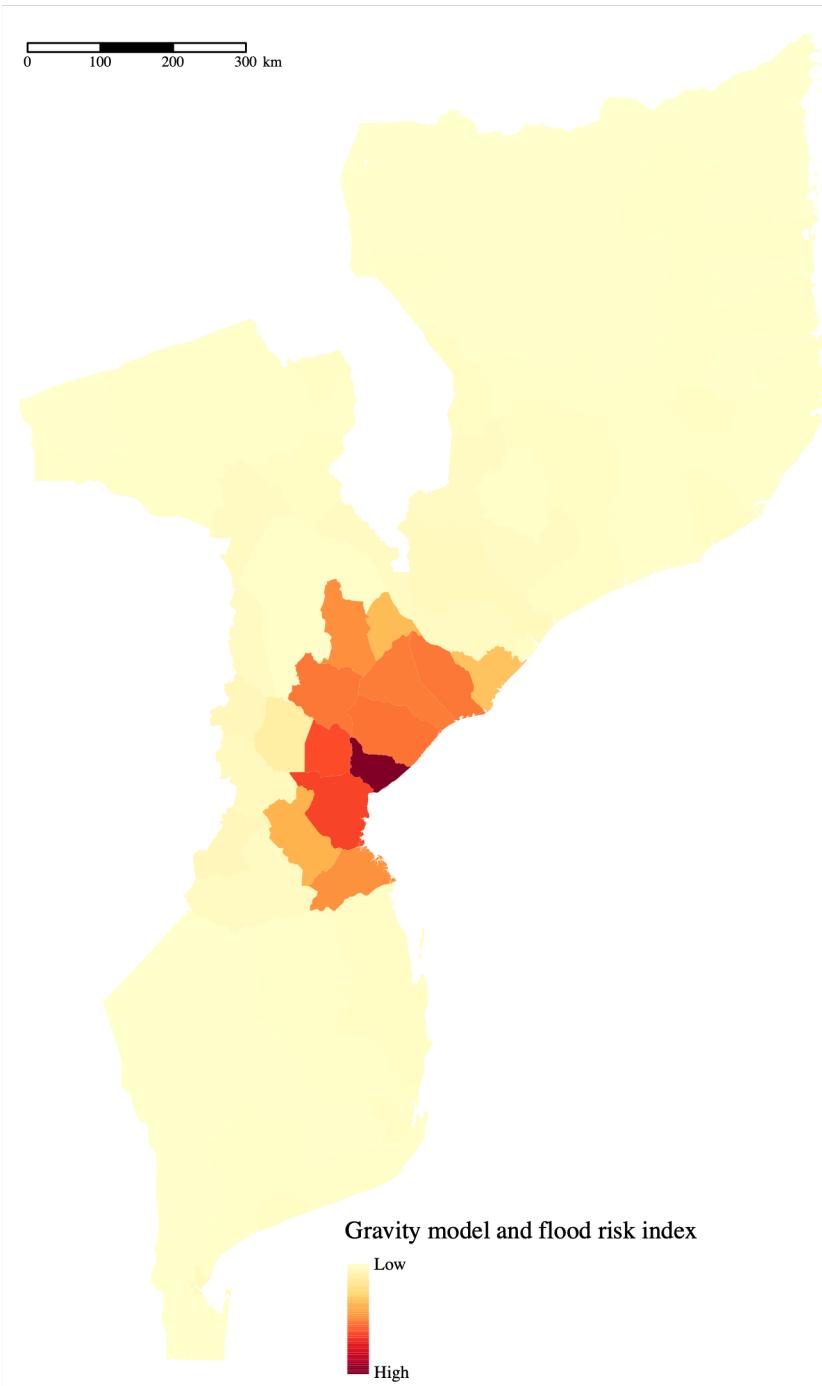
Idai Flood Model



Highest Risk Areas

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|----------|------------|------------|
| Sofala | Muanza | 41,681 |
| Sofala | Nhamatanda | 313,569 |
| Sofala | Cheringoma | 54,263 |
| Sofala | Dondo | 668,971 |
| Sofala | Marromeu | 192,047 |
| Sofala | Buzi | 186,642 |
| Sofala | Gorongosa | 174,101 |
| Sofala | Maringue | 101,841 |
| Sofala | Machanga | 51,643 |
| Sofala | Caia | 157,289 |
| Sofala | Chibabava | 145,198 |
| Zambezia | Chinde | 121,703 |

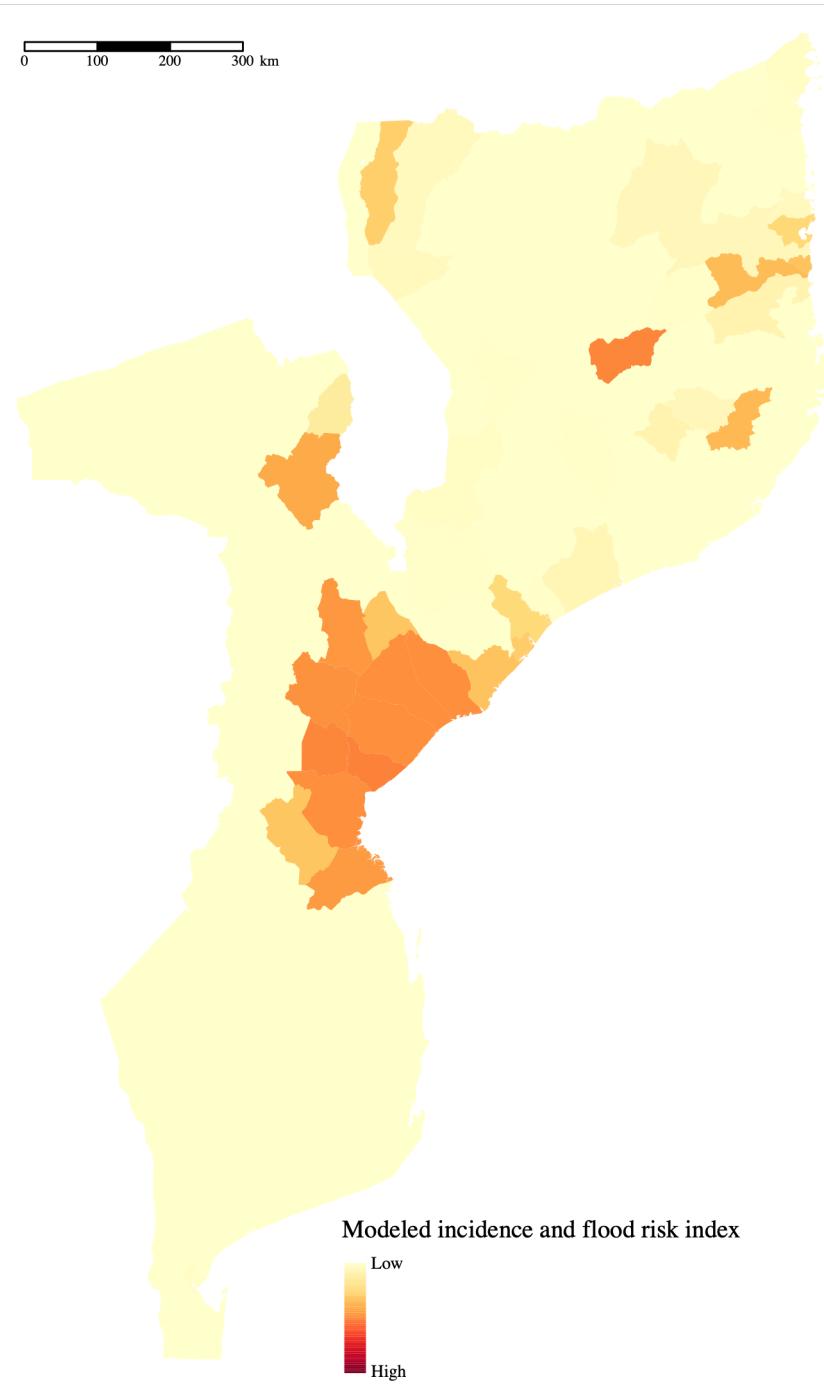
Gravity Model + Idai Flood



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| Sofala | Machanga | 51,643 |
| Sofala | Chibabava | 145,198 |
| Sofala | Caia | 157,289 |
| Zambezia | Chinde | 121,703 |
| Manica | Gondola | 701,661 |
| Manica | Mossurize | 305,083 |
| Manica | Manica | 304,457 |
| Manica | Sussundenga | 181,546 |
| Zambezia | Nicoadala | 539,132 |
| Zambezia | Morrumbala | 529,408 |
| Maputo City | Maputo | 2,347,211 |
| Zambezia | Milange | 746,845 |

Previous Cholera Incidence + Idai Flood

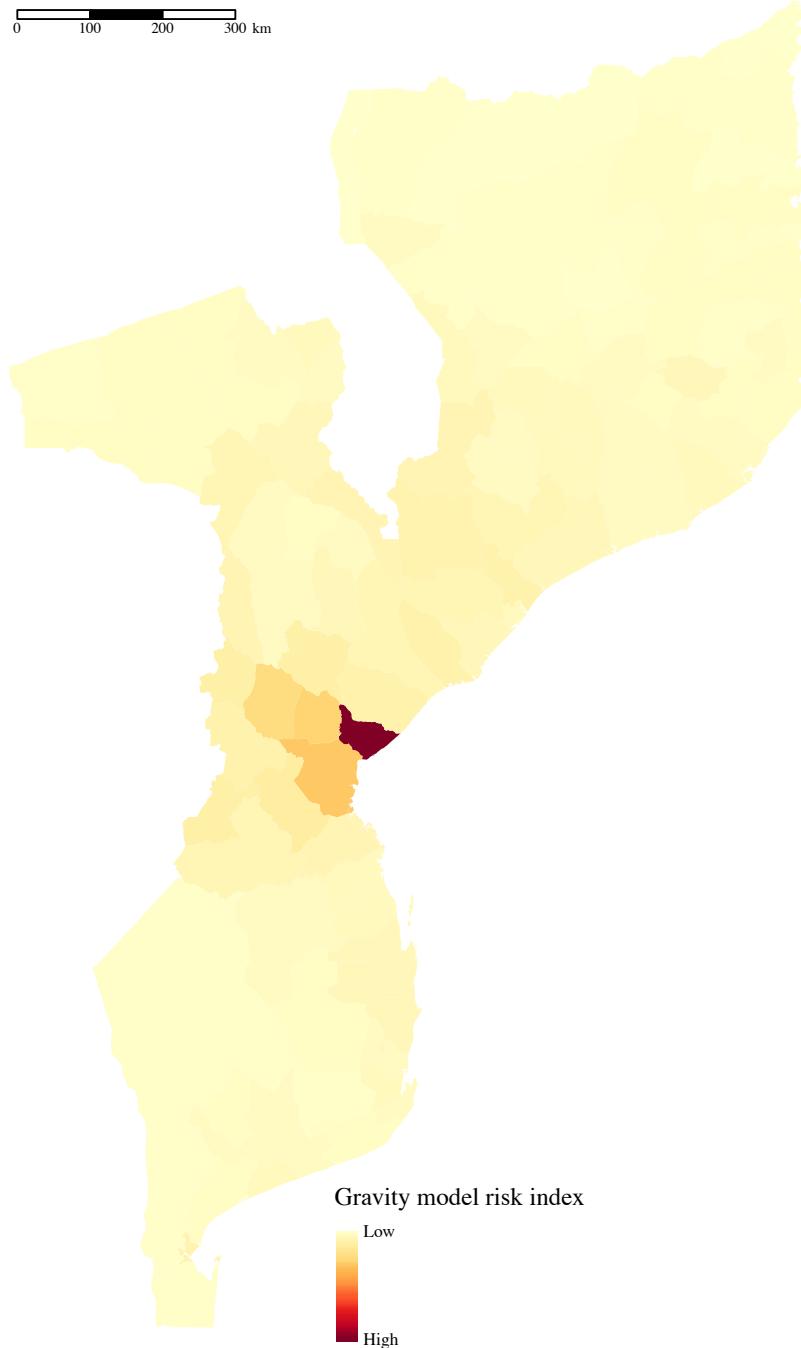


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| Sofala | Chibabava | 145,198 |
| Zambezia | Inhassunge | 101,215 |
| Nassa | Lago | 122,921 |
| Cabo Delgado | Pemba | 313,852 |

Gravity Model

0 100 200 300 km

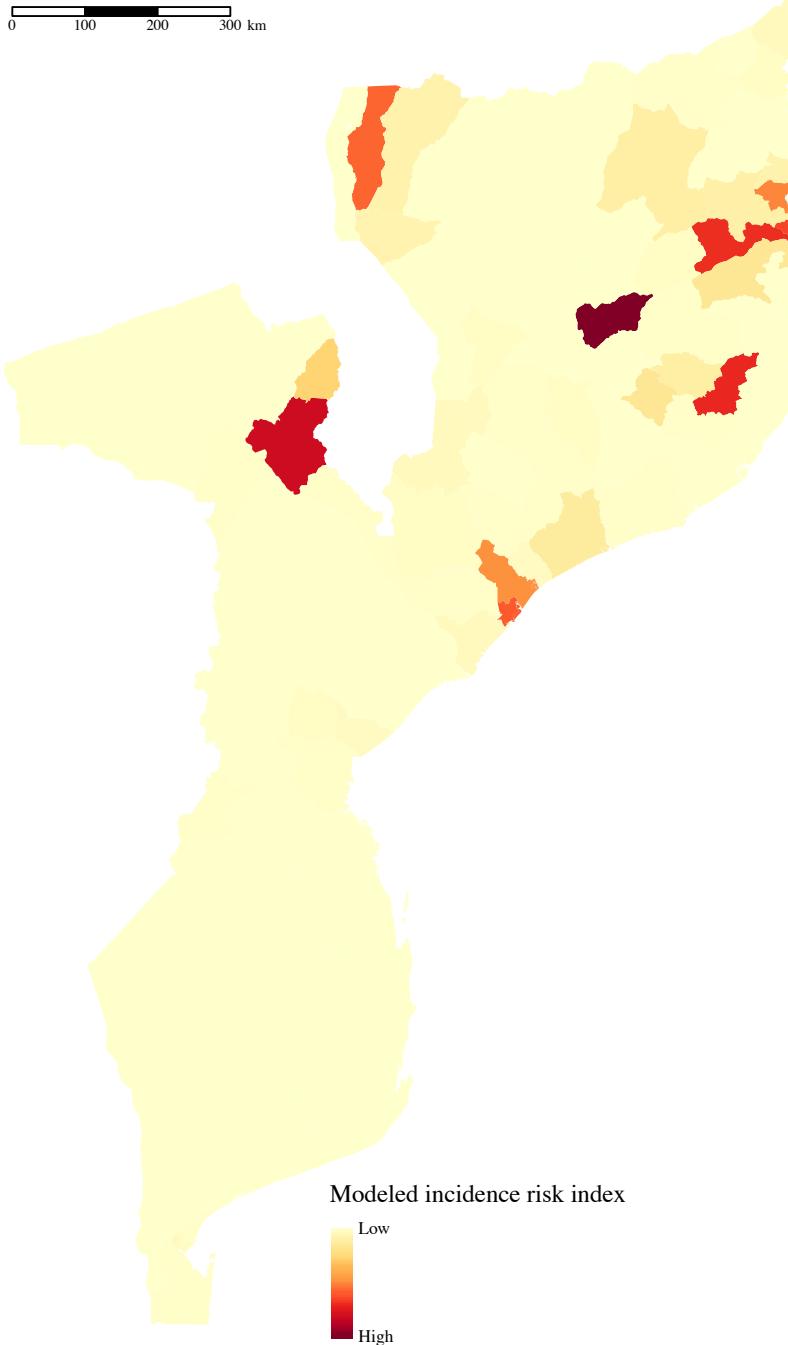


Highest Risk Areas

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| Sofala | Dondo | 668,971 |
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| Sofala | Nhamatanda | 313,569 |
| Manica | Gondola | 701,661 |
| Sofala | Chibabava | 145,198 |
| Sofala | Gorongosa | 174,101 |
| Manica | Mossurize | 305,083 |
| Manica | Manica | 304,457 |
| Manica | Sussundenga | 181,546 |
| Sofala | Marromeu | 192,047 |
| Sofala | Muanza | 41,681 |
| Zambezia | Nicoadala | 539,132 |
| Zambezia | Morrumbala | 529,408 |
| Maputo City | Maputo | 2,347,211 |
| Zambezia | Milange | 746,845 |
| Sofala | Machanga | 51,643 |
| Manica | Barue | 231,092 |
| Tete | Mutarara | 351,987 |
| Manica | Machaze | 140,941 |
| Sofala | Caia | 157,289 |

Previous Cholera Incidence

0 100 200 300 km

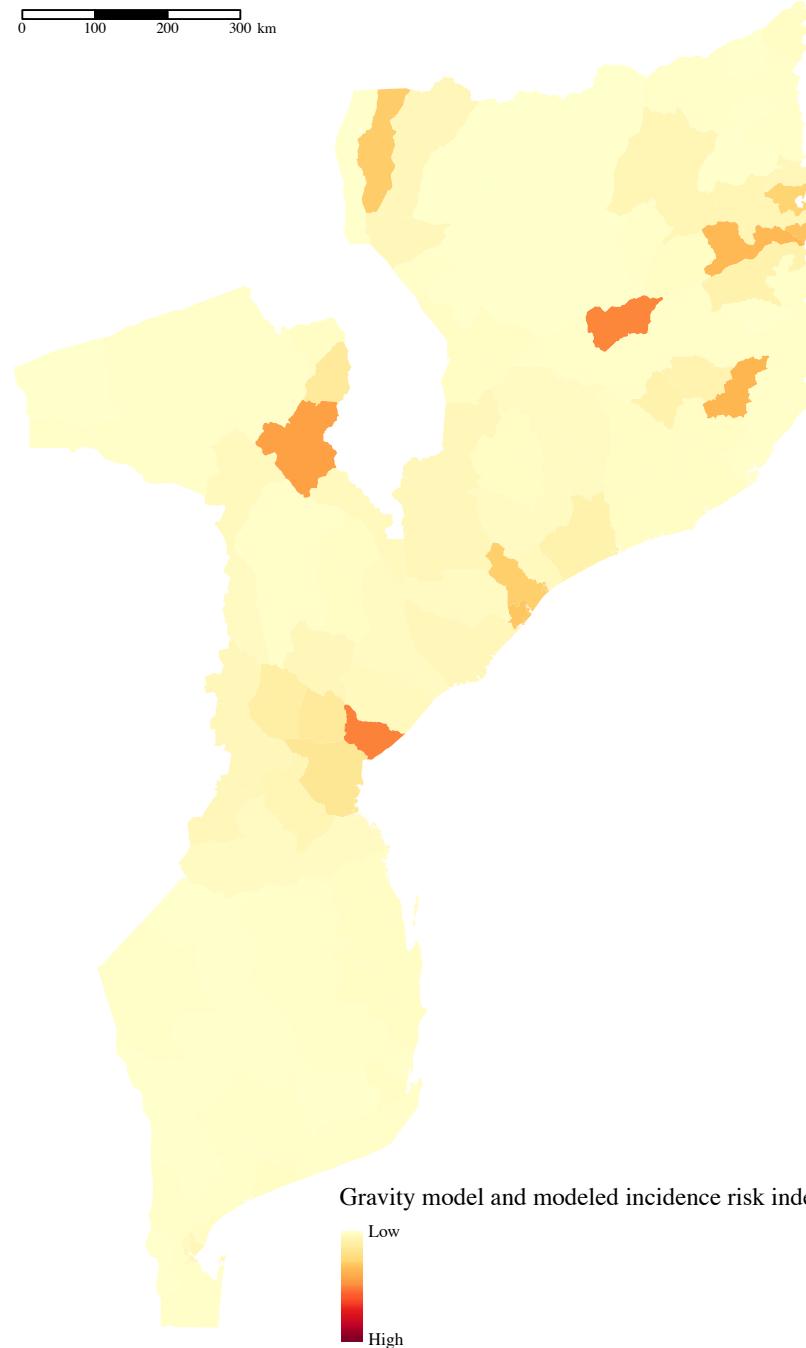


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| Zambezia | Nicoadala | 539,132 |
| Tete | Tsangano | 263,386 |
| Nampula | Namapa | 344,589 |
| Nampula | Murrupula | 196,930 |
| Zambezia | Maganja da Costa | 346,199 |
| Nampula | Nampula | 1,040,692 |
| Cabo Delgado | Montepuez | 256,119 |
| Cabo Delgado | Ancuabe | 250,173 |
| Nassa | Sanga | 75,537 |
| Cabo Delgado | Quissanga | 38,764 |
| Nassa | Lichinga | 371,941 |
| Maputo City | Boane | 54,824 |

Gravity Model + Previous Cholera Incidence

0 100 200 300 km



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