Using Analytics to Inform Resilient Risk Management of Critical Infrastructure: Jamaica Case Study

Monday, June 13

3:00-4:00 PM (BST) | 10:00 -11:00 AM (ET)

Disaster Risk Financing & Insurance Program
SUPPORTED BY WORLD BANK GROUP

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Oxford Programme for Sustainable Infrastructure Systems

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Credit: Photo by Yves Alarie from Unsplash

Housekeeping Rules

Reminder

Please keep your camera and microphone off for the entire duration of the event

Post-Event Resources

The session will be recorded. The post-event resources including slides and recording will be sent out after the event concludes.

Q&A

Please share your questions via chat box (If possible, please indicate which speaker(s) to address your question(s))

Agenda

Welcome and Introduction from the Chair	***Olivier Mahul***, *Practice Manager, Crisis and Disaster Risk Finance, Finance, Competitiveness and Innovation Global Practice, World Bank*
Presentation on WB - OIA work	***Shoko Takemoto***, *Disaster Risk Management Specialist, World Bank Tokyo Disaster Risk Management Hub*
Presentation from OIA	***Jim Hall***, *Professor of Climate and Environmental Risks, University of Oxford*
Presentation from UK CGFI on potential applications for OIA's work	***Nicola Ranger,*** *Deputy Director, UK Centre for Greening Finance & Investment and Head of Sustainable Finance Research for Development, Oxford Sustainable Finance Group*
Q & A and closing remarks	*All Participants*

Presentation on WB - OIA work

***Shoko Takemoto**, Disaster Risk Management Specialist, World Bank Tokyo Disaster Risk Management Hub*

Analytics for Financial Risk Management of Critical Infrastructure in Southeast Asia

Piloting the Next Generation Analytics for Climate-Related Financial Resilience of Critical Infrastructure in Southeast Asia

Using Analytics to Inform Resilient Risk Management of Critical Infrastructure
13 June 2022

Shoko Takemoto
Disaster Risk Management Specialist
World Bank

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GFDRR
Global Facility for Disaster Reduction and Recovery

Oxford Infrastructure Analytics

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GFDRR Global Facility for Disaster Reduction and Recovery

$18 billion

Annual direct damages from natural hazards to low- and middle-income countries to power generation and transport infrastructure

$391–$647 billion

The annual cost of infrastructure disruptions on households and firms in developing countries.

A traffic jam after flooding in Chiangrai, Thailand

Source: Hallegatte, Stephane; Rentschler, Jun; Rozenberg, Julie. 2019. Lifelines : The Resilient Infrastructure Opportunity. Sustainable Infrastructure;. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/31805

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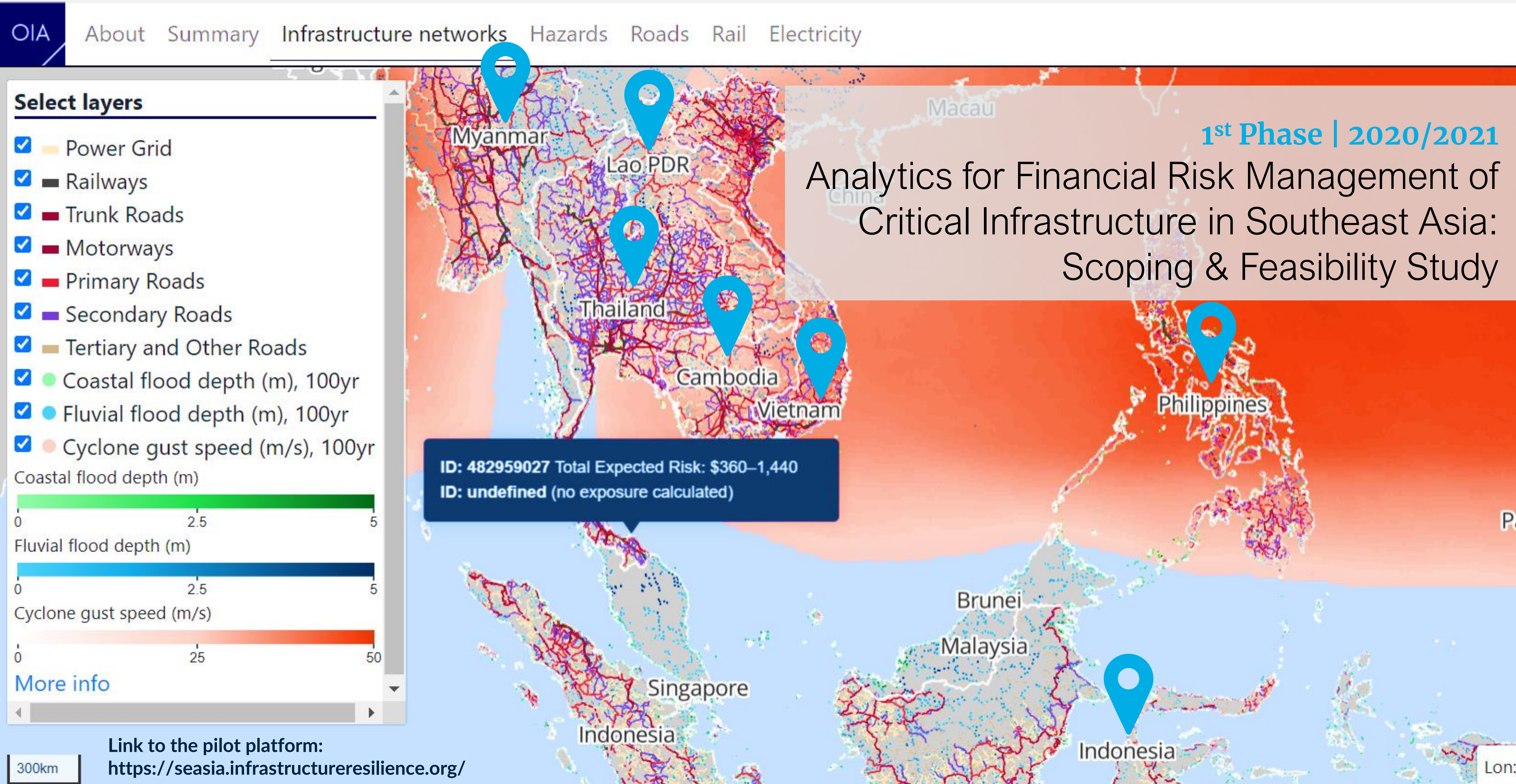
1st Phase | 2020/2021

Analytics for Financial Risk Management of Critical Infrastructure in Southeast Asia: Scoping & Feasibility Study



Link to the pilot platform:
https://seasia.infrastructureresilience.org/

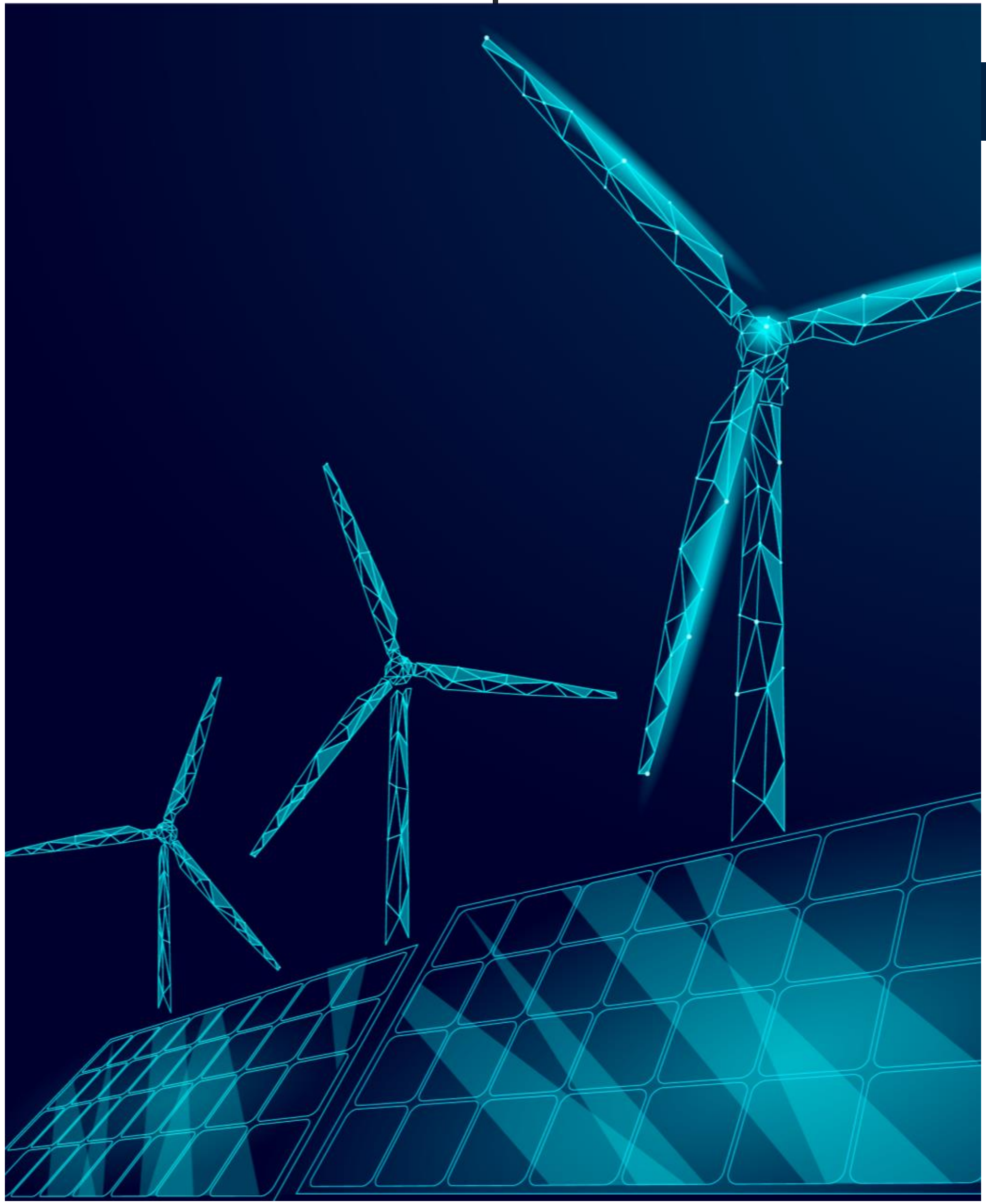
Data Sources and Outputs

The study assembled a number of globally available datasets for SE Asia to be incorporated within the **web interface** and fed into the **analysis**.

Data type	Source
Hazards	
Fluvial and coastal flooding	WRI Aqueduct
Cyclones	STORM IBTrACS model
Networks	
Road links	OpenStreetMap + OSRM
Railway tracks	OpenStreetMap
Electricity transmission lines	Gridfinder
Fragility estimates	Koks et al. 2019; Miyamoto et al. 2019; Habermann and Hedel 2018
Socio economic impacts	
People affected	Grided Population Density/Count (WorldPop Population Data)
Economic impact	Gridded GDP per capita (DRYAD Gridded GDP)
Costs	Koks et al. (2019), World Bank ROCKS database; World Bank PPI database .

Outputs within the web interface

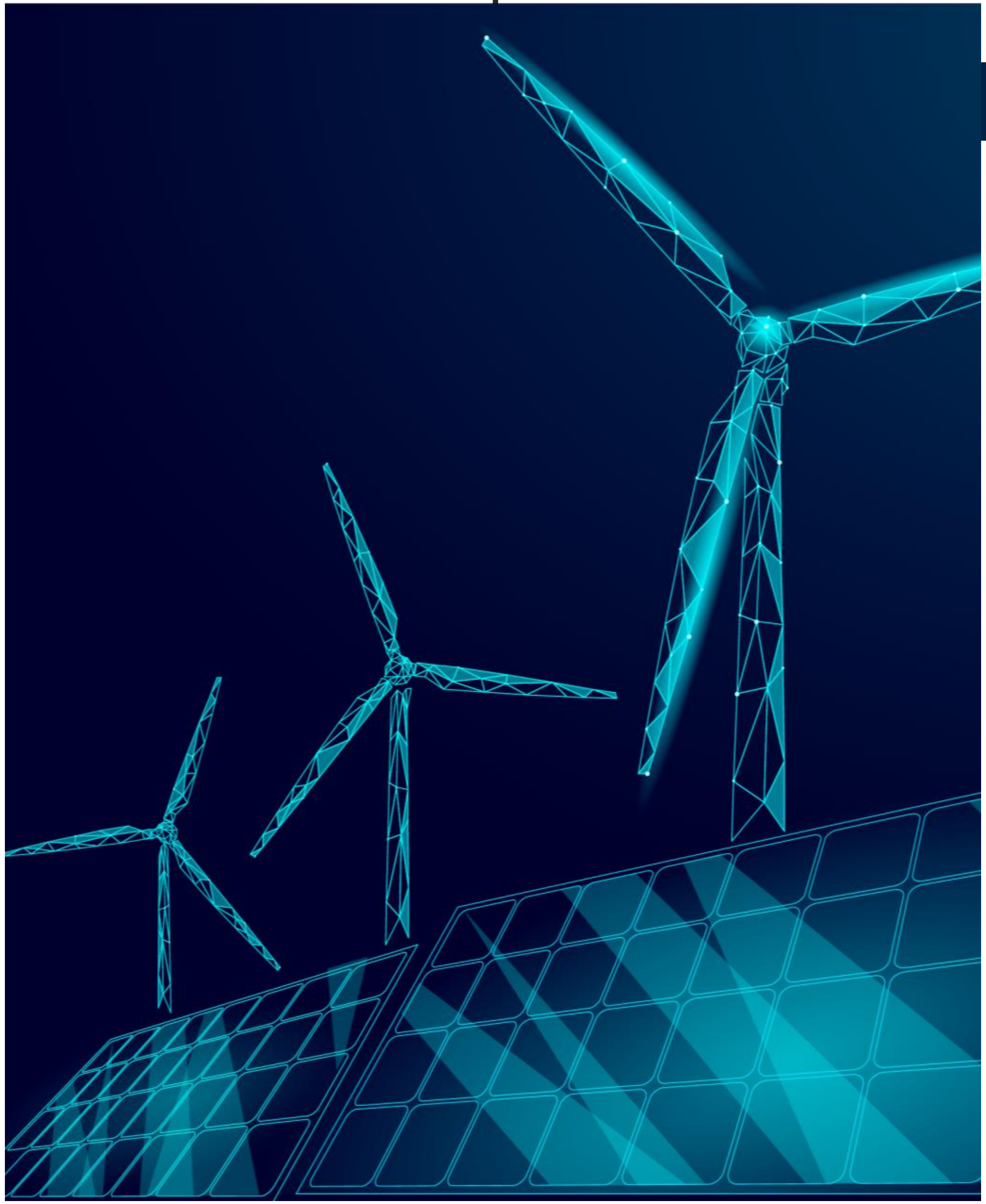
- Infrastructure failure probability by infrastructure sector
- Probabilistic estimates of infrastructure damage
    - Expected annual damages (EAD) – At asset level
    - Loss-probability distributions - At province level: by hazard and sector
- Probabilistic estimates of wider economic losses
    - Expected annual economic losses (EAD) – At asset level
    - Loss-probability distributions – At province level : by hazard and sector
- CBA of some resilience interventions: retrofit (Vietnam only)



Next Steps

2^{nd} Phase | 2022/2023

1. Enhancing the existing criticality risk analysis framework
2. Validating risk analysis output for pilot countries
3. Further develop the previous Southeast Asia prototype platform



Next Steps

Operational support

Disaster Risk Finance for Resilient Infrastructure Project

Global partnerships

APEC-DRFI Working Group

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This Study was led by the World Bank Disaster Risk Financing and Insurance Program (DRFIP) and Oxford Infrastructure Analytics with support from the Japan—World Bank Program for Mainstreaming DRM in Developing Countries, which is financed by the Government of Japan and managed by the Global Facility for Disaster Reduction and Recovery (GFDRR) through the Tokyo Disaster Risk Management Hub.

More information

Pilot platform is available at:
https://seasia.infrastructureresilience.org/

World Bank Disaster Risk Financing and Insurance Program (DRFIP)
https://www.financialprotectionforum.org/

Photo: Road reconstruction workers measuring new road site. Kazakhstan. Kubat Sydykov / World Bank Photo ID: KS-KZ002 World Bank

Presentation from OIA

***Jim Hall**, Professor of Climate and Environmental Risks, University of Oxford*

Using Analytics to Inform Resilient Risk Management of Critical Infrastructure: Jamaica Case Study

Jim Hall
Oxford Programme for Sustainable Infrastructure Systems
University of Oxford

‘We cannot handle anymore,’ Jamaica member of parliament says after storms Zeta, Eta

BY JACQUELINE CHARLES

NOVEMBER 10, 2020 03:53 PM, UPDATED NOVEMBER 11, 2020 07:23 AM

Two tropical storms, Zeta and Eta, has left Jamaica devastated. Many roads and bridges have been washed out, while flooding from swollen rivers continue. Climate change, said Member of Parliament Juliet Holness, is real.
BY JAMAICA MEMBER OF PARLIAMENT, ST. ANDREW EAST RURAL, JULIET HOLNESS OFFICE

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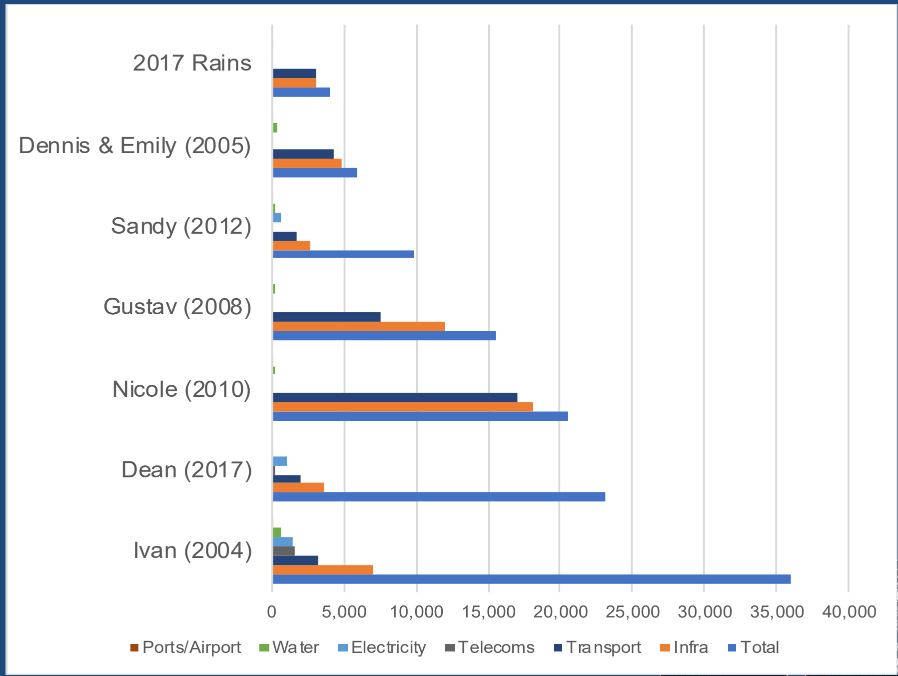
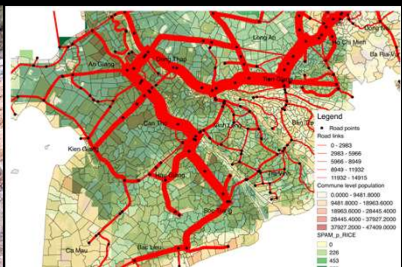
Prime Minister Andrew Holness @COP26: "A single disaster can set back the development of a small island for years"

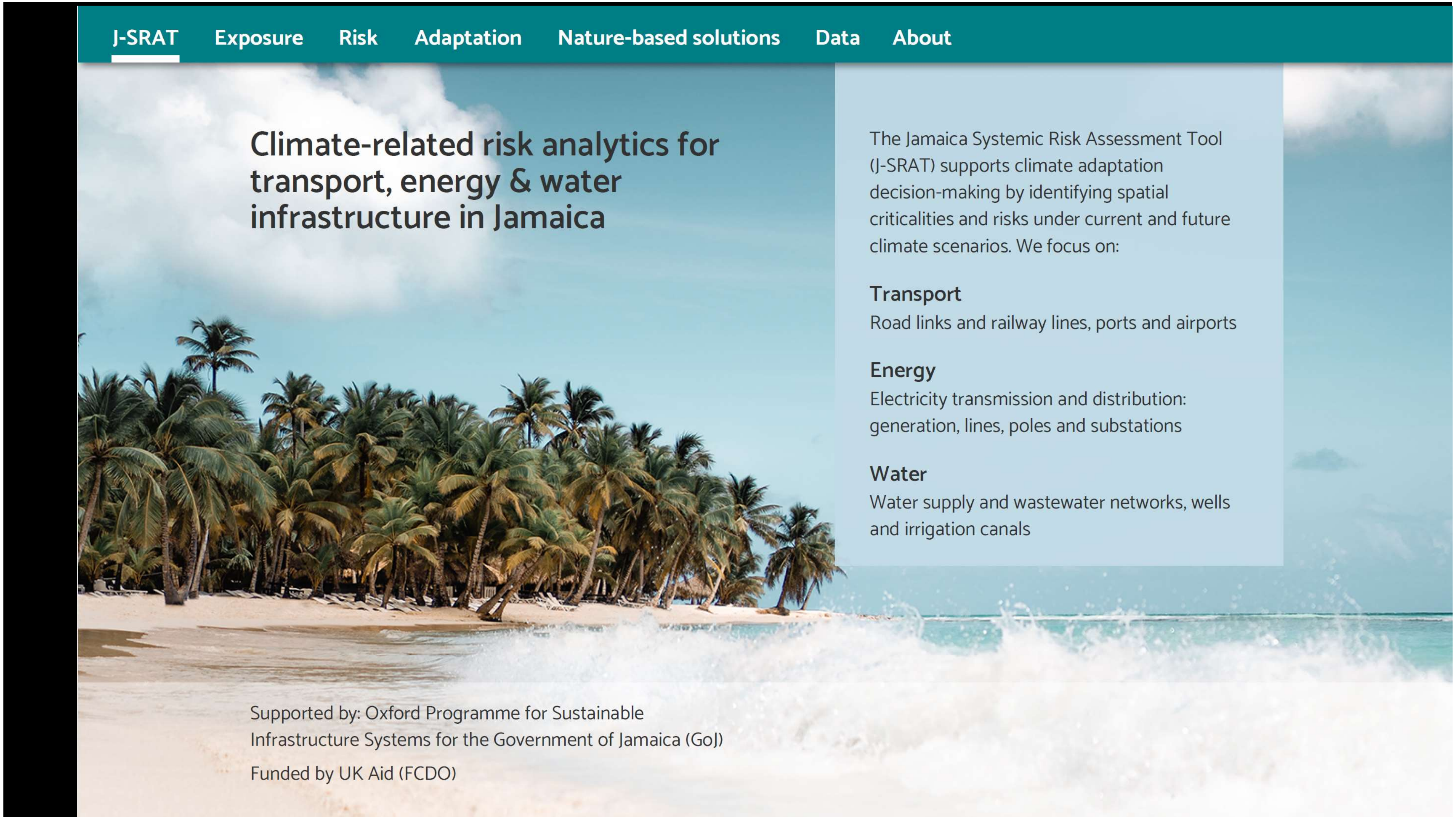
- Infrastructure damages contribute between 15 to 90% total damages for the seven largest storms in Jamaica from 2004
- Average annual losses related to hurricanes are over $J 5 billion
- Highest recorded infrastructure loss ($J 18 billion) in tropical storm Nicole



Questions vulnerable countries need to ask

- Where are the **most vulnerable** infrastructure assets **located**?
- How **likely** are **climate hazards, like hurricanes and floods**, to hit those infrastructure assets?
- What are the **direct damages and indirect economic losses** to infrastructures due to climate hazards?
- How might infrastructure **risks change** in the future **due to climate change**?
- What are the **adaptation options** that can **enhance infrastructure resilience** to climate impacts?
- How can **adaptation investments be prioritised to reduce the highest climate risks** to infrastructure assets?

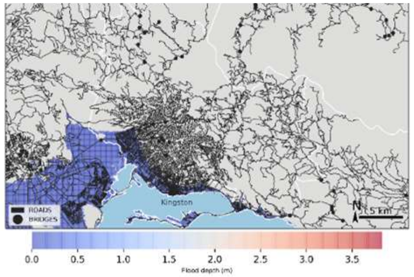

J-SRAT
Exposure
Risk
Adaptation
Nature-based solutions
Data
About
Climate-related risk analytics for transport, energy & water infrastructure in Jamaica
The Jamaica Systemic Risk Assessment Tool (J-SRAT) supports climate adaptation decision-making by identifying spatial criticalities and risks under current and future climate scenarios. We focus on:
Transport
Road links and railway lines, ports and airports
Energy
Electricity transmission and distribution: generation, lines, poles and substations
Water
Water supply and wastewater networks, wells and irrigation canals
Supported by: Oxford Programme for Sustainable Infrastructure Systems for the Government of Jamaica (GoJ)
Funded by UK Aid (FCDO)

Risk Methodology

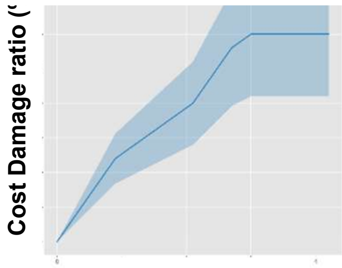
Multiple Hazard Return Period maps
Flooding, Tropical Cyclones

Infrastructure networks
Energy, Transport, Water

Hazard infrastructure spatial intersections

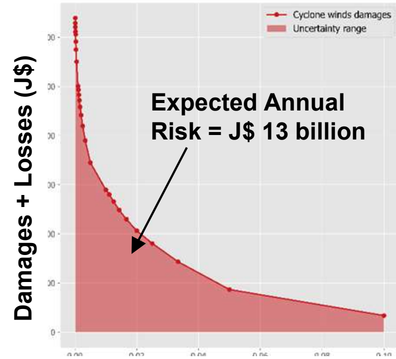


Infrastructure asset damage curves



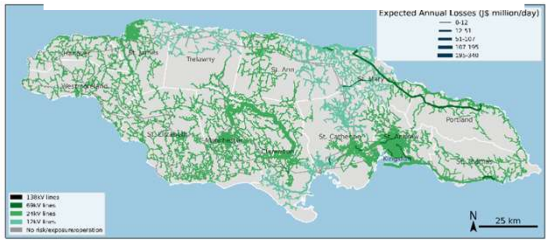
Infrastructure asset economic loss estimates

Hazard specific and combined Direct Damage + Indirect Loss Estimates



Infrastructure direct damage maps

Infrastructure indirect loss maps



Hazard datasets

All hazard datasets have full coverage over the entire island of Jamaica

Hazard type (data source)	Exceedance Probabilities (1/return periods in years)	Intensities and spatial extents	Climate scenario information
Fluvial (river) and Pluvial flooding (JBA UK global flood map product)	• 1/20, 1/50, 1/100, 1/200, 1/500, and 1/1,500	Flood depths in meters over **30m grid squares**.	• **RCP 2.6, 4.5 & 8.5** emission scenarios • Current + future maps in 2050 and 2080
Coastal flooding (storm surge) (Deltares NL Caribbean product)	1/1, 1/2, 1/5, 1/10, 1/50, 1/100	Flood depths in meters over **90m grid squares**.	• **RCP 2.6, 4.5 & 8.5** emission scenarios • Current + future maps in 2030, 2050, 2070 and 2100
Tropical cyclones (winds) (STORM IBTrACS model)	26 different exceedance probabilities from 1/1 to 1/10000	10 minute sustained maximum wind speeds in m/s at **10km grid squares**.	• **RCP 4.5 & 8.5** emission scenario • Current + future maps in 2050 and 2100
Droughts (REGCM4) **(specific to water assets only)**	No exceedance probabilities	Daily rainfall and precipitation	• **RCP 2.6, 4.5 & 8.5** emission scenario

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Infrastructure datasets

All infrastructure datasets have full coverage over the entire island of Jamaica

Sector	Sub-sector	Asset highlights	Important failure attributes	Data sources
Energy	Generation	• **9 Power plants**	• Damage costs (J$), • Population served • GDP disrupted (J$/day)	• NSDMD • JPS • MSET • OUR • OpenStreetMap • STATIN
	Transmission & Distribution	• **59 Substations, 30,000 Poles** • **11,440 kms of overhead lines**	• Damage costs (J$ or J$/m) • Population served • GDP disrupted (J$/day)	
Transport	Airports	• **7 airports areas**	• Damage costs (J$/m^2), • Annual passengers, • Annual freight (tonnes)	• NSDMD • NWA • NROCC • MTM • STATIN
	Ports	• **13 Port dock areas**	• Damage costs (J$/m^2), • Annual passengers, • Annual freight (tonnes)	
	Railways	• **20 functional stations** • **201 kms of functional tracks**	• Damage costs (J$ or J$/m) • Trade flow disruptions (J$/day)	
	Roads	• **572 bridges** • **23,200 kms of roads**	• Damage costs (J$ or J$/m), • Reopening costs (J$ or J$/m), • Road traffic counts • Trade flow disruptions (J$/day)	
Water	Potable water	• **1,208 point assets** • **10,500 kms of pipelines**	• Damage costs (J$ or J$/m), • Population served • GDP disrupted (J$/day)	• NSDMD • WRA • NWC • NIC • STATIN
	Irrigation	• **178 Wells** • **248 kms of canals and 220 kms of pipelines**	• Damage costs (J$ or J$/m) • Agriculture GDP disrupted (J$/day)	
	Wastewater	• **151 Point assets**	• Damage costs (J$ or J$/m)	
Buildings	Buildings	• **995,984 buildings**	• Damage costs (J$/m^2) • GDP disrupted (J$/day)	• OpenStreetMap • NLA • STATIN

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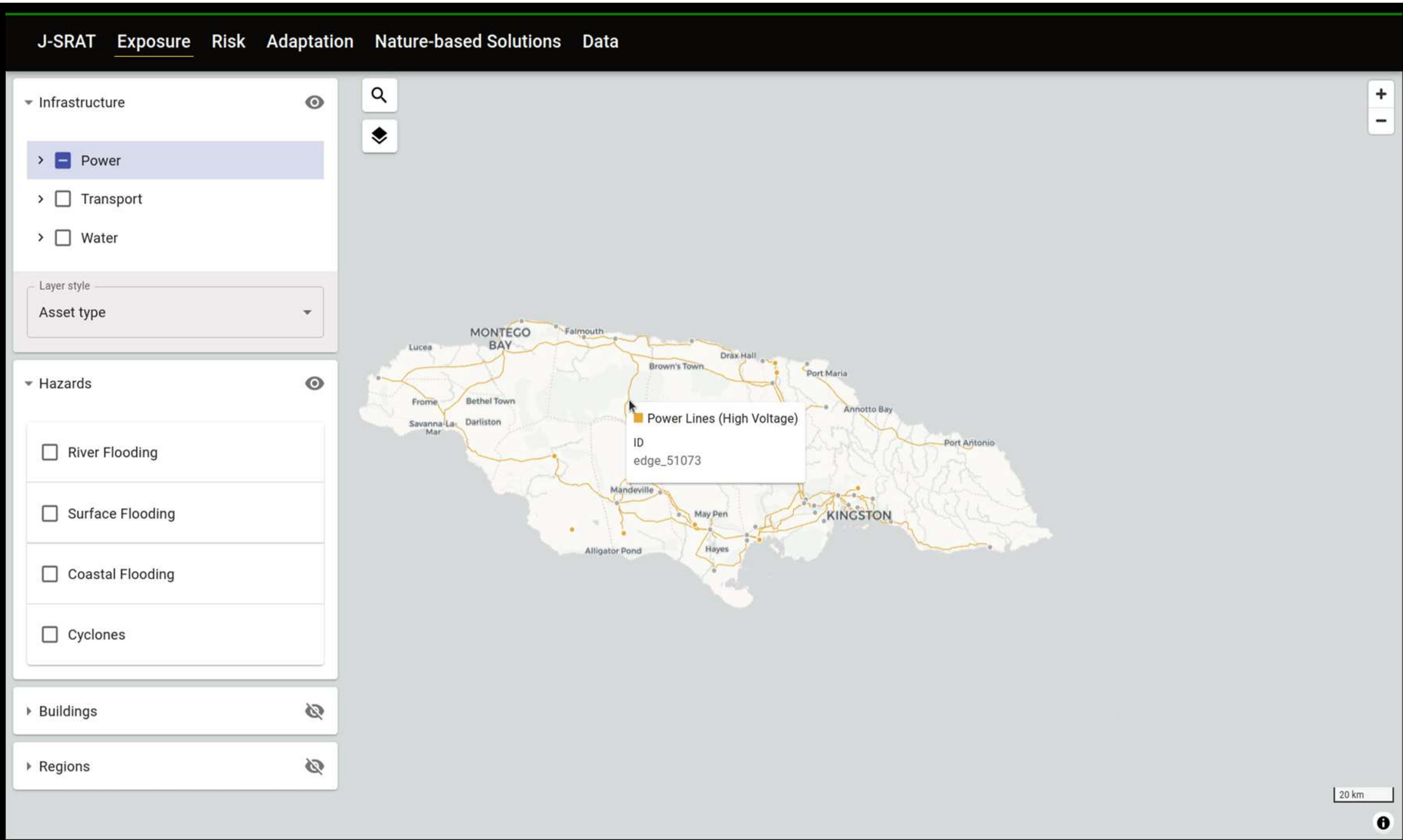

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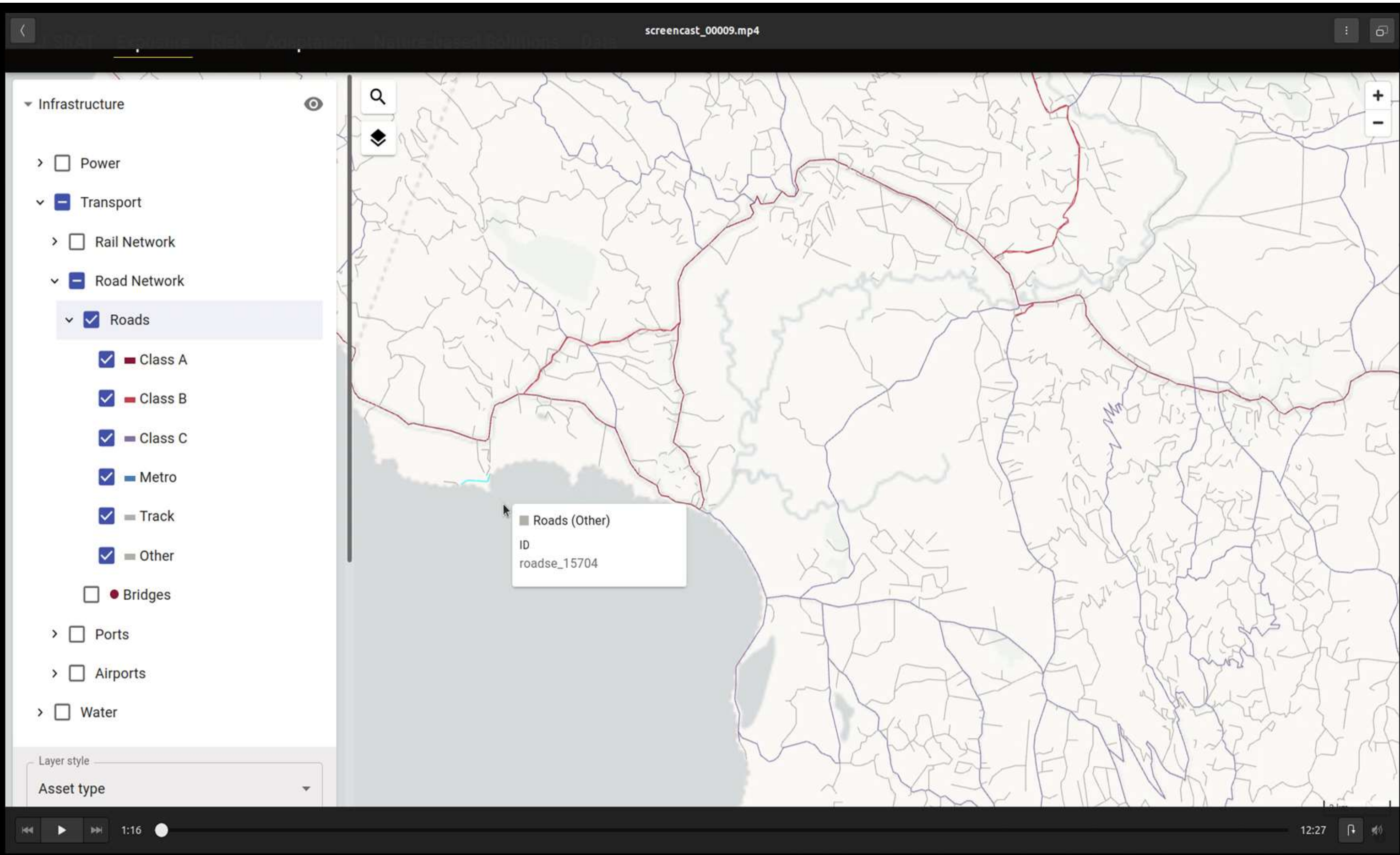

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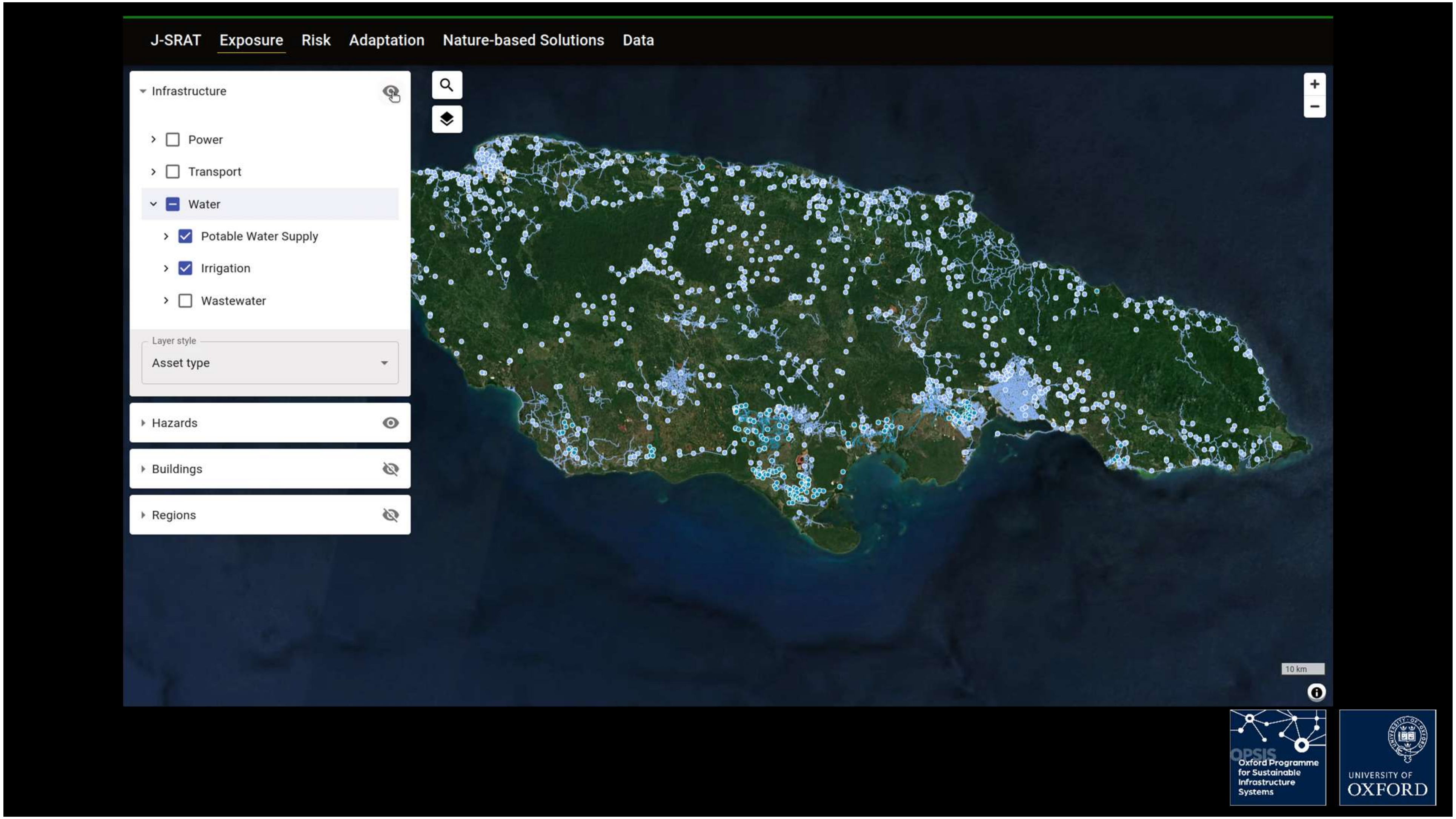
J-SRAT
Exposure
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Data
Infrastructure
Power
Transport
Water
Potable Water Supply
Irrigation
Wastewater
Layer style
Asset type
Hazards
Buildings
Regions
10 km
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Infrastructure hazard damage possibilities

- The table below shows all instances of **types of hazards exposures, which could lead to infrastructure asset damages** for the assets considered in Jamaica
- The **damages** induced on the asset will be a **function of the hazard intensity and asset fragility**

Sector	Sub-sector	Fluvial, Pluvial and Coastal Flooding	Tropical Cyclone Winds
Energy	Generation & Substations	**Y (excluding solar and wind plants)**	**Y (excluding solar and wind plants)**
	Transmission & Distribution Poles and Lines	**N**	**Y**
Transport	Airports	**Y**	**Y**
	Ports	**Y**	**Y**
	Railways	**Y**	**N**
	Roads	**Y**	**N**
Water	Potable water	**Y**	**Y**
	Irrigation	**Y**	**N**
	Wastewater	**Y**	**N**

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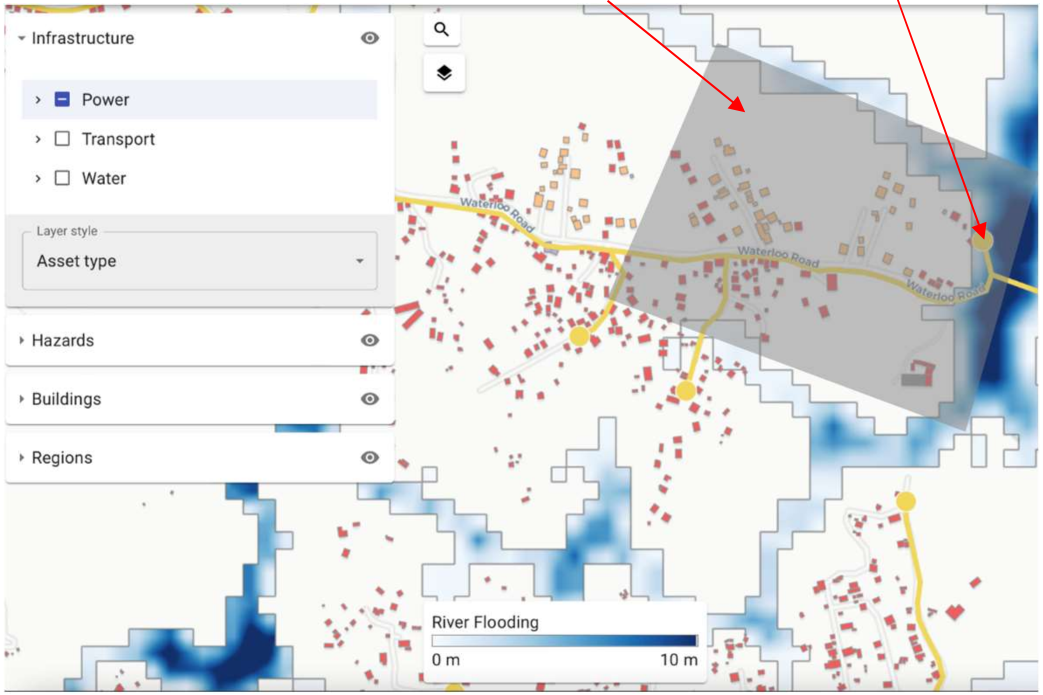
SRAT failure metrics



The main failure metrics from the analysis include (shown in the figure):

- **Damages** corresponding to **rehabilitation costs associated with replacing assets** corresponding to different hazard return periods

- **Losses** corresponding to **GDP/day associated with the buildings using the services of infrastructure assets and the disruption of trade and labor using transport assets**.

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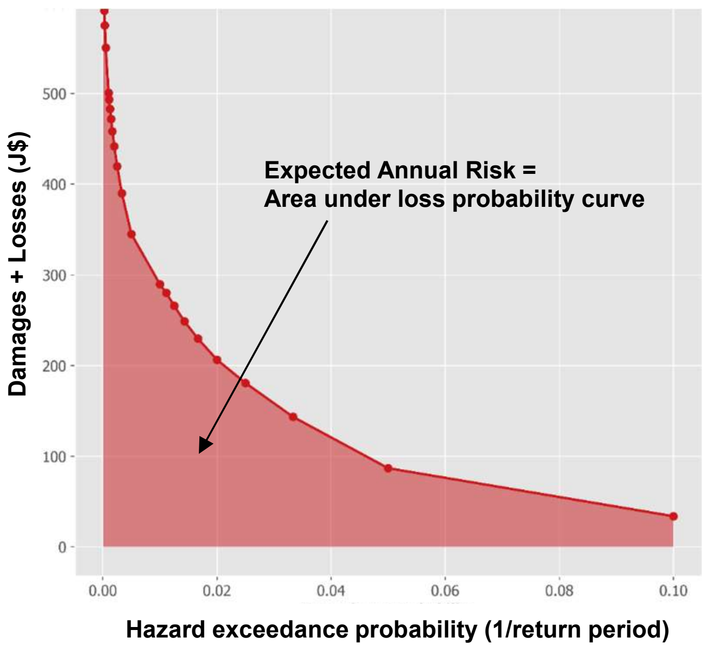
SRAT output metrics

The main output metrics from the analysis include:

- **Expected Annual Damages (EAD) (direct physical risks)** estimated as the area under the direct damage vs exceedance probability curve

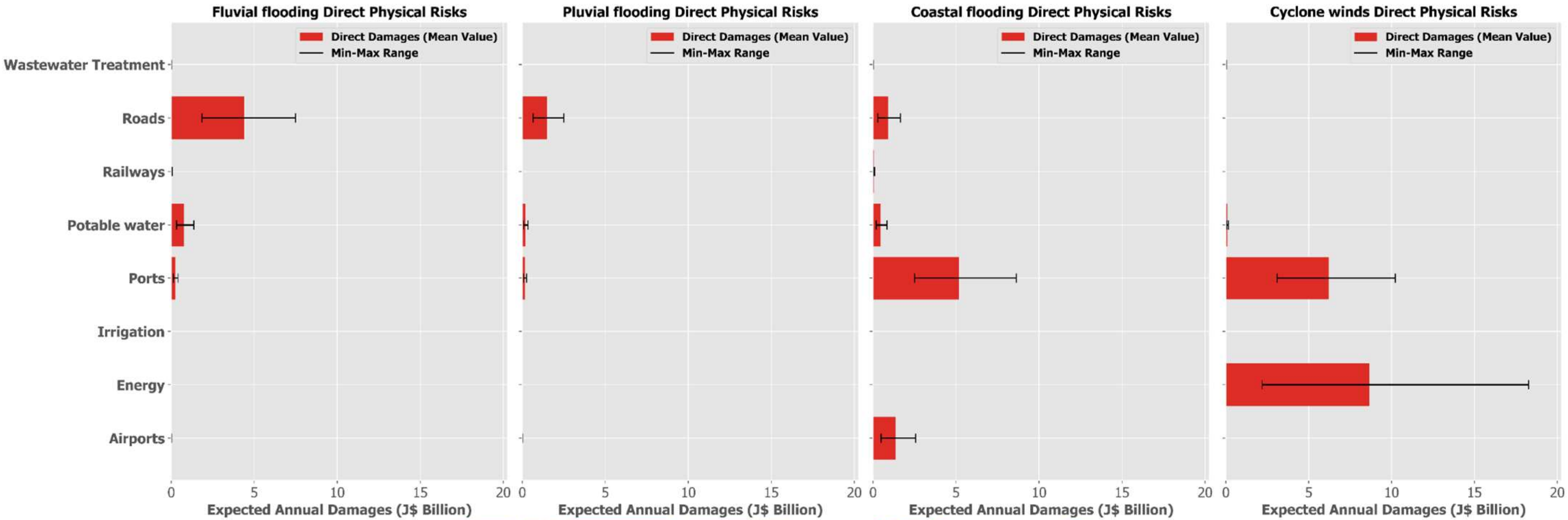
- **Expected Annual Economic Losses (EAEL) (indirect economic risks)** estimated as the area under the economic loss vs exceedance probability curve



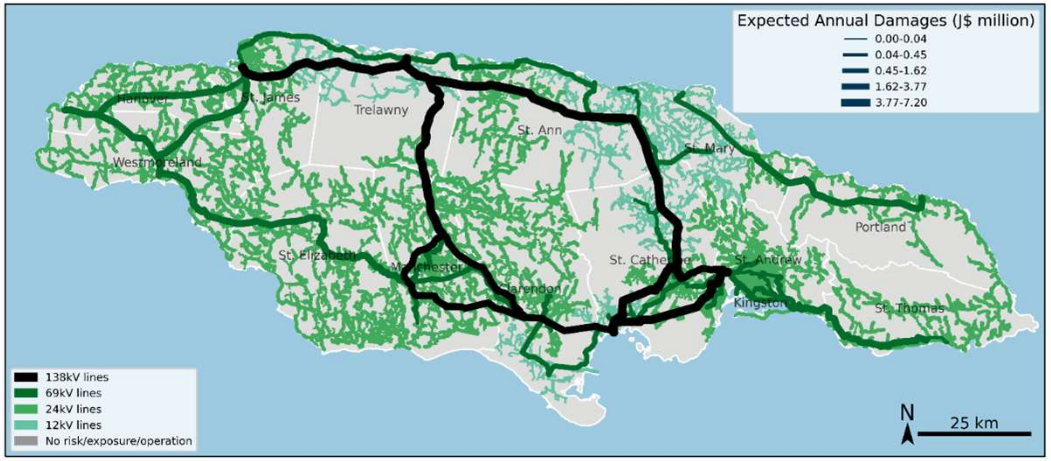
Baseline climate risks – Sector specific direct damage risks

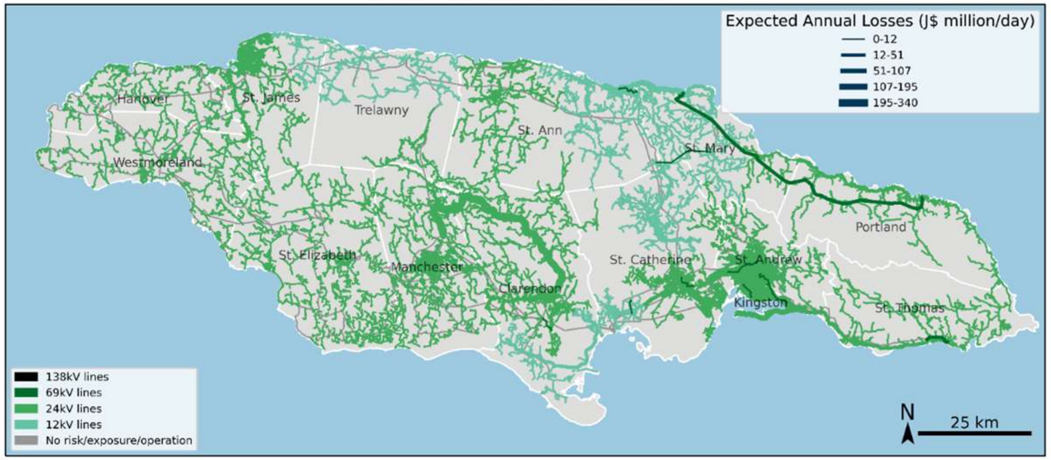
- Roads and potable water assets are most affected by fluvial and pluvial flooding.
- Ports airports are most affected by coastal flooding
- Ports and energy assets are most affected by cyclone winds

Observed annual infrastructure damages: J$2-18billion



Damage and economic disruption: electricity lines





EAD and EAEL map plots here show:

- The locations on electricity lines with the highest annual expected physical damages and economic losses.
- Some electricity lines have **physical risks** in excess of J$ 3.7 million, with some as high as J$ 7.2 million.
- **Economic risks** due to electricity line failures can be as high as J$ 195 - 340 million/day.
- Lines with highest physical risks might not have the highest economic risks.

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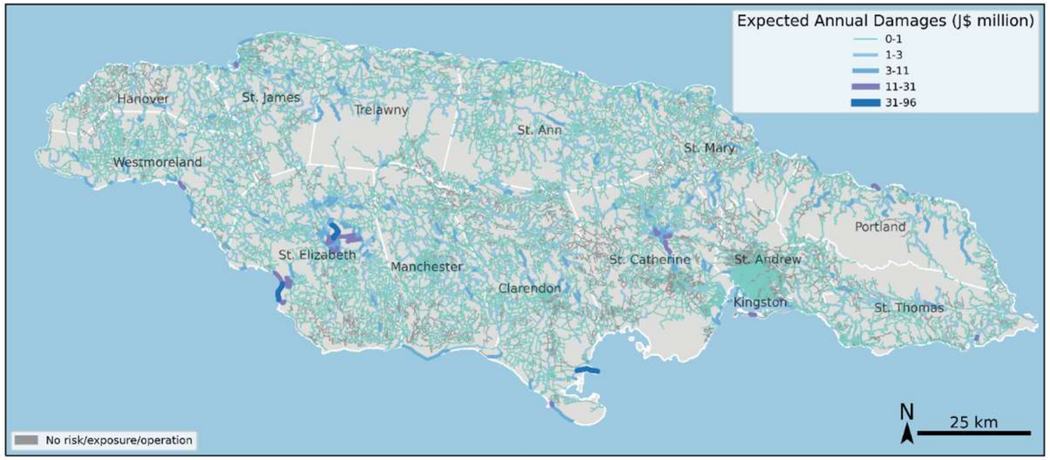
Damage and economic disruption: Road links

Roads multi-hazard Expected Annual Damages



Roads multi-hazard Expected Annual Losses

EAD and EAEL map plots here show:

- The locations on roads with the highest annual expected physical damages and economic losses.
- Some road links have **physical risks** in excess of J$ 31 million, with some as high as J$ 96 million.
- **Economic risks** due to road link failures can be as high as J$ 118 - 250 million/day.
- Assets with highest physical risks might not have the highest economic risks.

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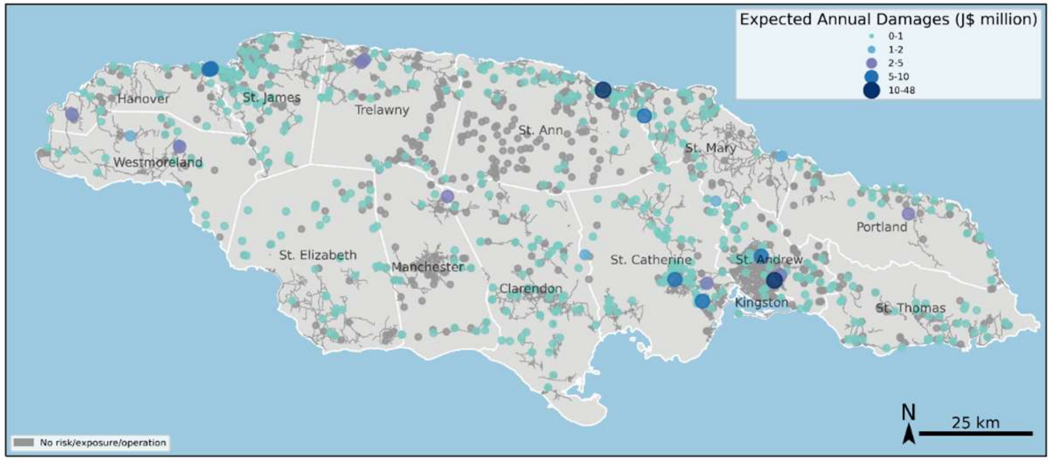
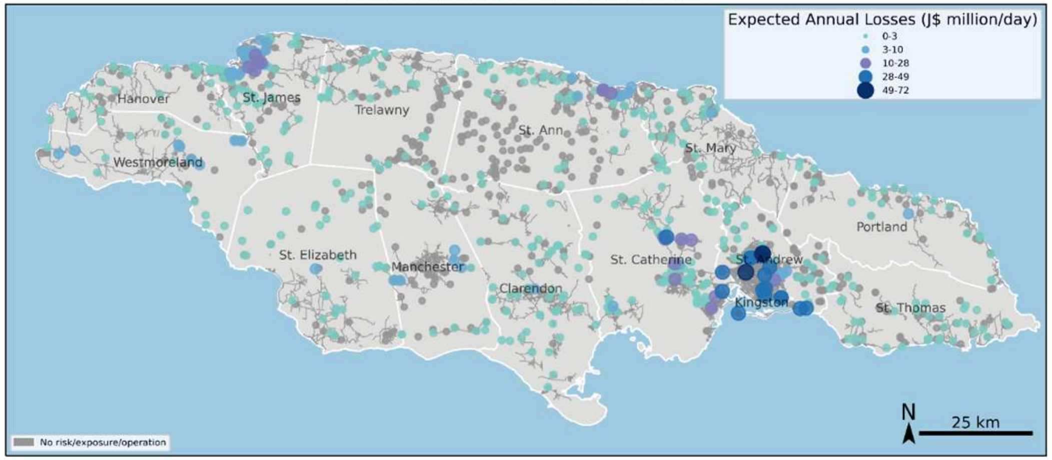
Damage and economic disruption: Potable water nodes

Potable water multi-hazard Expected Annual Damages



Potable water multi-hazard Expected Annual Losses



EAD and EAEL map plots here show:

- The locations on potable water nodes with the highest annual expected physical damages and economic losses.
- Some potable water nodes have **physical risks** in excess of J$ 10 million, with some as high as J$ 48 million.
- **Economic risks** due to potable water node failures can be as high as J$ 48 - 72 million/day.
- Assets with highest physical risks might not have the highest economic risks.

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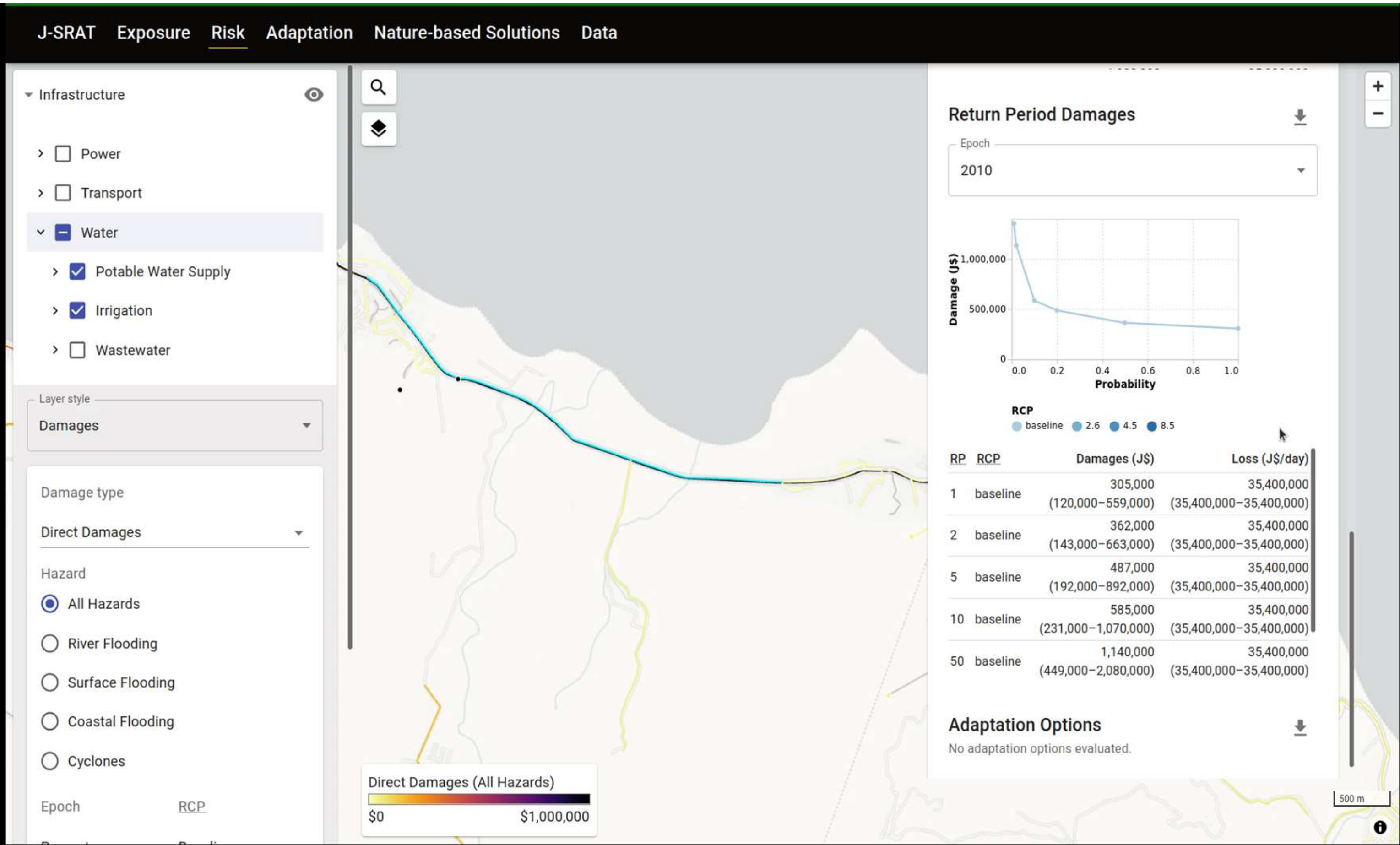

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Adaptation metrics

- **Costs** of adaptation options
  - **Initial cost of investment** to implement the adaptation options
  - **Net Present values of Maintenance costs** – Recurrent and Periodic

- **Benefits** – which include the avoided losses in terms of:
  - **Net Present Values of Avoided Expected Annual Damage (EAD)**
  - **Net Present Values of Avoided Expected Annual Economic loss (EAEL) over an assumed duration of disruption**

- **Benefit-Cost ratios (BCR)** = Benefit/Cost

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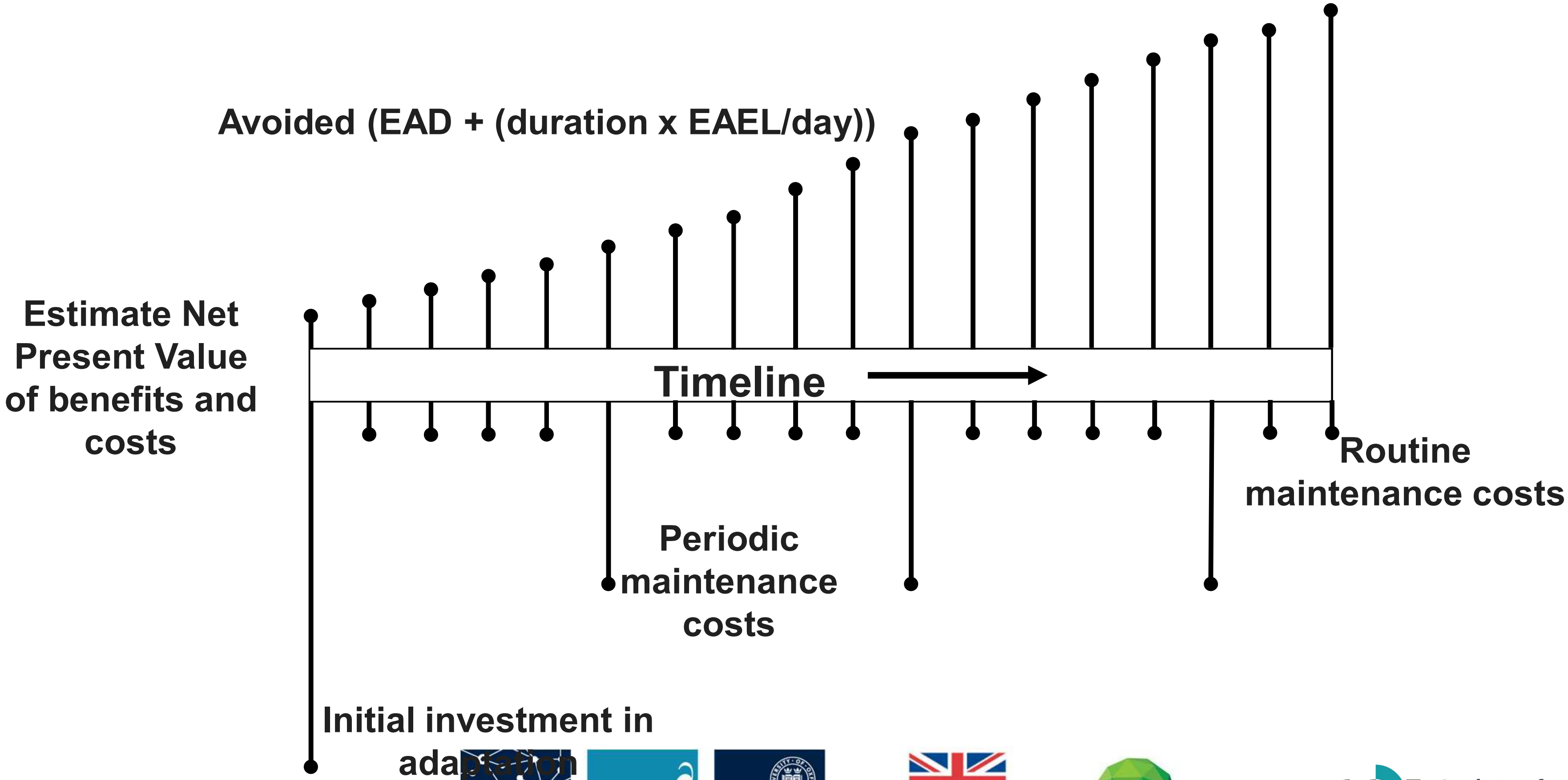
Adaptation analysis



Adaptation example – Energy assets flood protection

- Two type of adaptation options:
  - **Protection wall:** build a protective flood wall around power plants + substations

Initial investment cost (for raising wall per m)	Maintenance costs (for raising wall per m)	Discounting rate	Option timeline
105 J$ million/m	0.5 J$ million/m/year	10%	2019-2100

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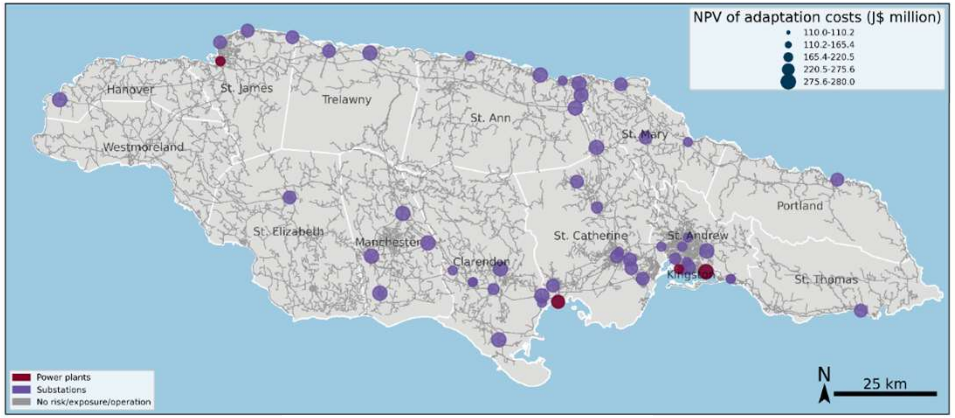
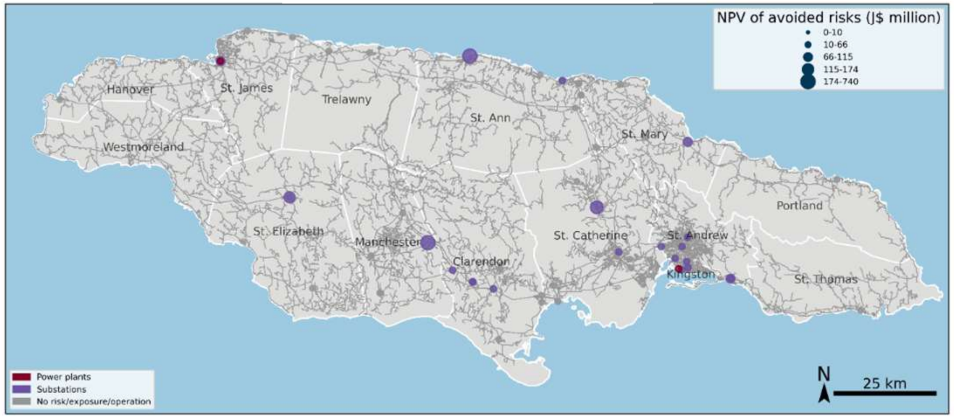
Costs and benefits of adaptation: Flood protection of energy assets

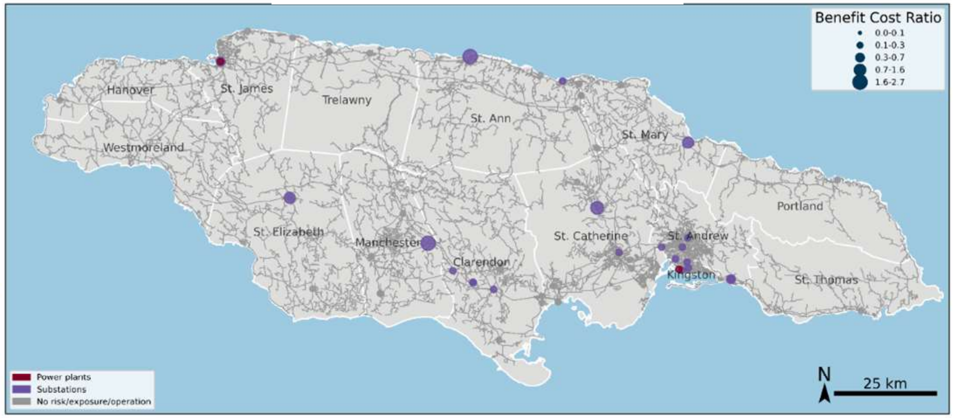
Adaptation Cost



Avoided losses



Benefit Cost Ratios



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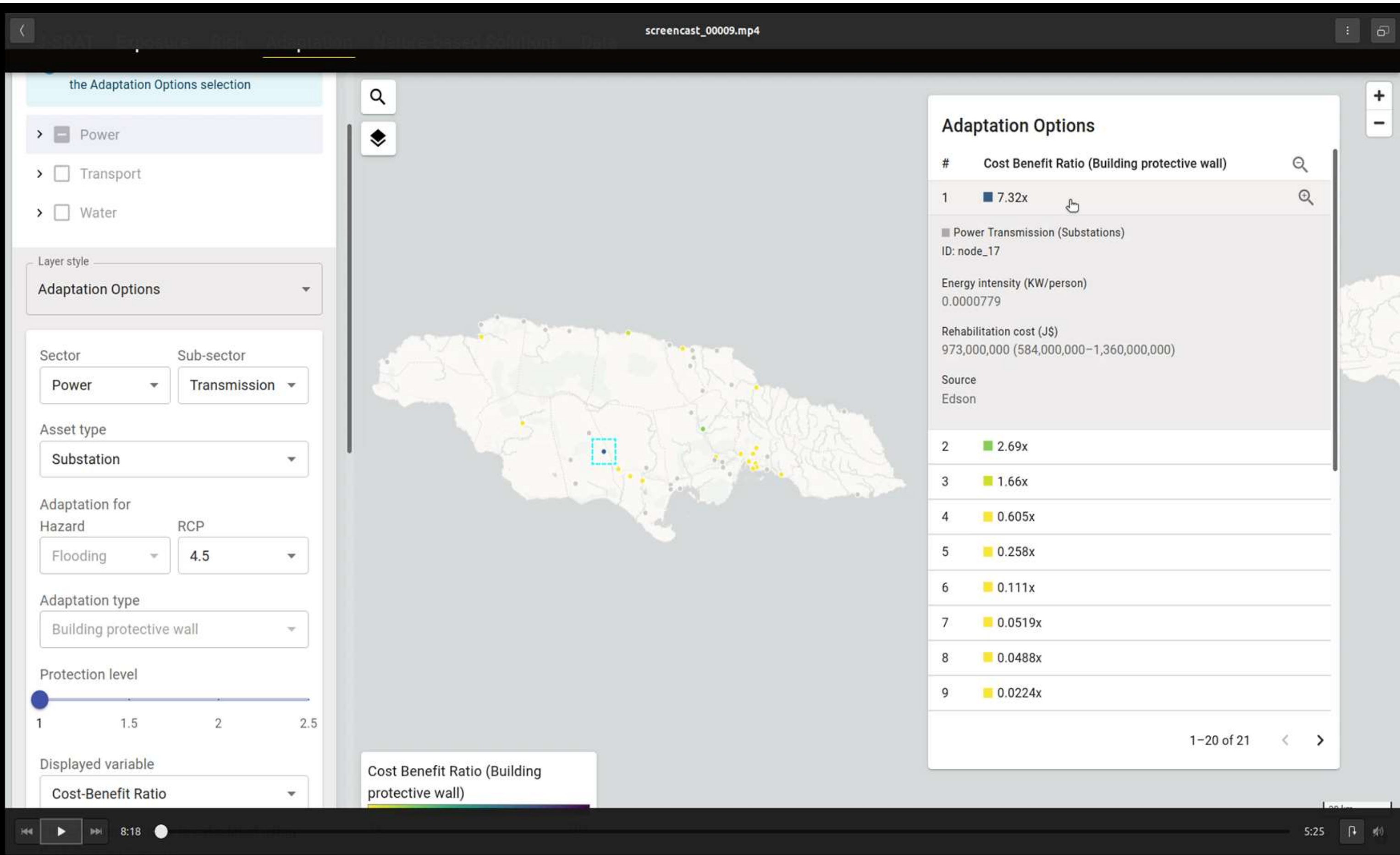

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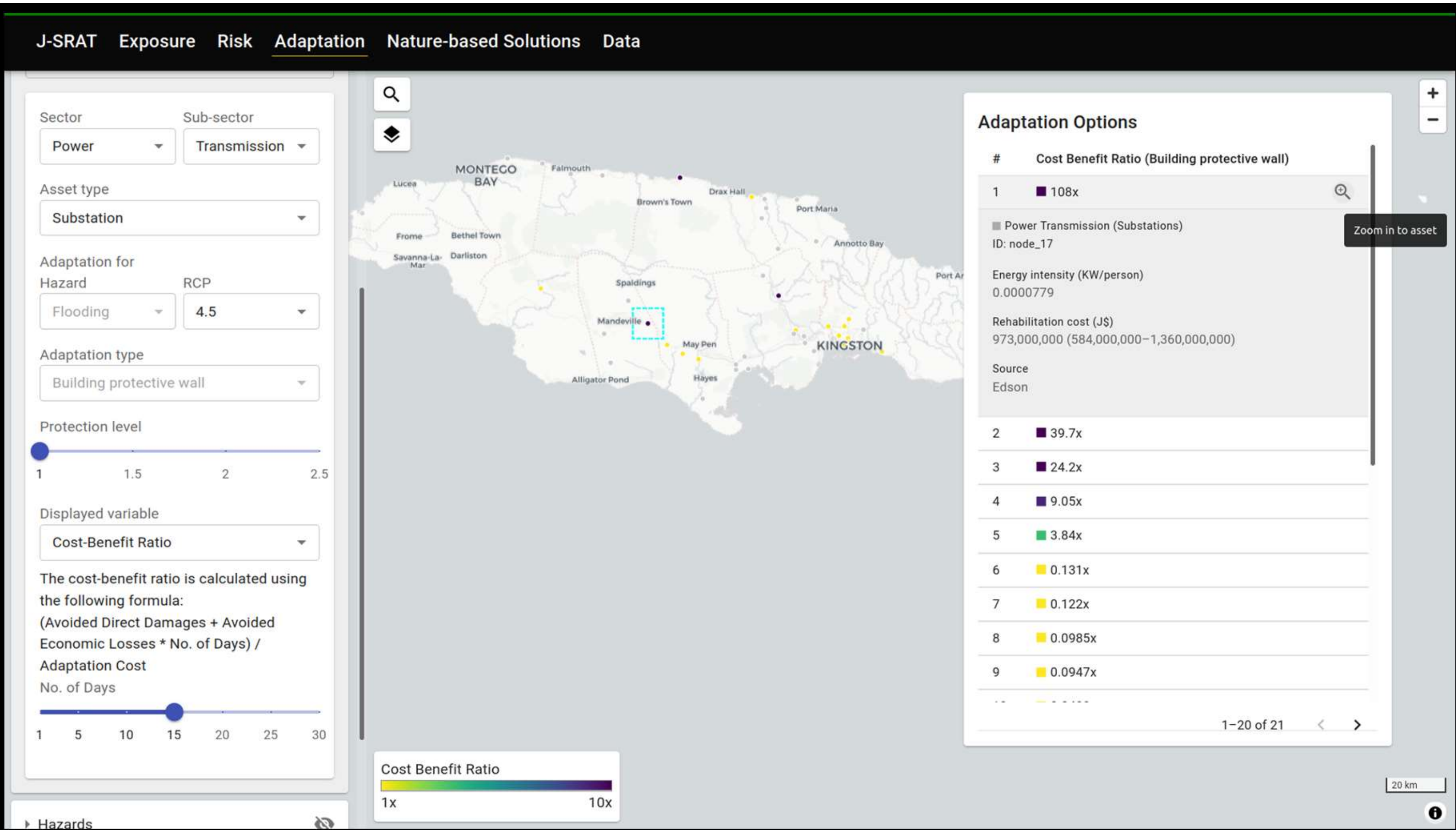

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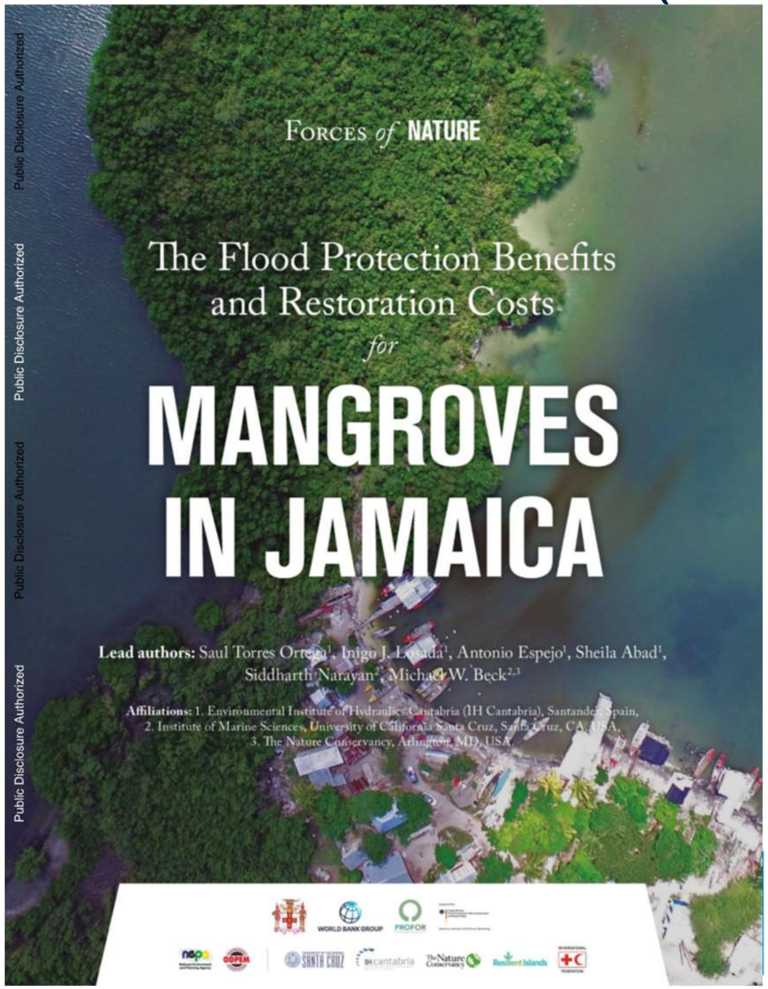
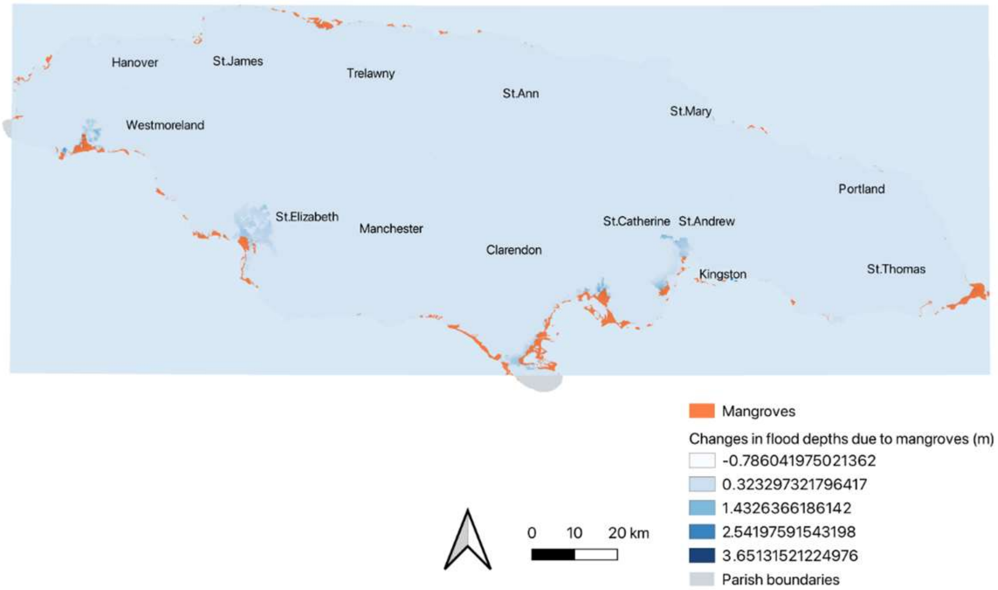
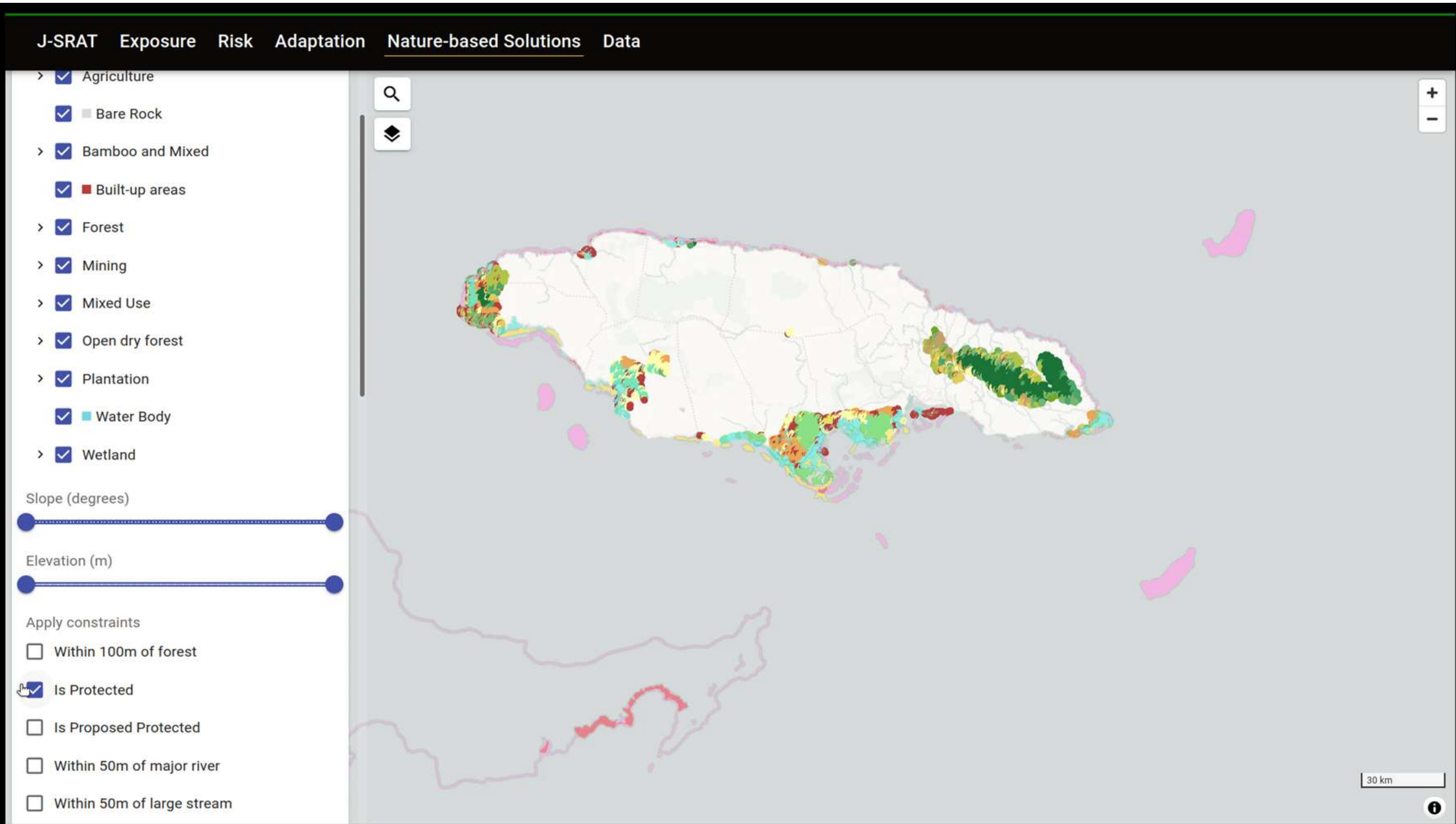
Nature based solutions (NbS) as an Adaptation option



Using a previous study on changes in coastal flood depths and outlines due to mangroves in Jamaica, we have applied similar changes to coastal flood maps in our study. This gives us changing risks due to mangroves.





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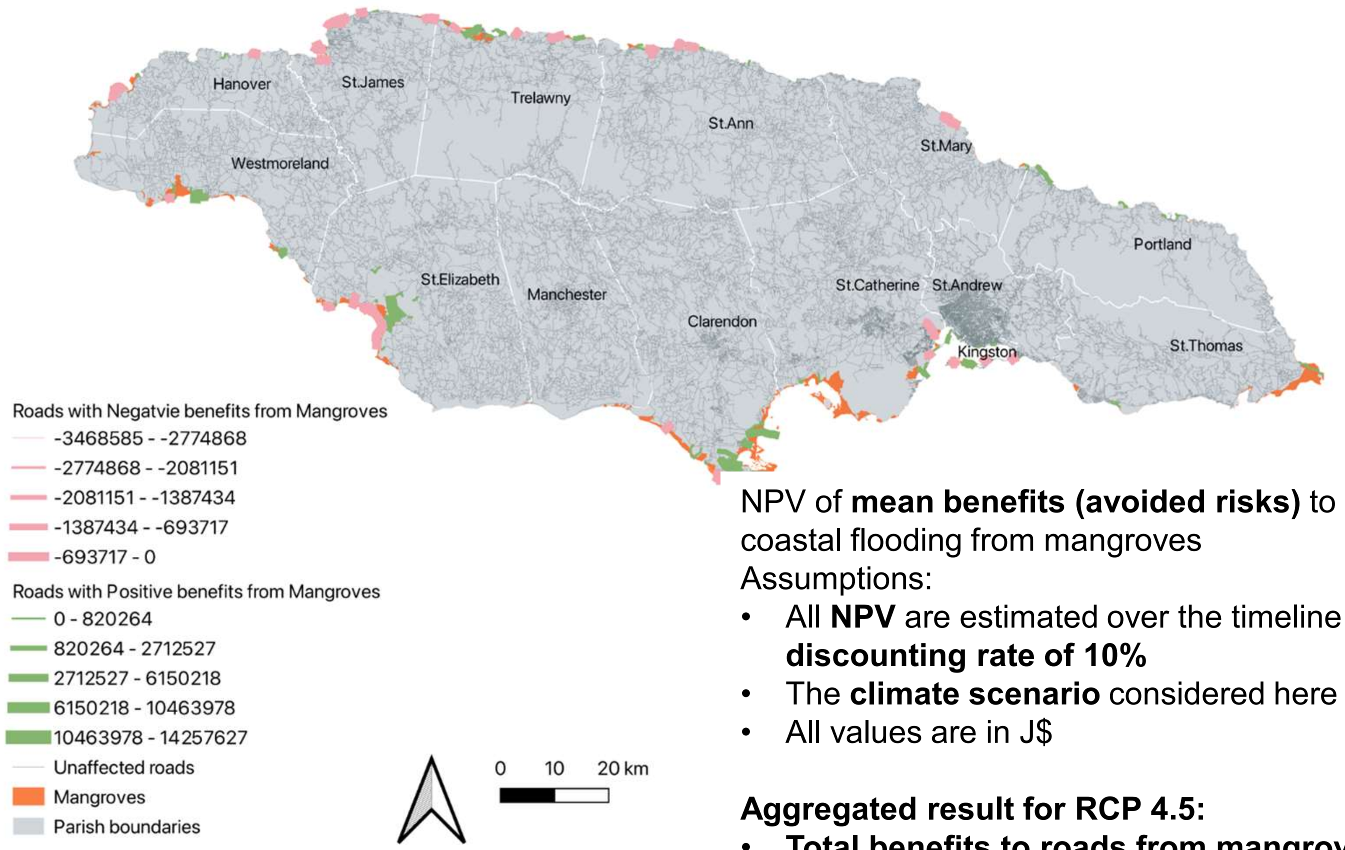
Nature based solutions (NbS) benefits - Roads



NPV of **mean benefits (avoided risks)** to roads due to changes in coastal flooding from mangroves

Assumptions:

- All **NPV** are estimated over the timeline of **2019-2100 with discounting rate of 10%**
- The **climate scenario** considered here is **RCP 4.5**
- All values are in J$

Aggregated result for RCP 4.5:

- **Total benefits to roads from mangroves is between 50 – 180 J$ million with mean estimate of 108 J$ million**


IPCC approach to risk analysis
Risk = function(Hazard, Exposure, Vulnerability)

Achievements of J-SRAT

- An extensive database of spatial infrastructure networks and hazards has been created.
- Systemic hazard exposure, vulnerability and physical current and future risks mapping has been done.
- Asset criticality analysis has been done to identify locations on network where risk concentrations are highest.
- A process for incorporating adaptation options and assessing their effectiveness has been developed.

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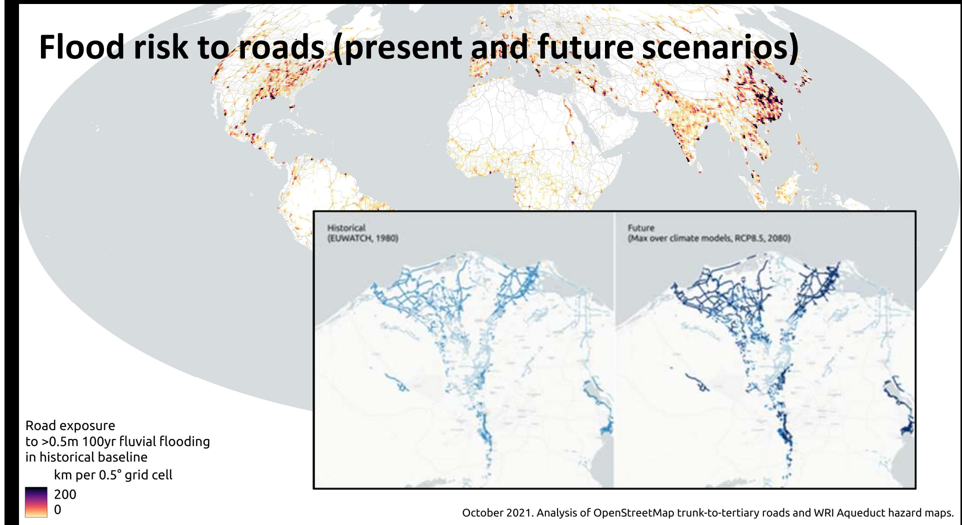
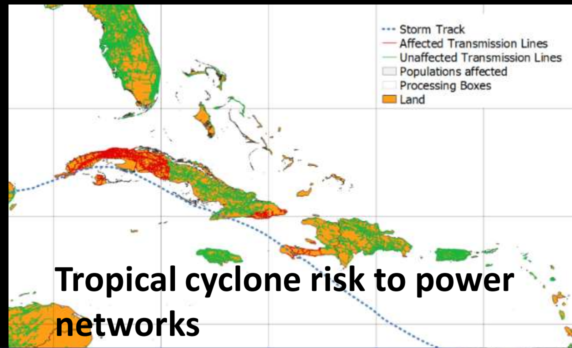
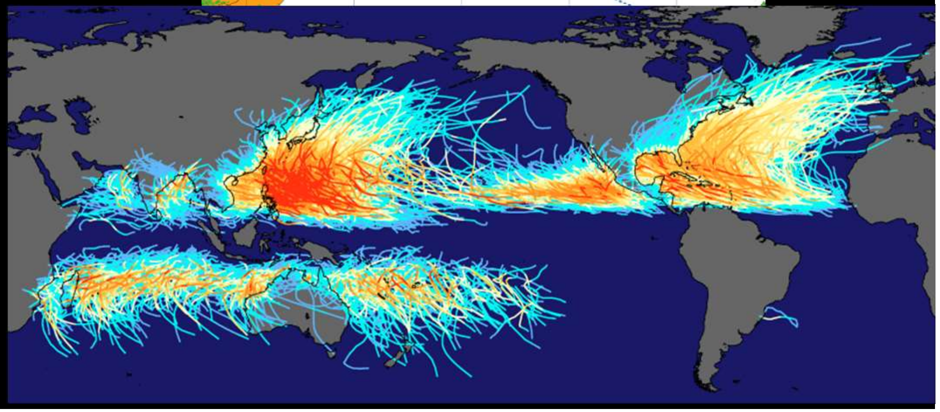
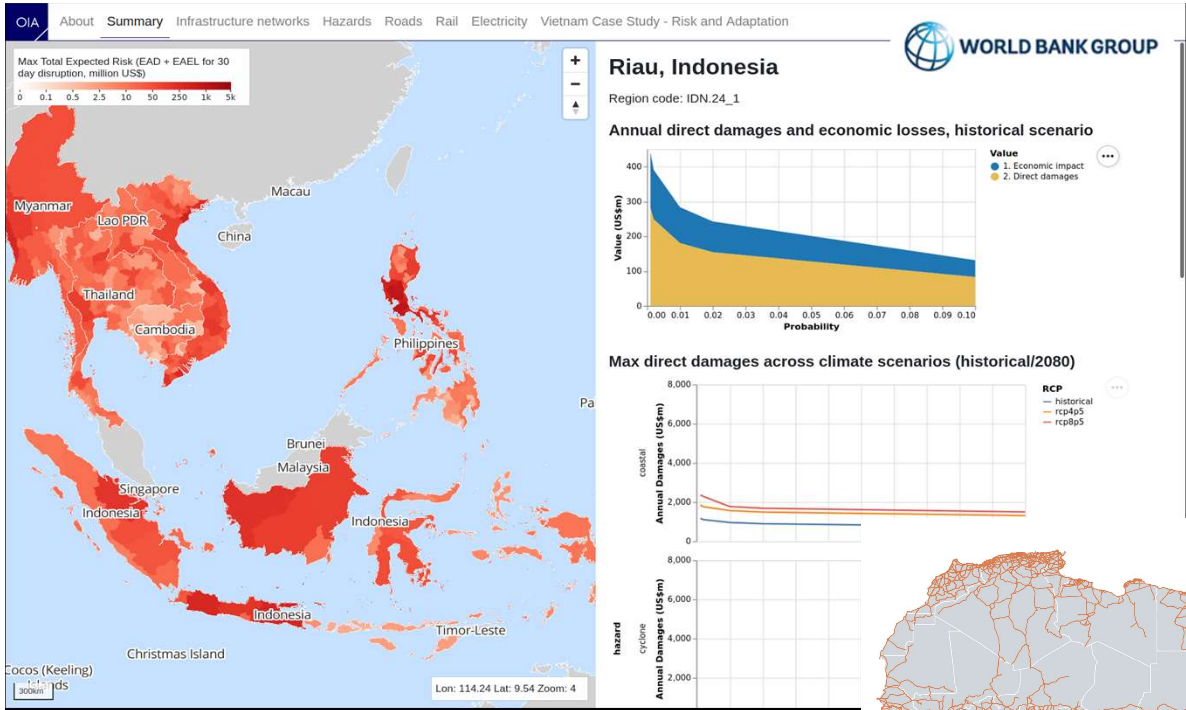
Upscaling to global analytics

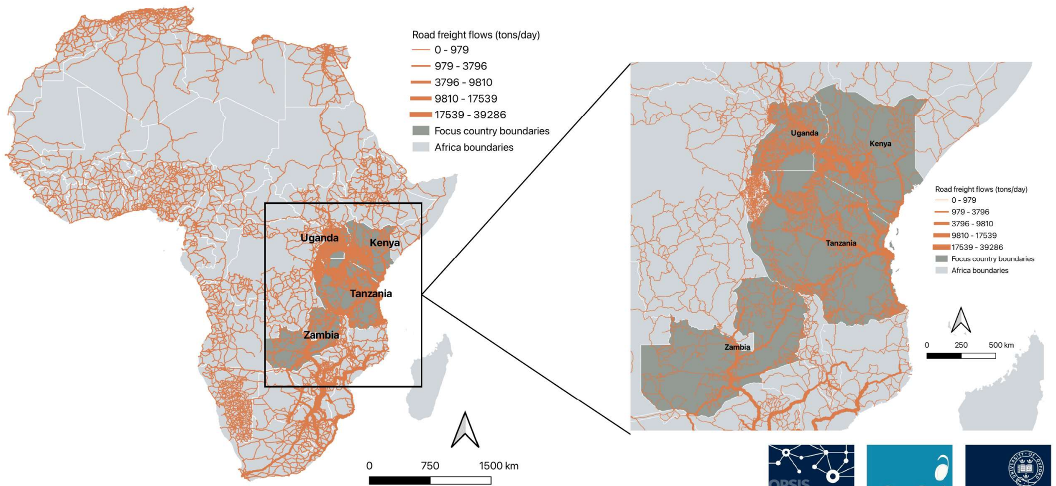






Global tools





The destination

- Quantified spatial analysis of climate risks to infrastructure networks… everywhere on Earth
- Starter kits for national scale assessment
- Estimates of economic losses in present and future scenarios to drive prioritization and tiered risk management
- Attribution of risk to assets in infrastructure networks… which enables prioritization of resilience in planning and asset management
- Open and accessible data and analysis…
  to build capacity and democratize decision-making

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Acknowledgements

- UK Foreign Commonwealth and Development Office
- Planning Institute of Jamaica
- Coalition for Climate Resilient Investments
- Green Climate Fund
- World Bank

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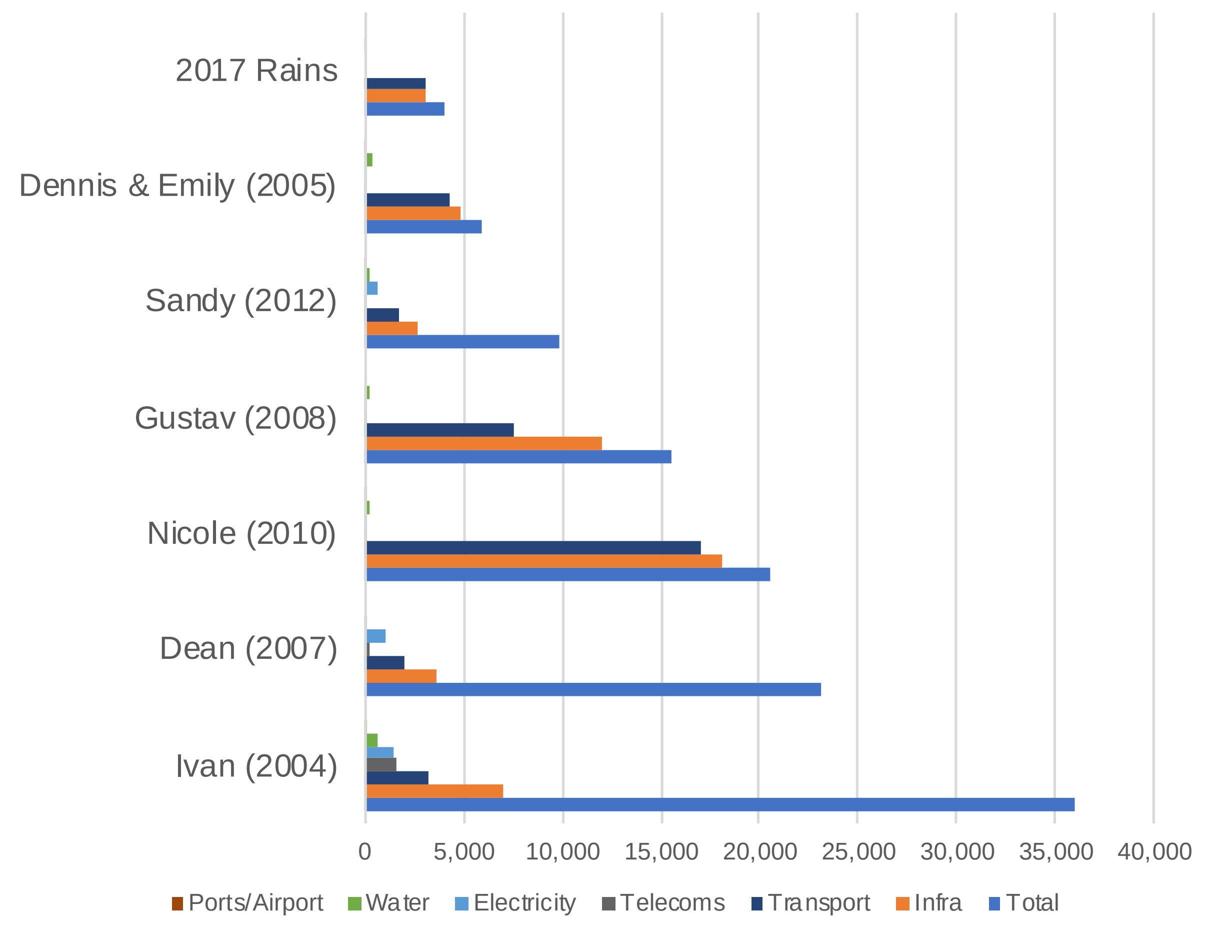
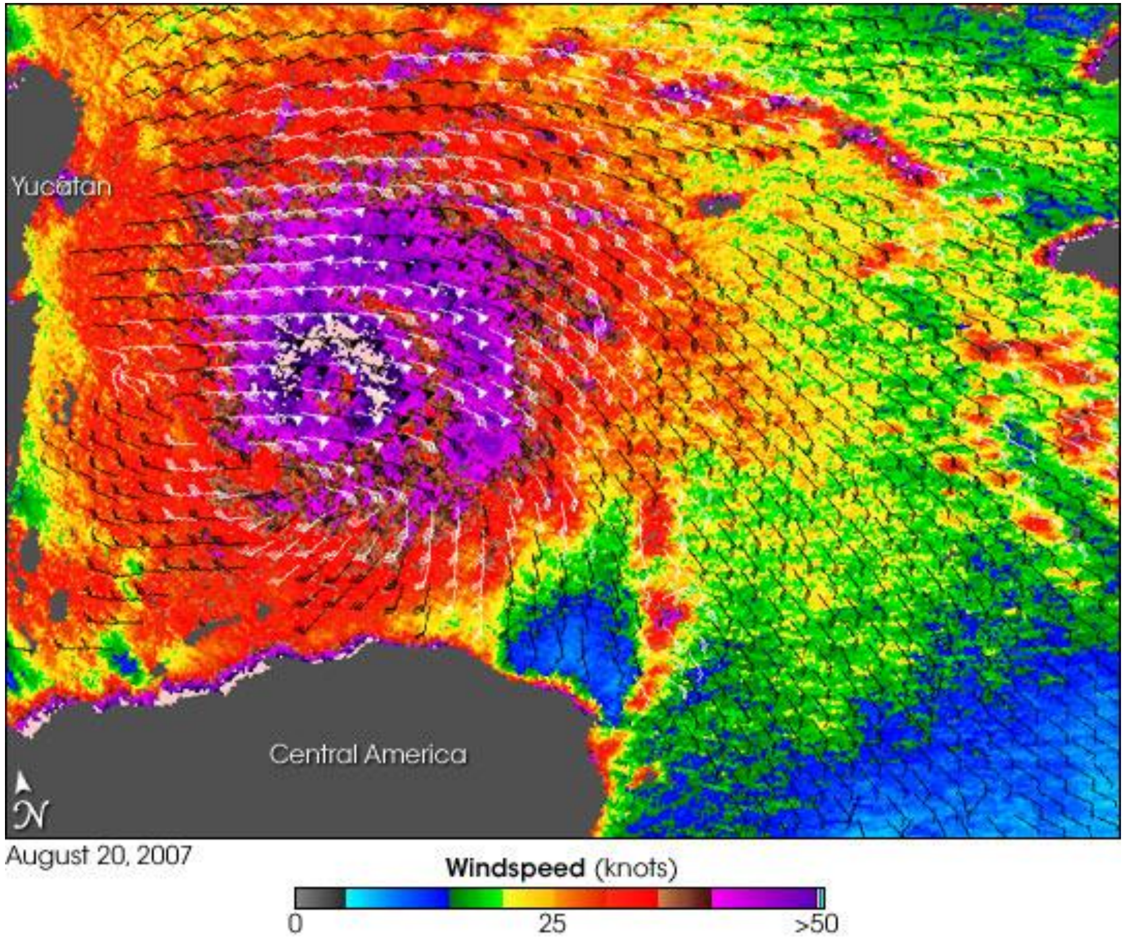
Presentation from UK CGFI on potential applications for OIA's work

Nicola Ranger, *Deputy Director, UK Centre for Greening Finance & Investment and Head of Sustainable Finance Research for Development, Oxford Sustainable Finance Group*

Quantitative (Results) Verification Methodology





Applications to Disaster Risk Finance(+)

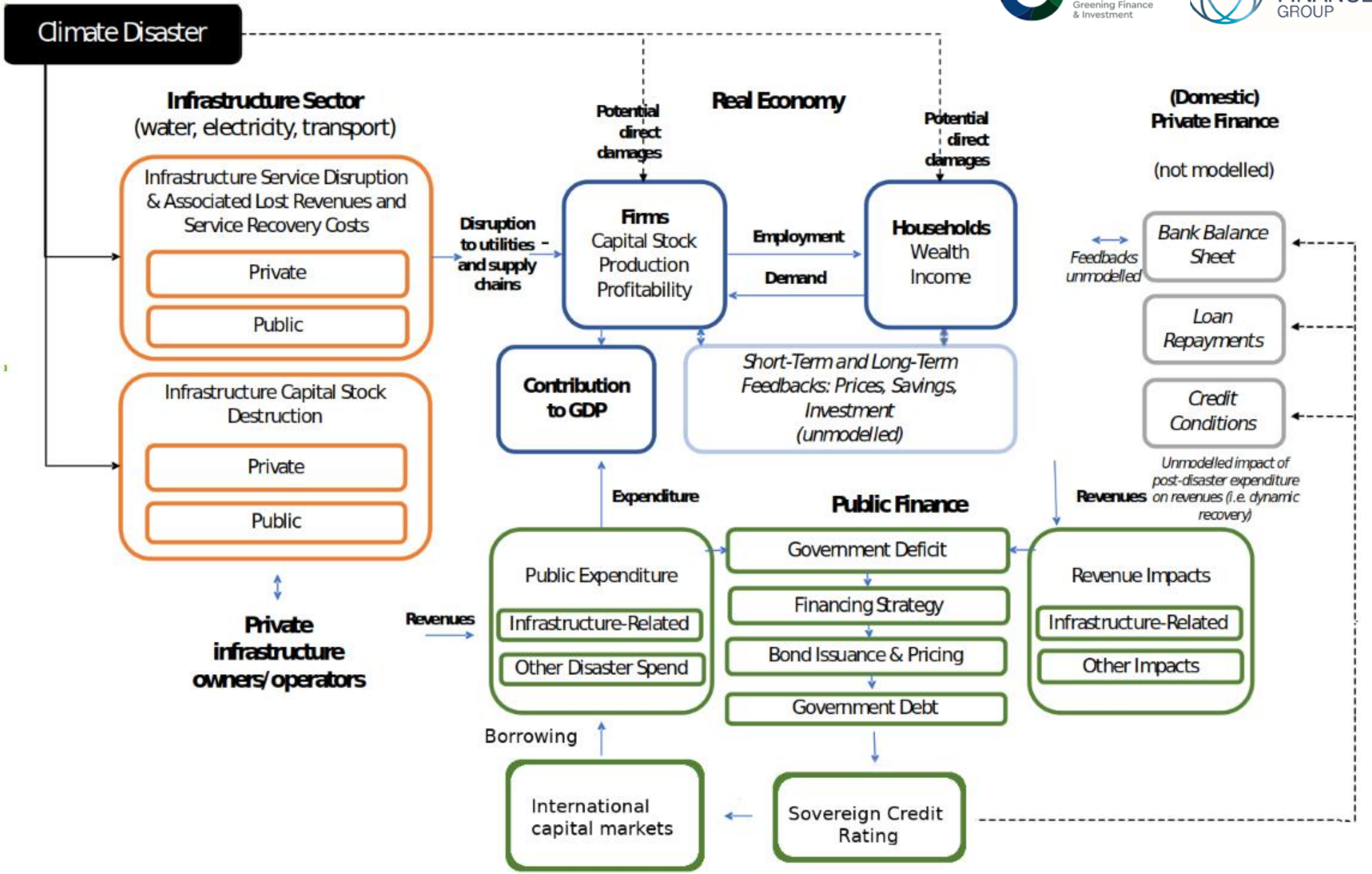
Dr Nicola Ranger
UK Centre for Greening Finance and Investment and University of Oxford

What is the value-add of infrastructure analytics for DRF decision making?

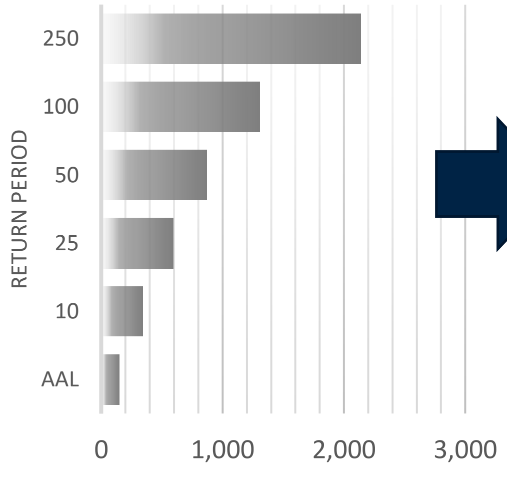
More comprehensive management of financial risk to government: Enables assessment of the wider contingent liabilities, beyond just the physical asset, and gives a better sense of revenue implications, e.g. water distribution in Jamaica. Helps create clarity on risk ownership and incentives for private sector to better manage risk.

Supports faster recovery of critical services: Enables estimation of response costs for rapid recovery of critical services (water, power, transport, telecoms) and informs development of preparedness plans

Financial protection & resilient infrastructure: added information on the costs and benefits of investing in more resilient infrastructure

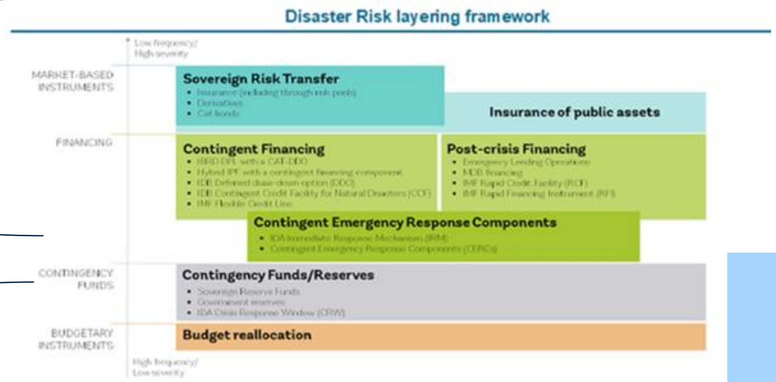


Climate Disaster
Infrastructure Sector
(water, electricity, transport)
Infrastructure Service Disruption & Associated Lost Revenues and Service Recovery Costs
Private
Public
Infrastructure Capital Stock Destruction
Private
Public
Private infrastructure owners/operators
Revenues
Disruption to utilities and supply chains
Potential direct damages
Real Economy
Firms
Capital Stock
Production
Profitability
Employment
Demand
Households
Wealth
Income
Potential direct damages
Contribution to GDP
Short-Term and Long-Term Feedbacks: Prices, Savings, Investment (unmodelled)
(Domestic) Private Finance
(not modelled)
Feedbacks unmodelled
Bank Balance Sheet
Loan Repayments
Credit Conditions
Unmodelled impact of post-disaster expenditure on revenues (i.e. dynamic recovery)
Revenues
Expenditure
Public Finance
Public Expenditure
Infrastructure-Related
Other Disaster Spend
Government Deficit
Financing Strategy
Bond Issuance & Pricing
Government Debt
Revenue Impacts
Infrastructure-Related
Other Impacts
Borrowing
International capital markets
Sovereign Credit Rating



VALUE OF LOSSES
[ILLUSTRATIVE]

Ministry of Finance



Line Ministries

Local Government

State-owned Enterprises

Private Infrastructure Providers

Households & Firms

Who owns the risk? Who holds contingent liability?

Who 'creates' the risk? Can risk be reduced? Are there incentives to reduce risk?

Where are the spillovers? Systemic impacts?

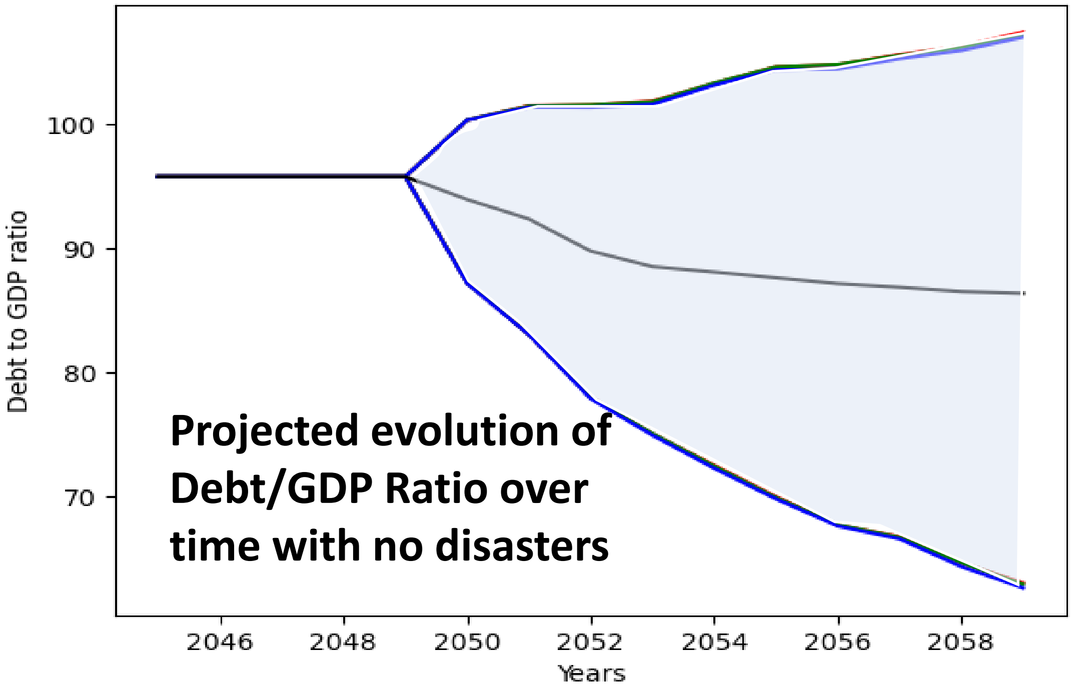
Who benefits from risk reduction?

Who pays? Who absorbs the risk if it is not managed effectively?

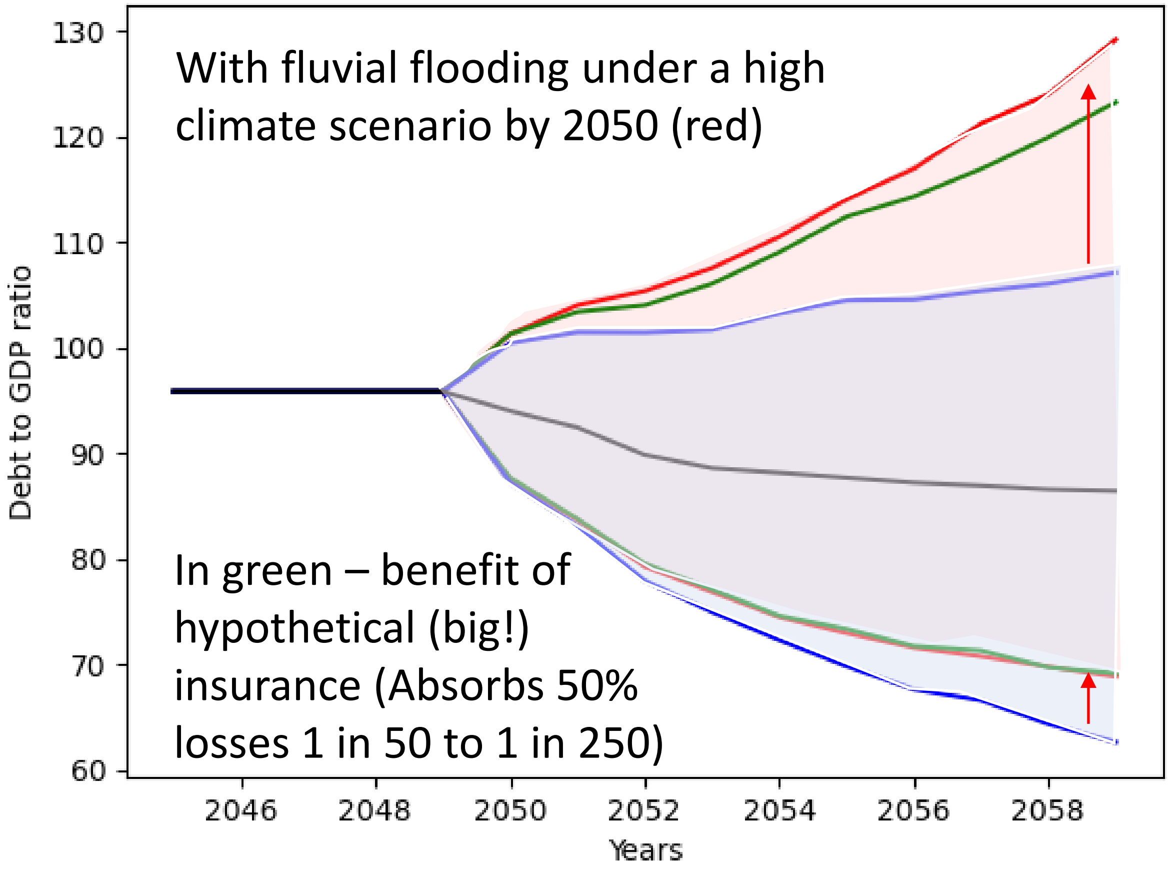
Water Sector

When supply fails (e.g., flood has affected treatment plant operations), the utility will pay for water tanker trucks. However, they have a limited capacity and budget. So private vendors come in where the utility tanker trucks are insufficient. The costs to the utility are roughly 100 million $J per year, but can go up to 300 million $J. The costs to society are ultimately borne by households and businesses and are very high, as people still must pay their tariffs, as well as the cost of purchasing water.

Infrastructure risk and sovereign debt (and credit ratings)



Range represents the 80th percentile range of projections, given uncertainty over time in future interest rates and surpluses. Central black line is 50th percentile



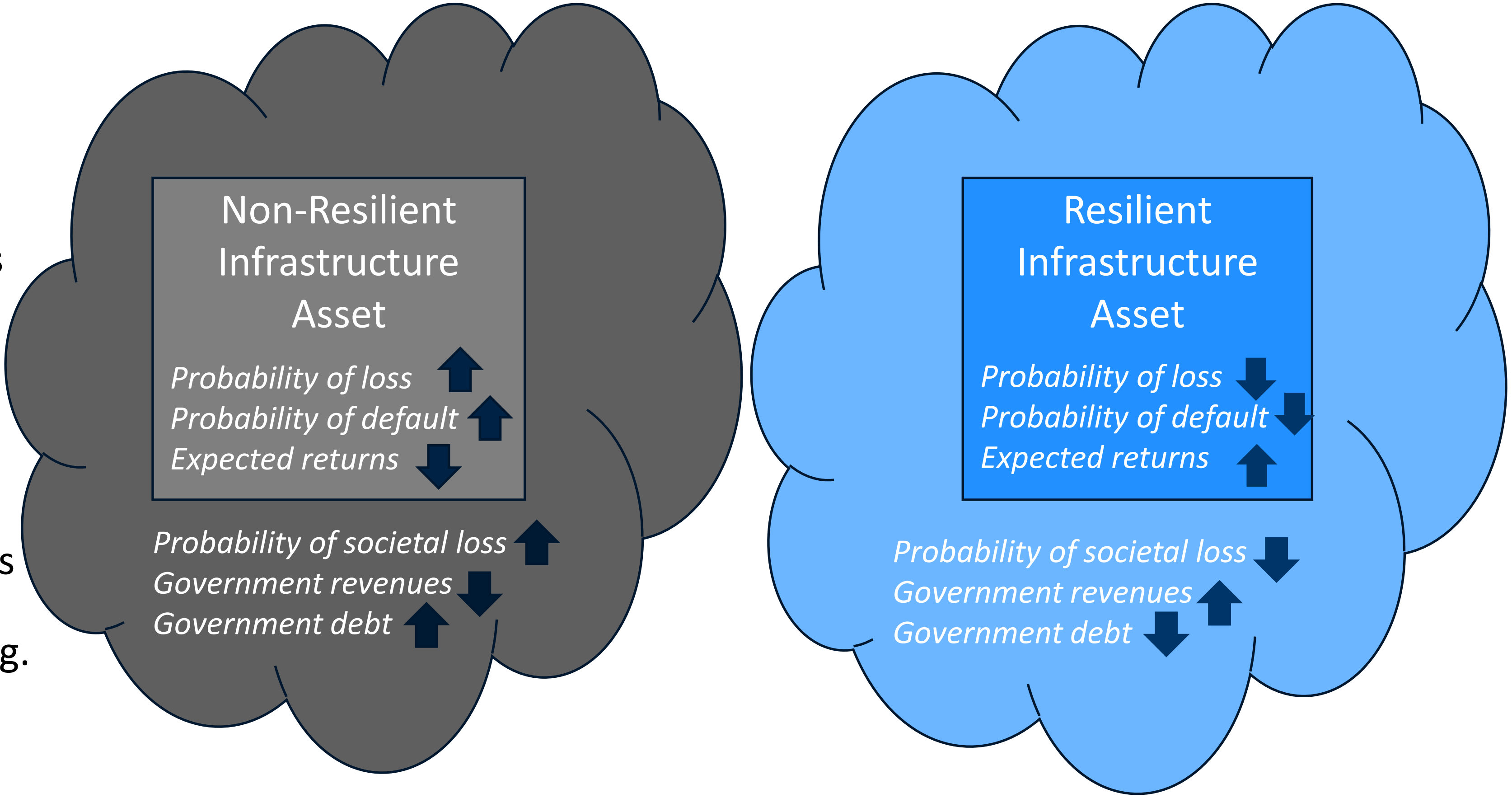
Valuing Systemic Resilience
Mobilize financing for adaptation

For investor:

Cost of capital proportionate to **expected returns** and **probability of default**

Insurance cost proportionate to probability of loss

Opportunities, e.g. resilience-linked lending products



Can we value and monetize the societal benefit of resilient infrastructure investment?

Monetizing e.g. reduced sovereign and real-economy credit risk? Worth billions to economy!

Climate-related ESG investment? Resilience-linked sovereign lending? Bond issuance? Blended finance facility?

Please contact us for further information:

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Q & A

SCAN ME

Scan the QR code to join the Disaster Risk Finance Community!

Thank you for your time