GLOBAL EXPOSURE MODELLING FOR MULTI-HAZARD RISK ASSESSMENT

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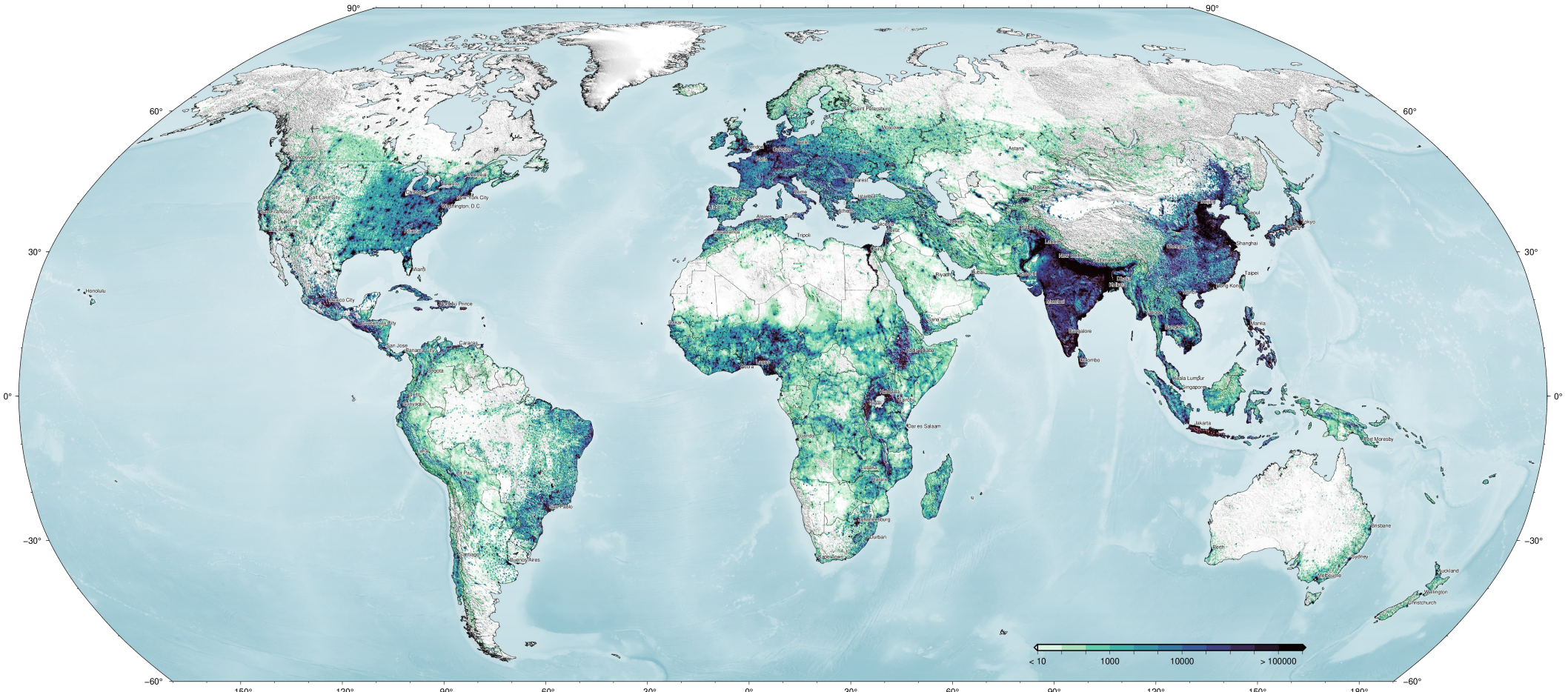
EFEHR Scientific Session 2024

GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

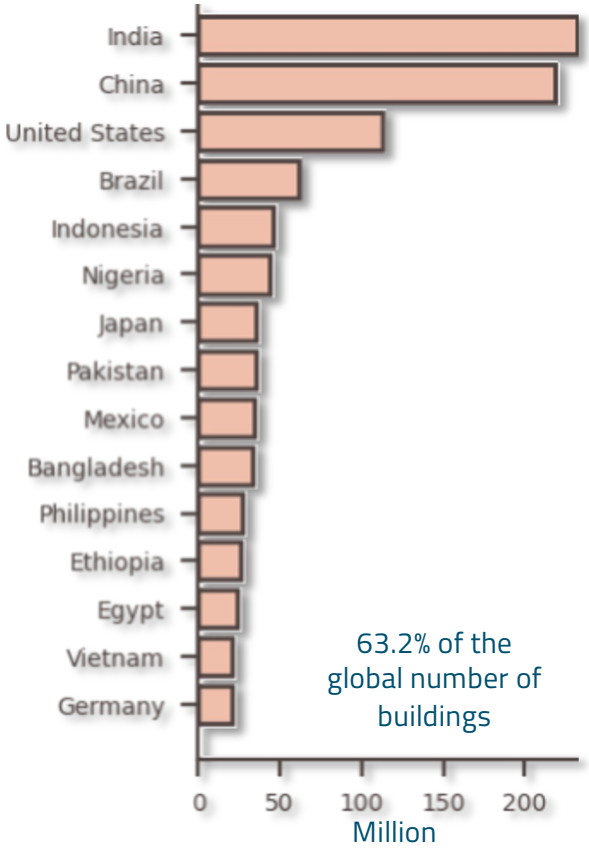
The 2023 GEM's Global Exposure Model



Number of residential, commercial and industrial buildings on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

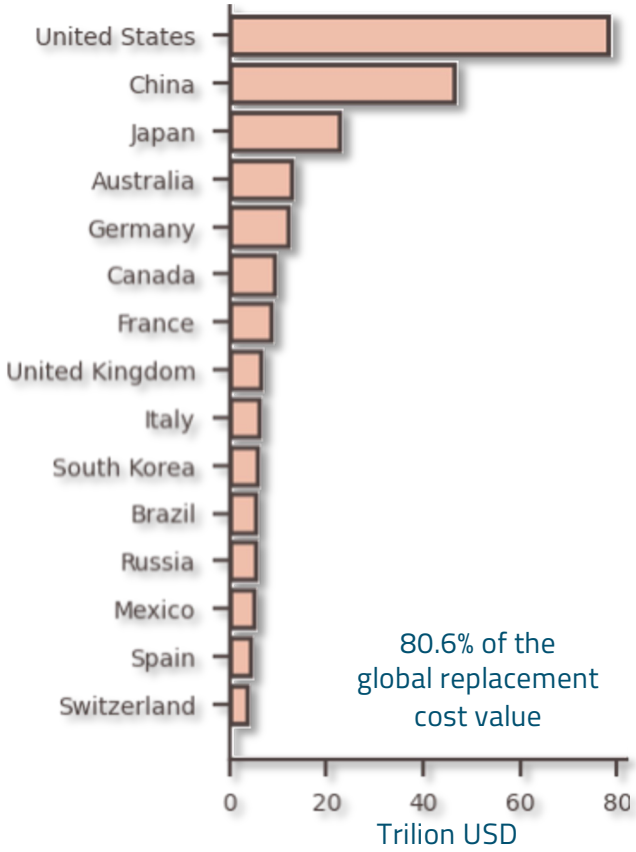
The 2023 GEM's Global Exposure Model

Number of buildings



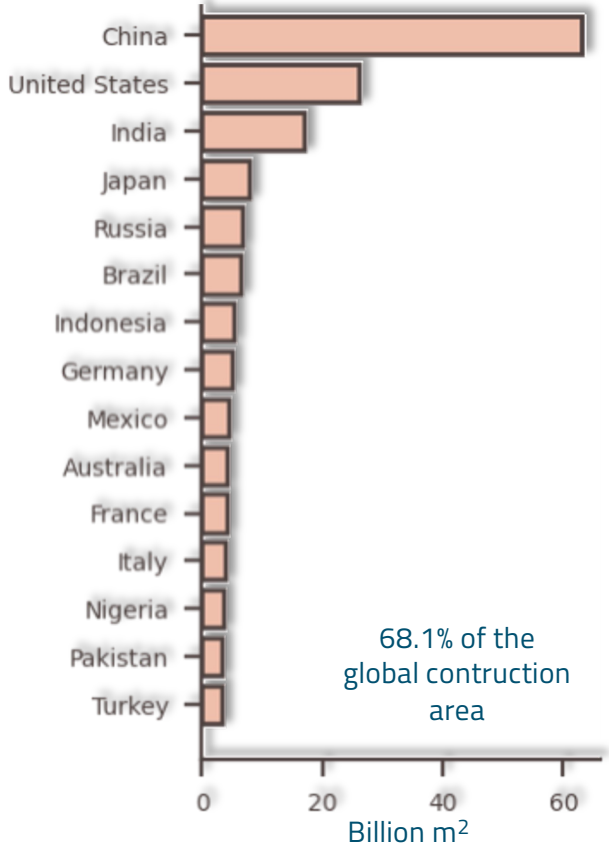
63.2% of the global number of buildings

Replacement cost



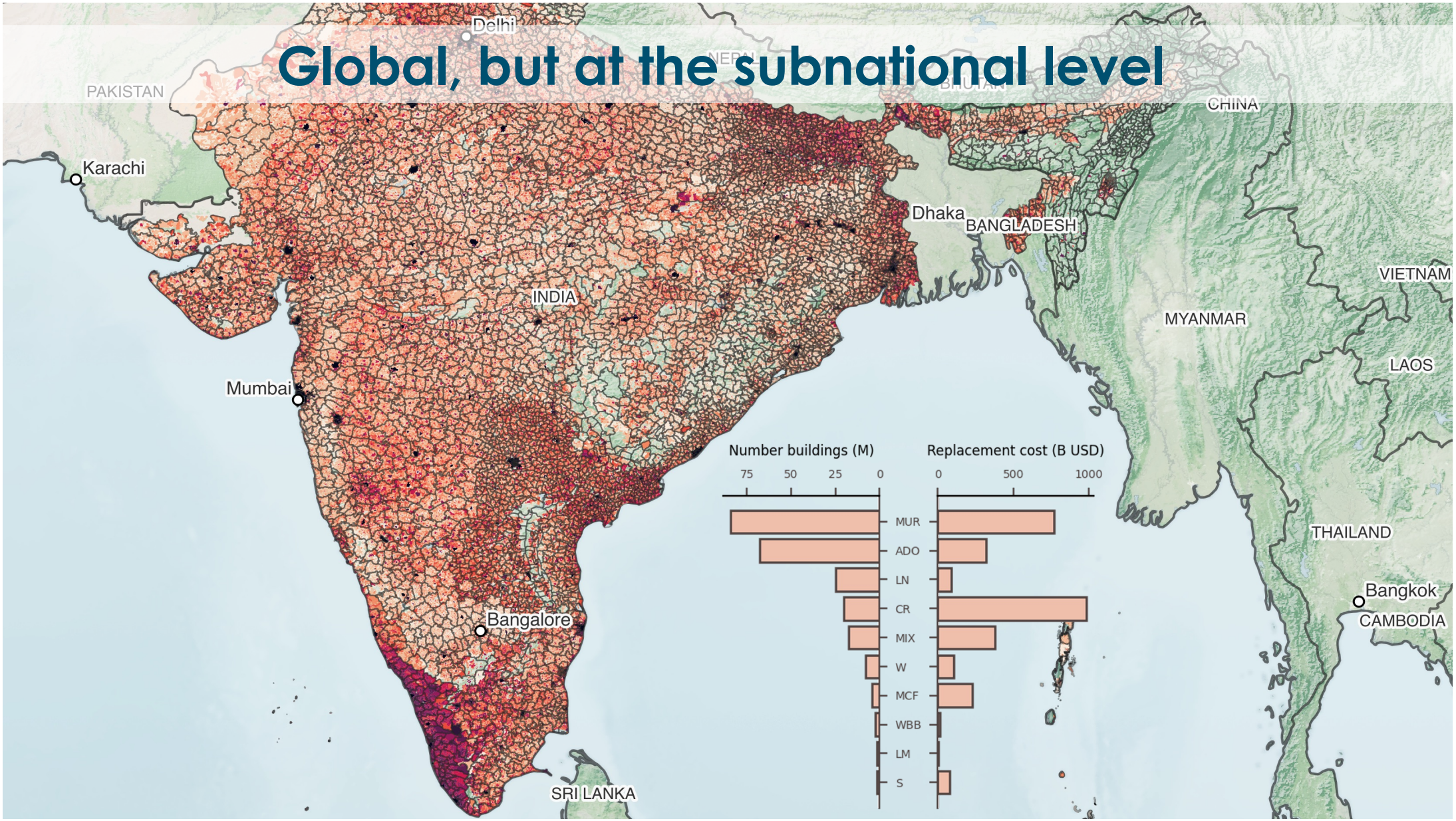
80.6% of the global replacement cost value

Construction area



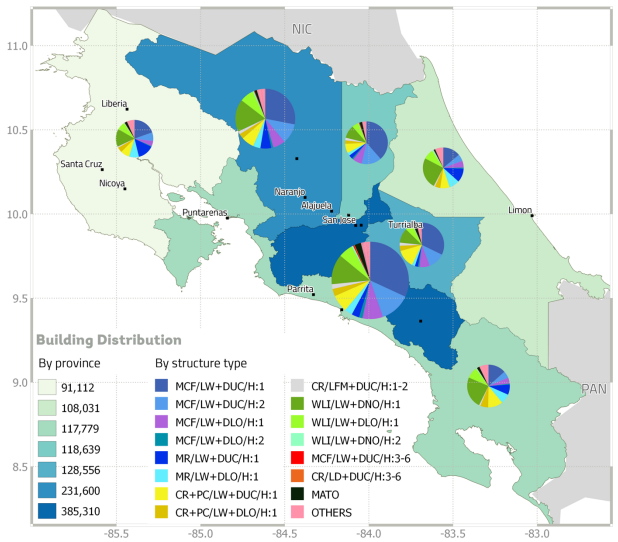
68.1% of the global contruction area

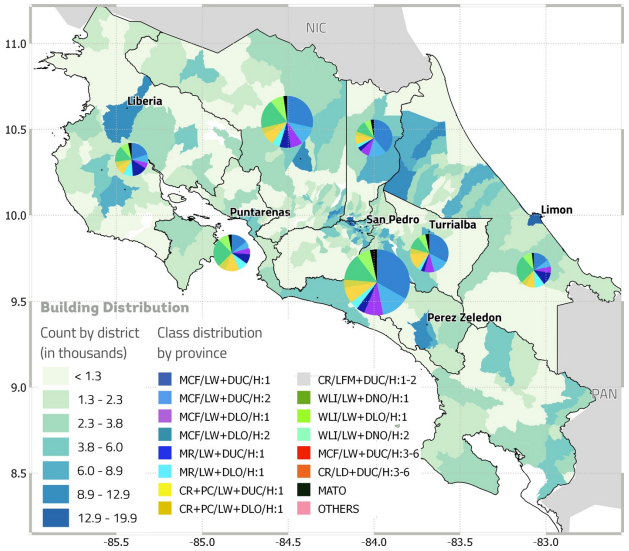
Global, but at the subnational level



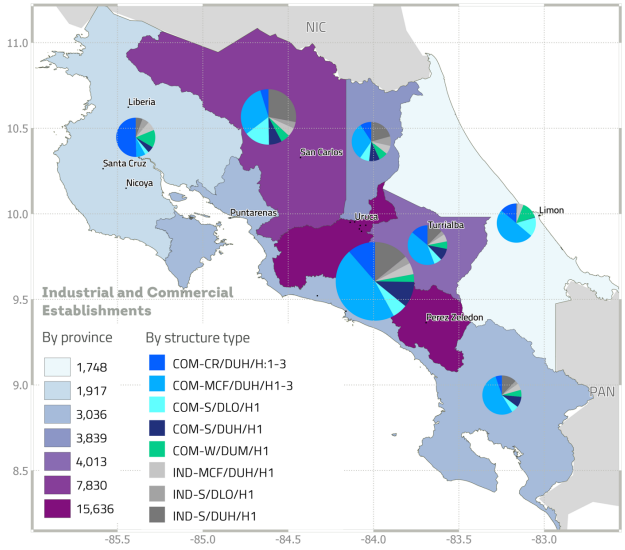
Exposure modelling within the GEM Foundation

Residential building stock

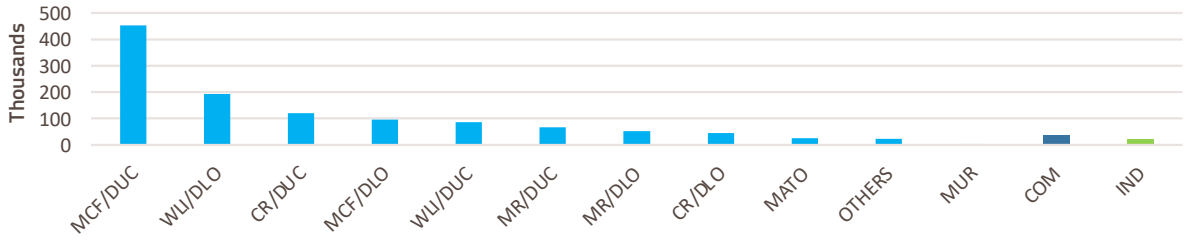




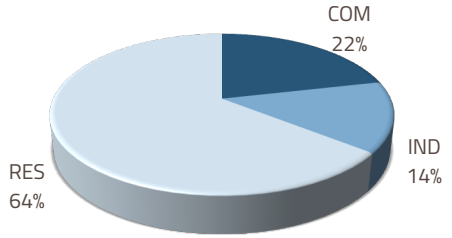
Non-residential building stock



Distribution of building classes

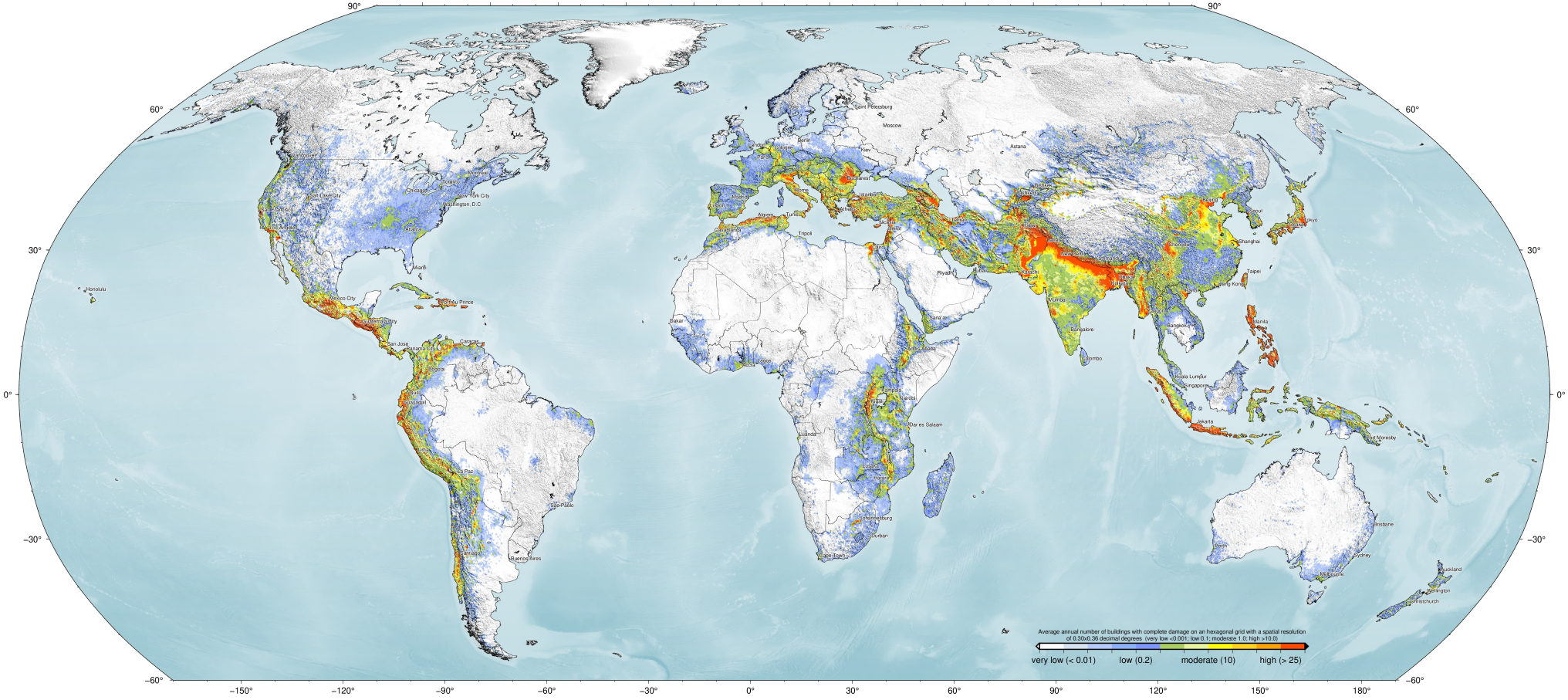


Distribution of capital stock



Some Recent Use Cases

Global Seismic Risk Assessment

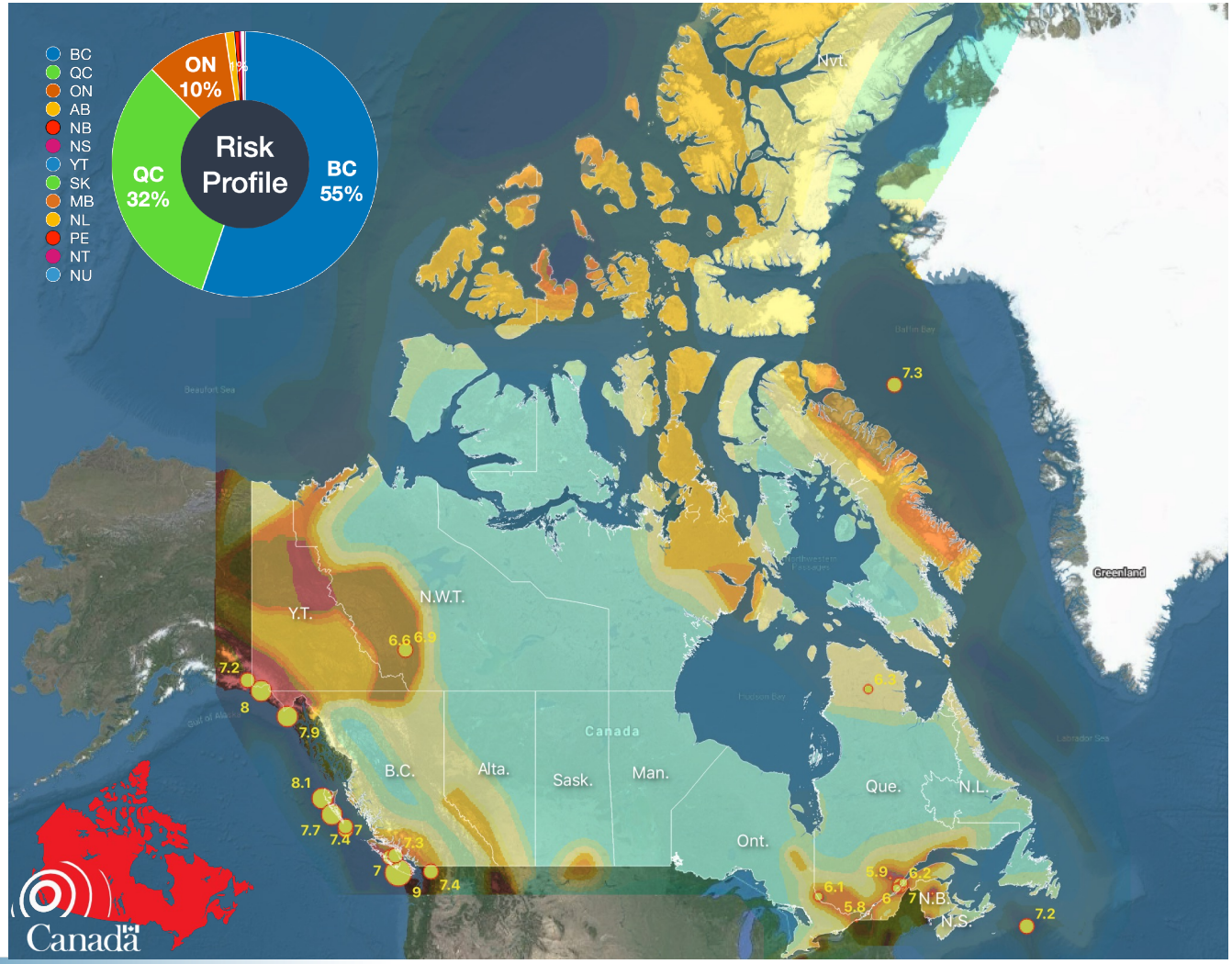


Average Annual Number of Buildings Destroyed on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

Some Recent Use Cases

National Seismic Risk Model for Canada

- A new generation risk model
- Comprises updated hazard and new exposure information country-wide
- Developed with NRCanada



Some Recent Use Cases

Investment in Earthquake and Flood Risk Reduction in Türkiye

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Who We Are / News | This page in: English | Türkçe

PRESS RELEASE | SEPTEMBER 27, 2022

$512 million World Bank Loan to Expand Finance for Bolstering Homes, Infrastru
Earthquakes, Flooding in Tü

WASHINGTON, September 27, 2022–
today approved $512.2 million in finan
expand access to housing and infrastru
climate and natural hazards, with the g
supporting the country's economic dev

THE WORLD BANK
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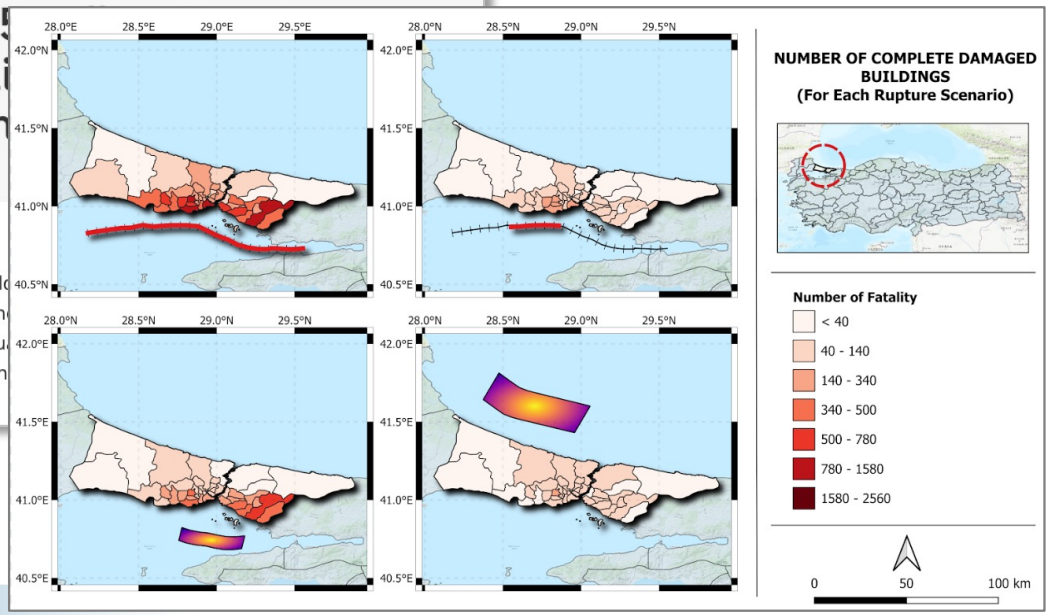
Who We Are / News | This page in: English | Türkçe

PRESS RELEASE | JUNE 9, 2021

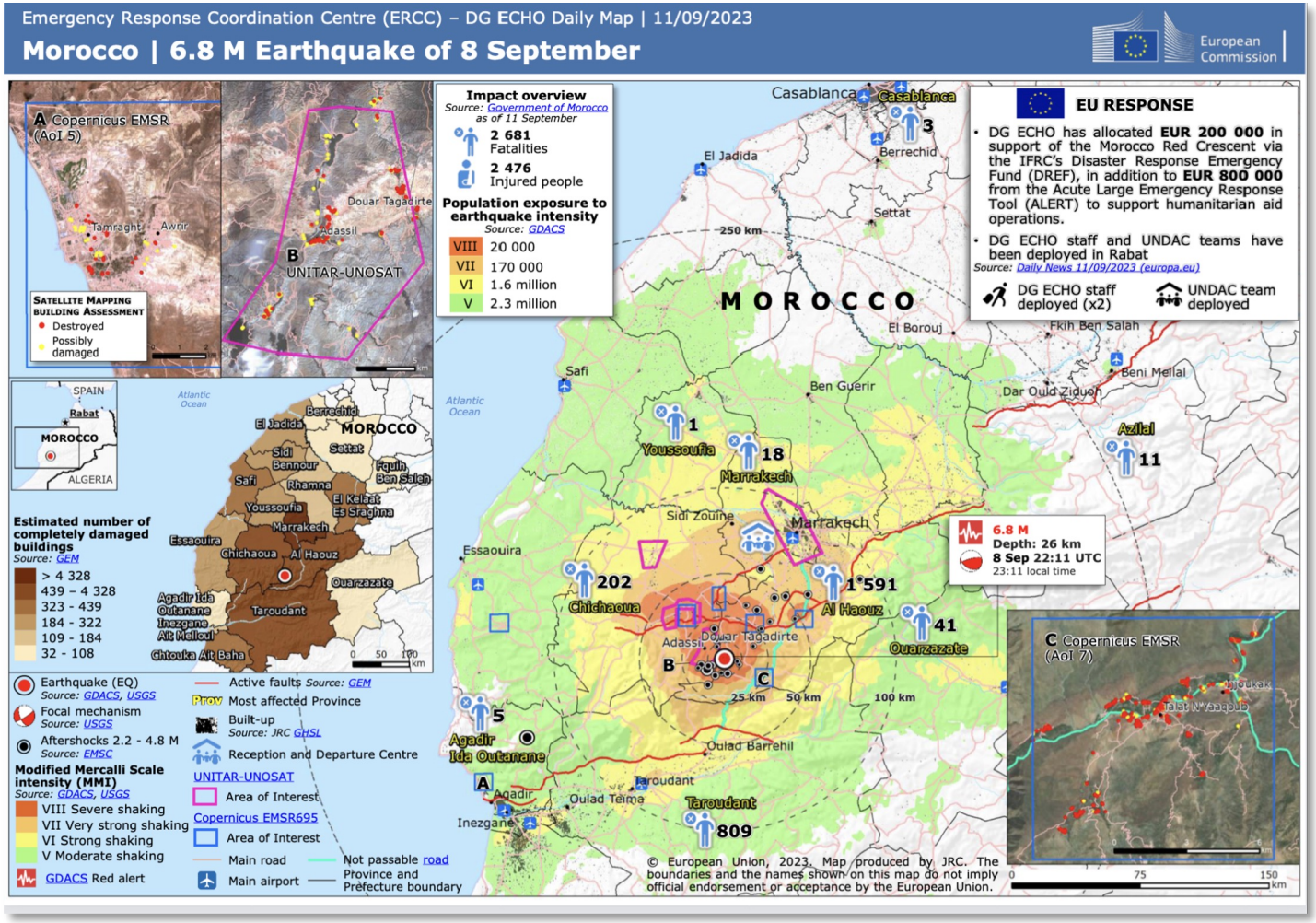
World Bank Provides $26
Improve Earthquake Resili
Efficiency of Public Buildin

WASHINGTON, June 9, 2021 – The World
a $265 million loan to Turkey to strengthe
buildings against the dangers of earthqua
improving energy efficiency to reduce en
carbon emissions.



Some Recent Use Cases

Rapid multi-hazard impact assessment for DGECHO, the JRC and the World Food Programme



Some Recent Use Cases

Expansion of the Earthquake Risk CAT Bond in Latin America to Floods

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CASE STUDY

Super-sized Catastrophe Bond for Earthquake Risk in Latin America

OVERVIEW

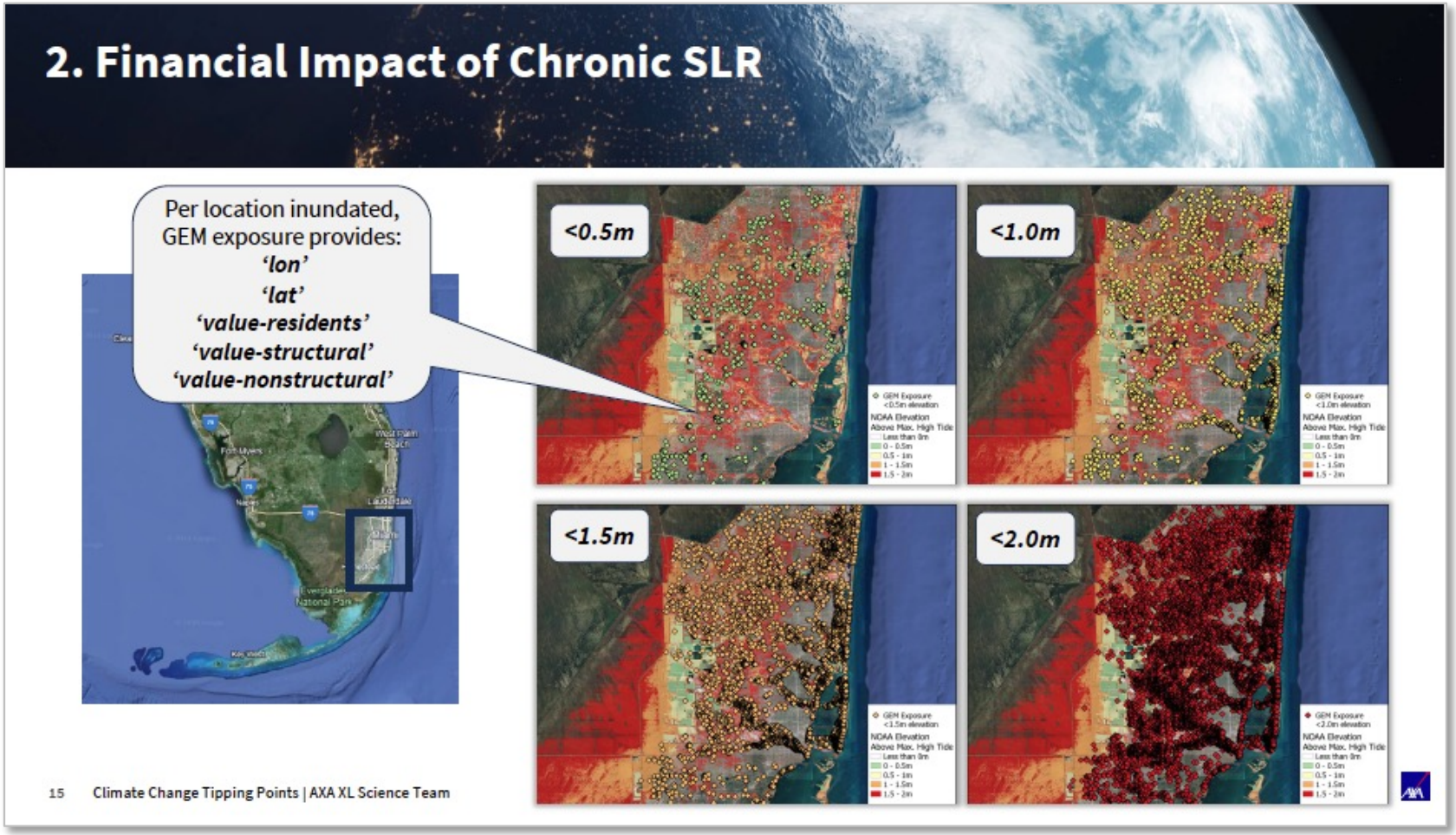
The World Bank helped the countries of the Pacific Alliance—Colombia, Chile, Mexico, and Peru—insure themselves against earthquake risk.

Understanding the significant financial implications that earthquakes can have for a country's economy, the finance ministers of the four countries set the ambitious goal of working together to address this risk, increase countries' resilience to natural disasters, and expand their disaster financing options—all without increasing sovereign debt.

Earthquake recovery. Photo credit: Thinkstock.

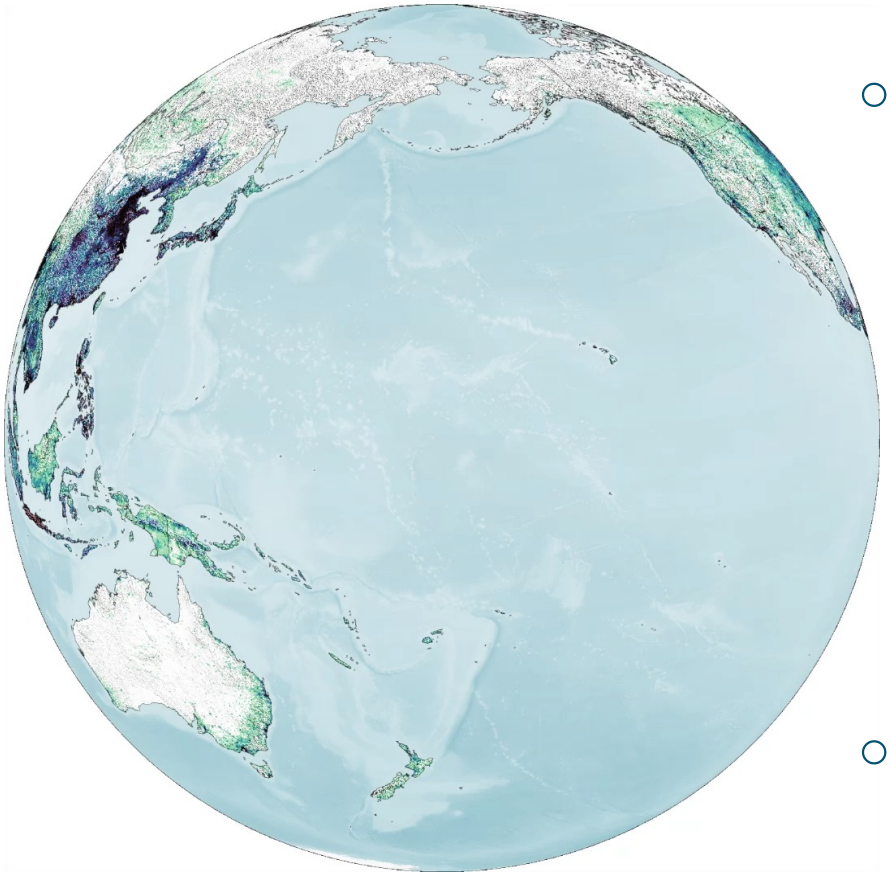
Some Recent Use Cases

Assessment of the impact of tsunamis in coastal areas



Courtesy of **Dr. Alec Vessey** (AXAXL) alexander.vessey@axaxl.com

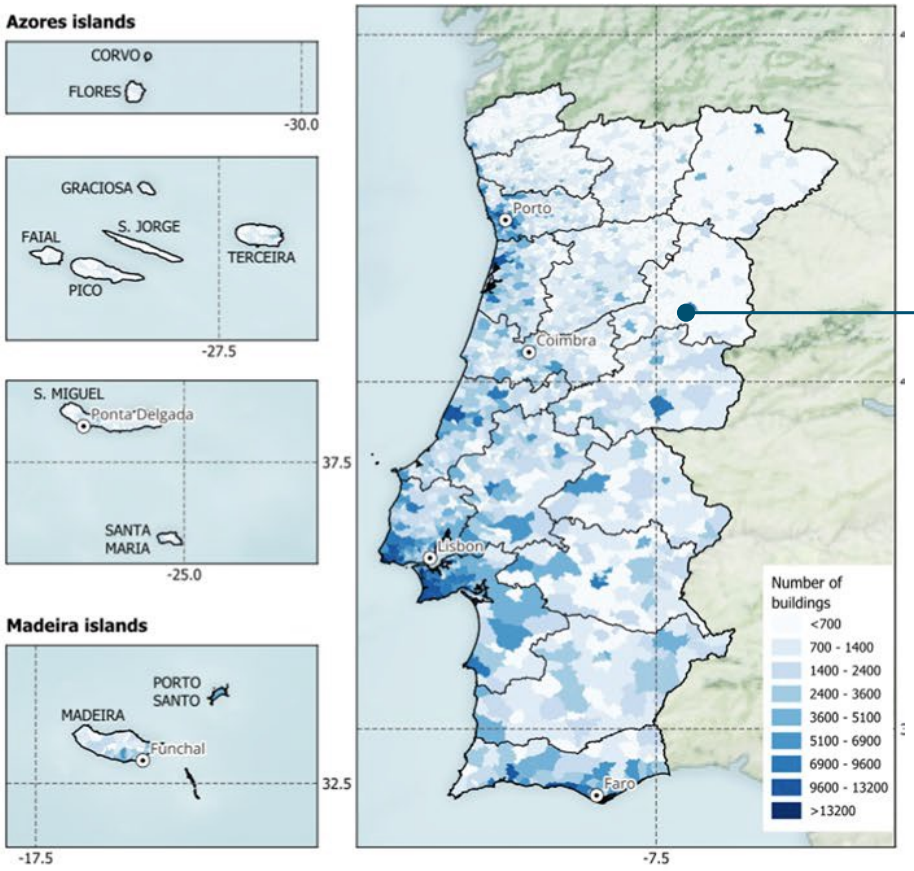
Main Ingredients of an Exposure Model



- Number of buildings
  - Average areas
    - Construction costs
  - Vulnerability classes
- Location of buildings

Estimating Number of Buildings

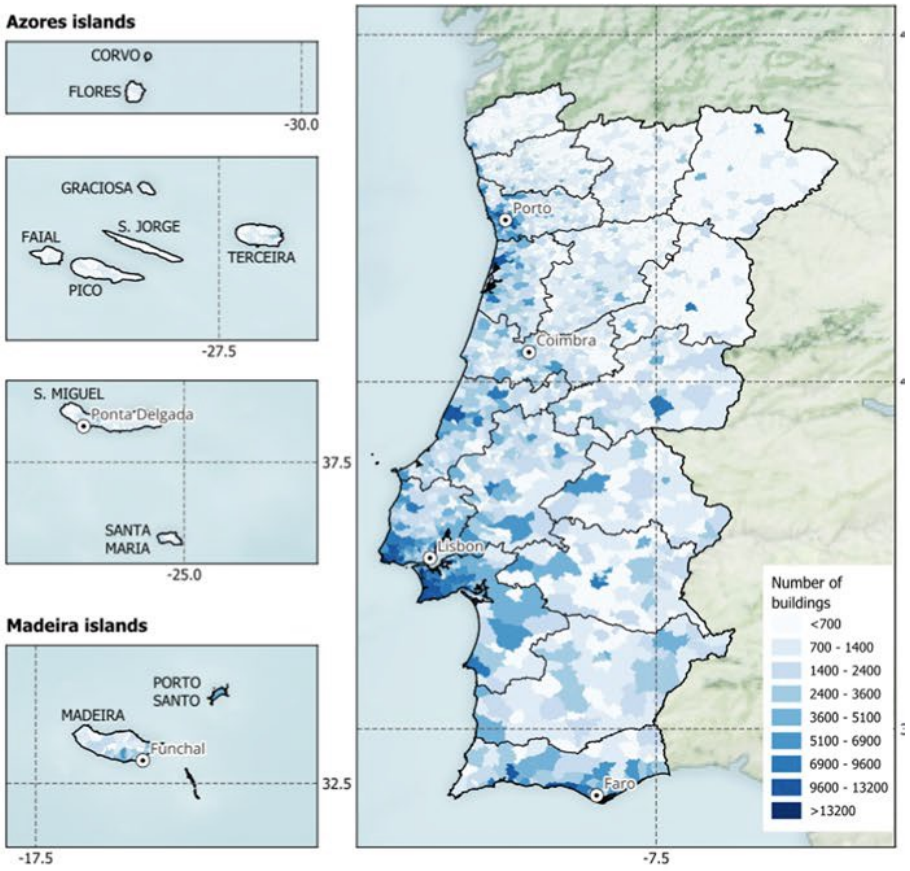
Leveraging housing census information and socio-economic data



- Number of buildings or dwellings
- Construction material
- Type of roof
- Height (number of floors)
- Age of construction
- Type of floor
- Material of the walls
- Type of building

Estimating Number of Buildings

Leveraging housing census information and socio-economic data



Advantages

- Covers entire countries
- May provide information about vulnerability attributes
- May be correlated with socio-economic variables

Disadvantages

- Does not provide building-by-building information
- Sometimes only provides information about material of the walls or type of dwelling

Estimating Number of Buildings

Volunteered Geographic Information (VGI) such as OpenStreetMap (OSM)

- Number of building footprints
- In some cases:
  - Type of use
  - Number of floors

Estimating Number of Buildings

Volunteered Geographic Information (VGI) such as OpenStreetMap (OSM)

Advantages

- Information at the building level
- Covers building area

Disadvantages

- Heavily incomplete in many parts of the world
- Covers assets that are not buildings

Estimating Number of Buildings

Automatic Building Footprint Detection (e.g., Microsoft)

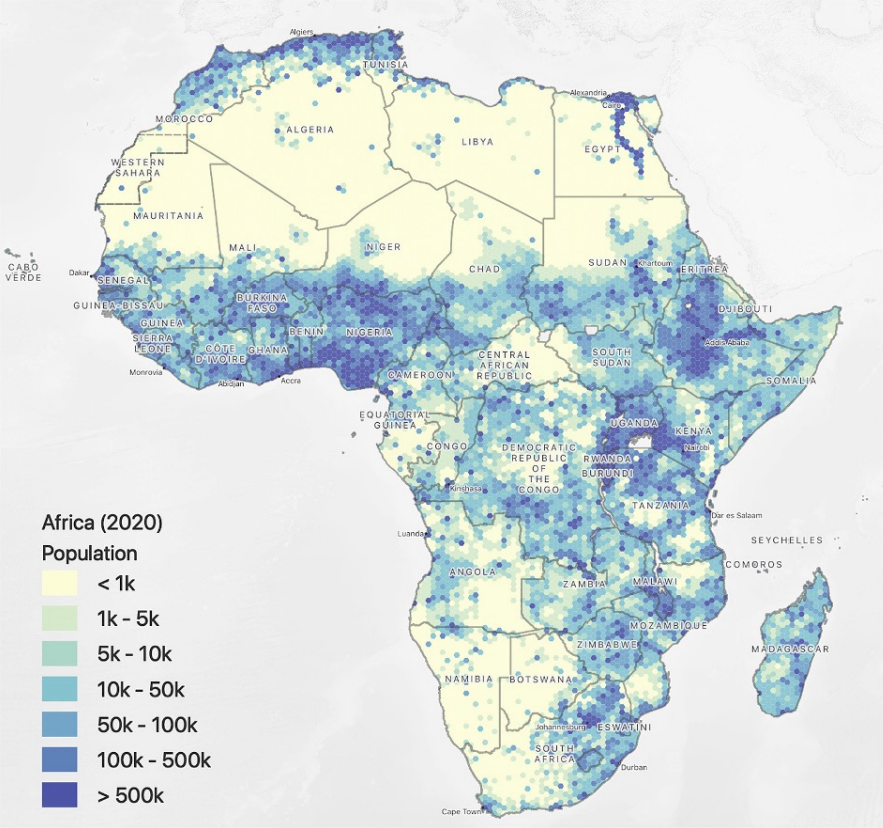
Inacurate building footprints

Missing footprints

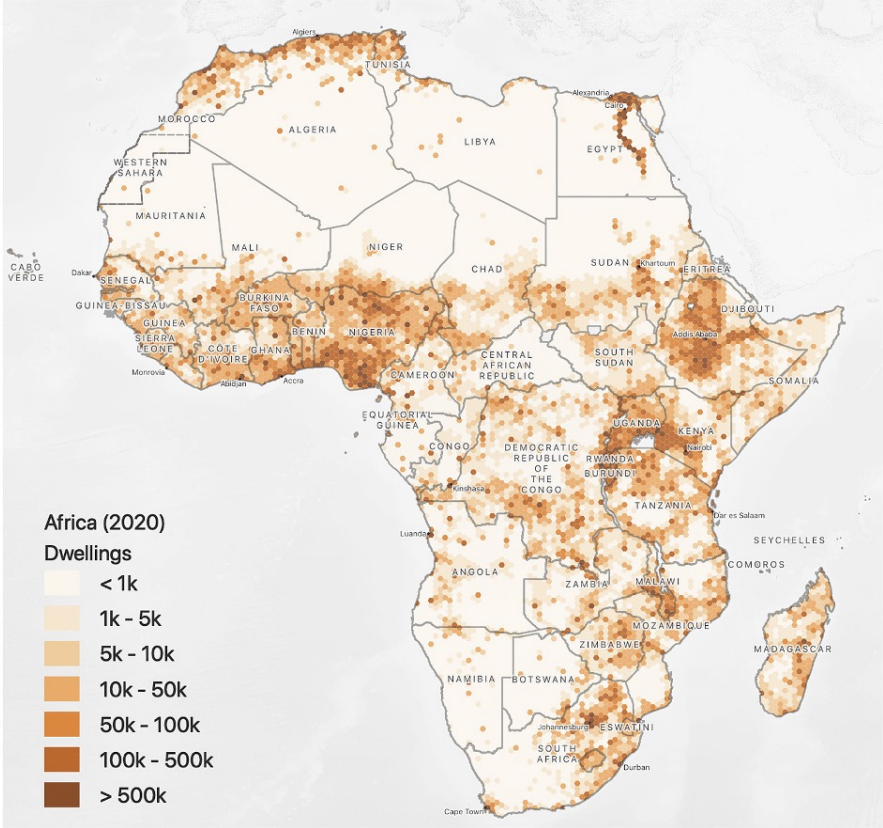
Estimating Number of Buildings

Population datasets and household sizes

From population



To dwellings and buildings



Estimating Average Areas

Surveys from National Statistical Offices and NGOs

Housing Types		Plot Size (M^2)	Floor Area (M^2)	Occupants (People)	Monthly rent (USD)	Value (USD)	Water	Sanitation	Tenure
Formal	Apartment Kabul	n/a	90	4	250	65,000	Piped water or own well	Septic tank or composing toilet	Owner with title deeds/ Owner with other documents (sales transaction) / renter
	Apartment Large Size	n/a	150	8-9	250-350	100,000			
	Apartment Medium Size	n/a	80	5-7	150-250	80,000			
	Apartment Small Size	n/a	50	4-6	100	40,000-65,000			
	Average	**n/a**	**90**	**6**	**200**	**80,000**			
	Dwelling Kabul	300	170	9	600	250,000			
	Dwelling Large Size	300-450	200	10-12	300	150,000			
	Dwelling Medium Size	200-300	150	10-12	250	100,000			
	Dwelling Small Size	200	100	8-9	200	50,000			
	Average	**300**	**150**	**9**	**250**	**100,000**			
Informal	Planned Kabul	400	200	7	180	50,000	Piped water or own well	Septic tank or dry pit latrine	Sales transaction/ Inheritance / municipal notebook
	Planned Large Size	500	200	8-15	200	60,000			
	Planned Medium Size	400	150		150	45,000			
	Planned Small Size	300	100		100	30,000			
	Average	**400**	**150**	**11**	**150**	**45,000**			
	Spontaneous Kabul	180	120	9	160	-	Shared well/ public taps/ water tanker	Dry pit latrine	No documentation / municipal notebook
	Spontaneous Large Size	250- 600	100-200	10—15	60	20,000			
	Spontaneous Medium Size	150	80	7-9	50	15,000			
	Spontaneous Small Size	80-100	50- 70	5-6	40	7,000			
	Average	**150**	**80**	**9**	**50**	**12,000**			

SOURCE: SOAC FIELD SURVEY

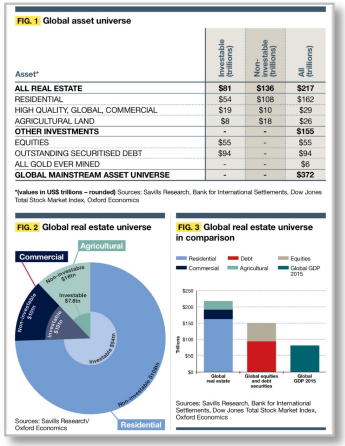
[Source: 'State of Afghan Cities 2017' p. 88].

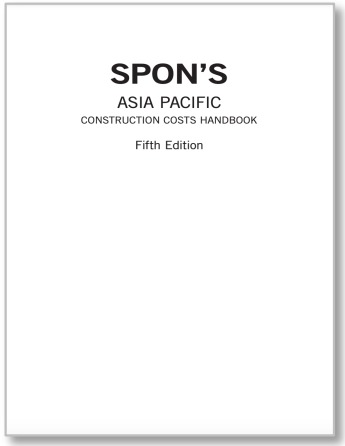
Estimating Average Areas

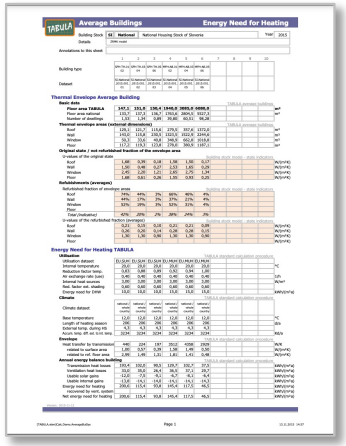
Combine cadastral datasets (building footprints) with land use layers

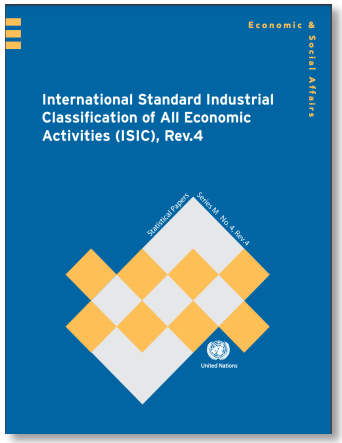
Estimating Construction costs

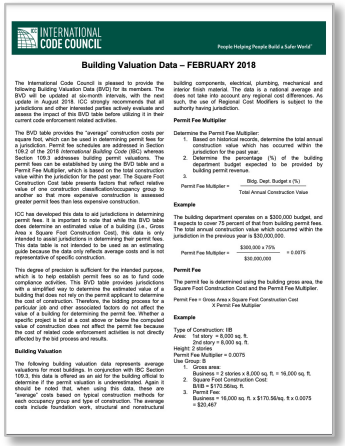
Combine cadastral datasets (building footprints) with land use layers





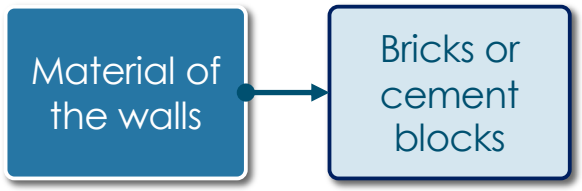






Defining Vulnerability Classes

Defining mapping schemes to convert building attributes to vulnerability classes



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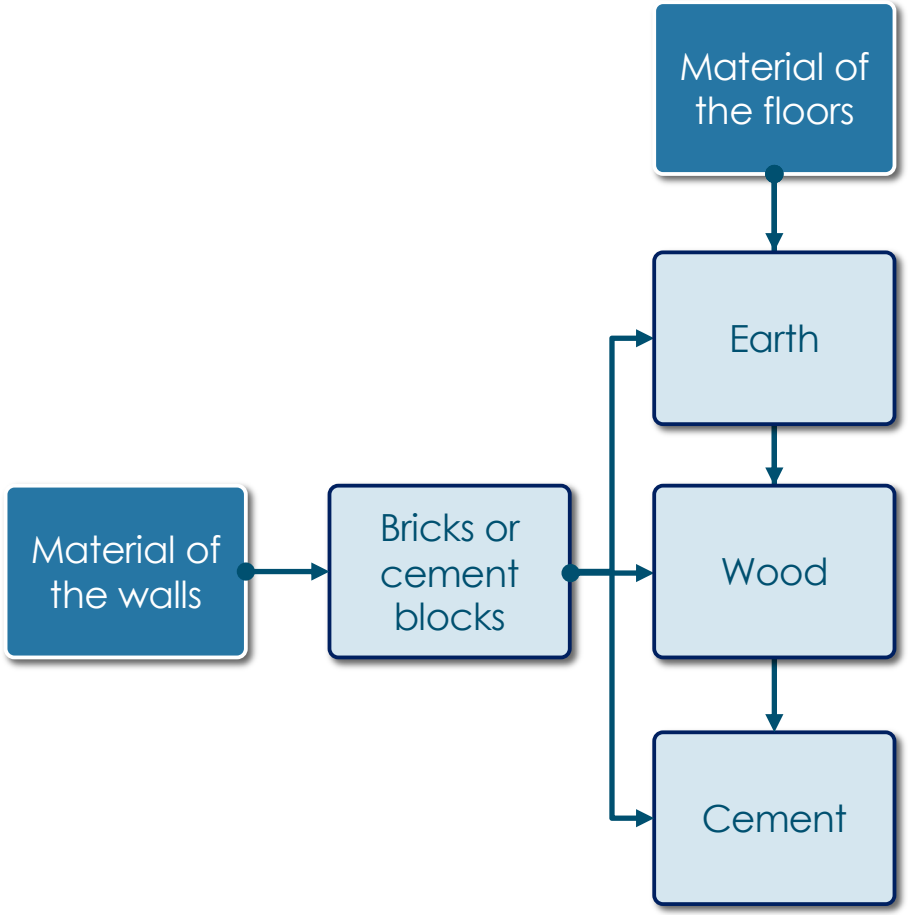

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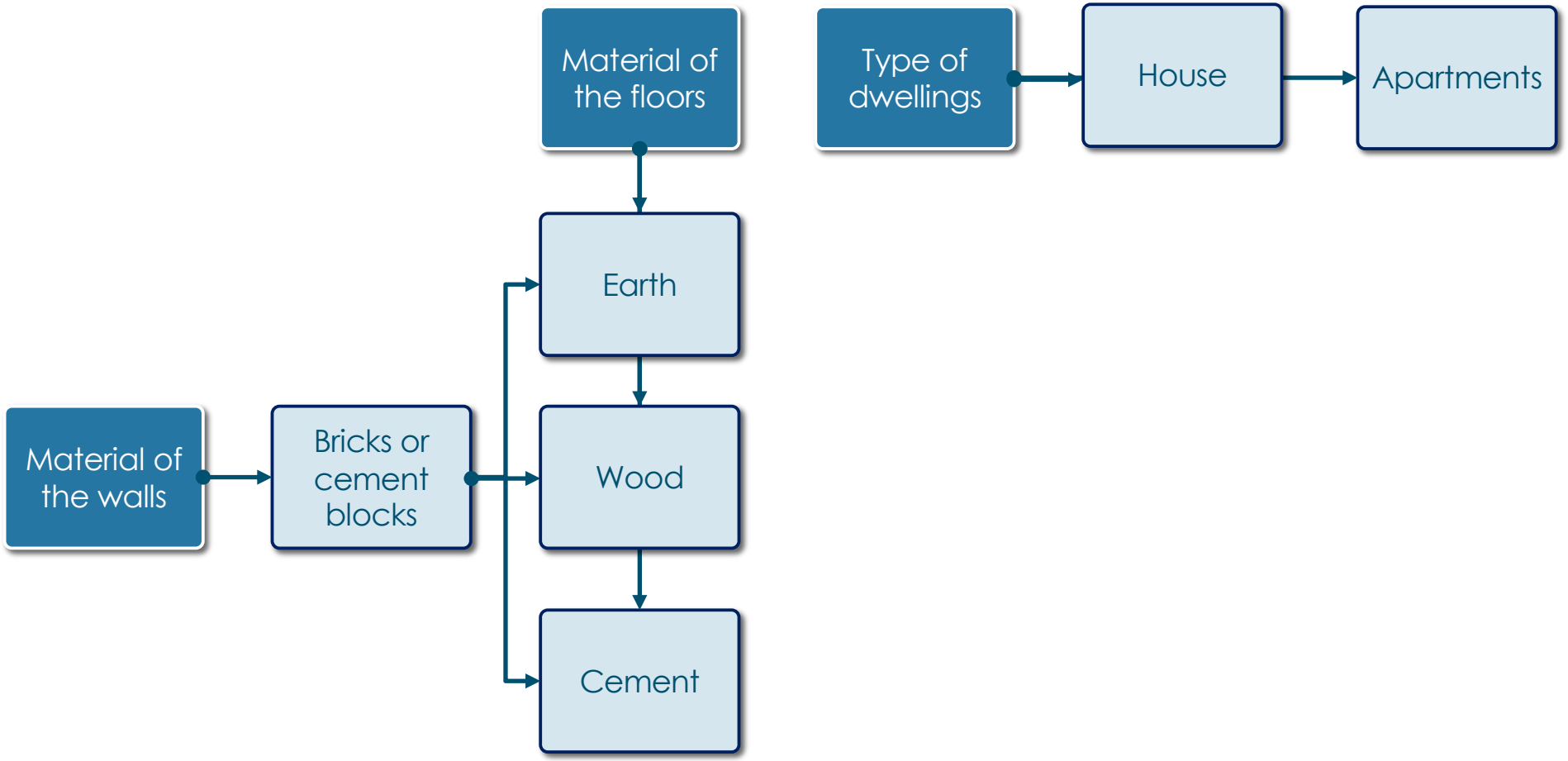

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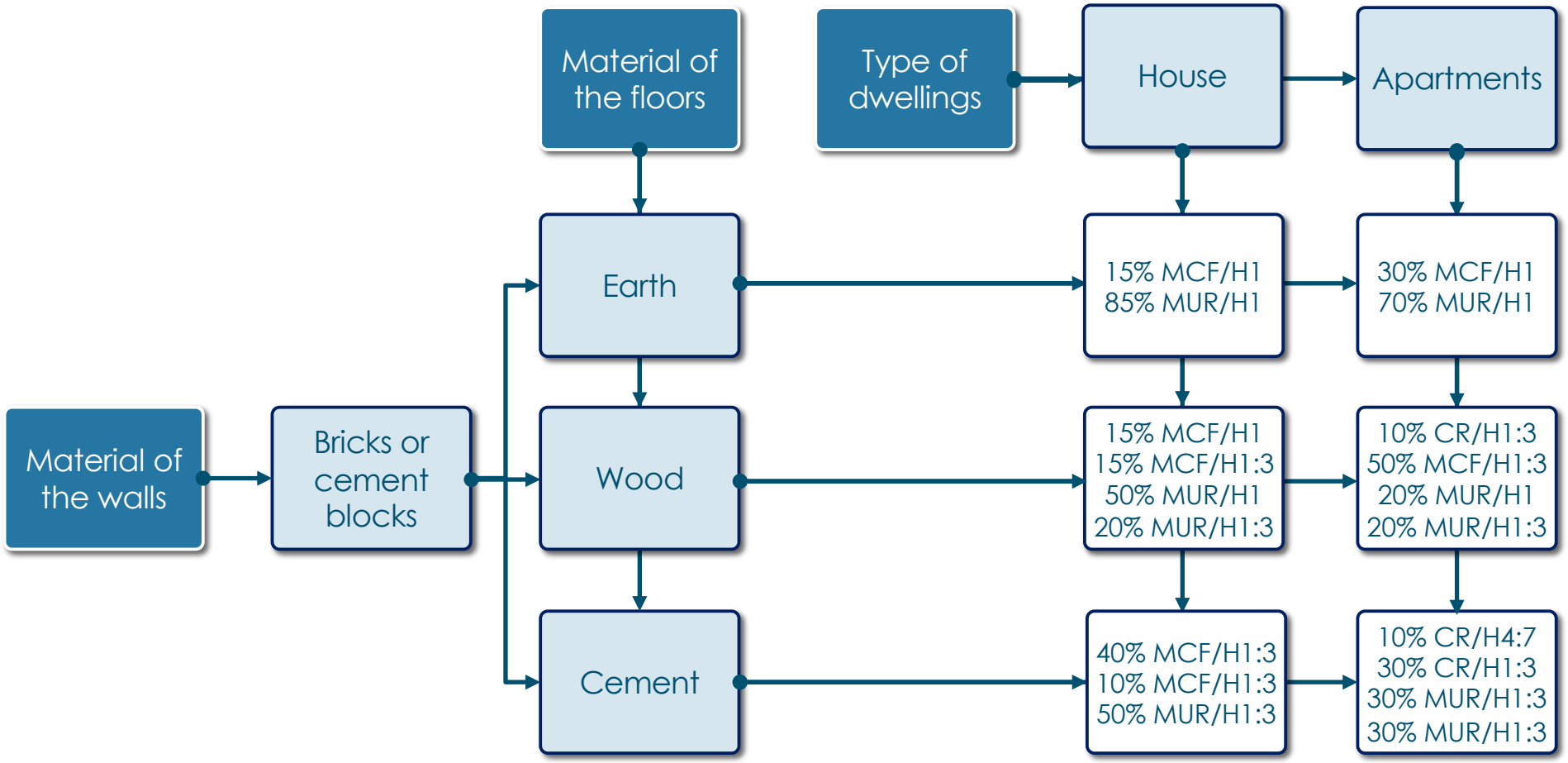
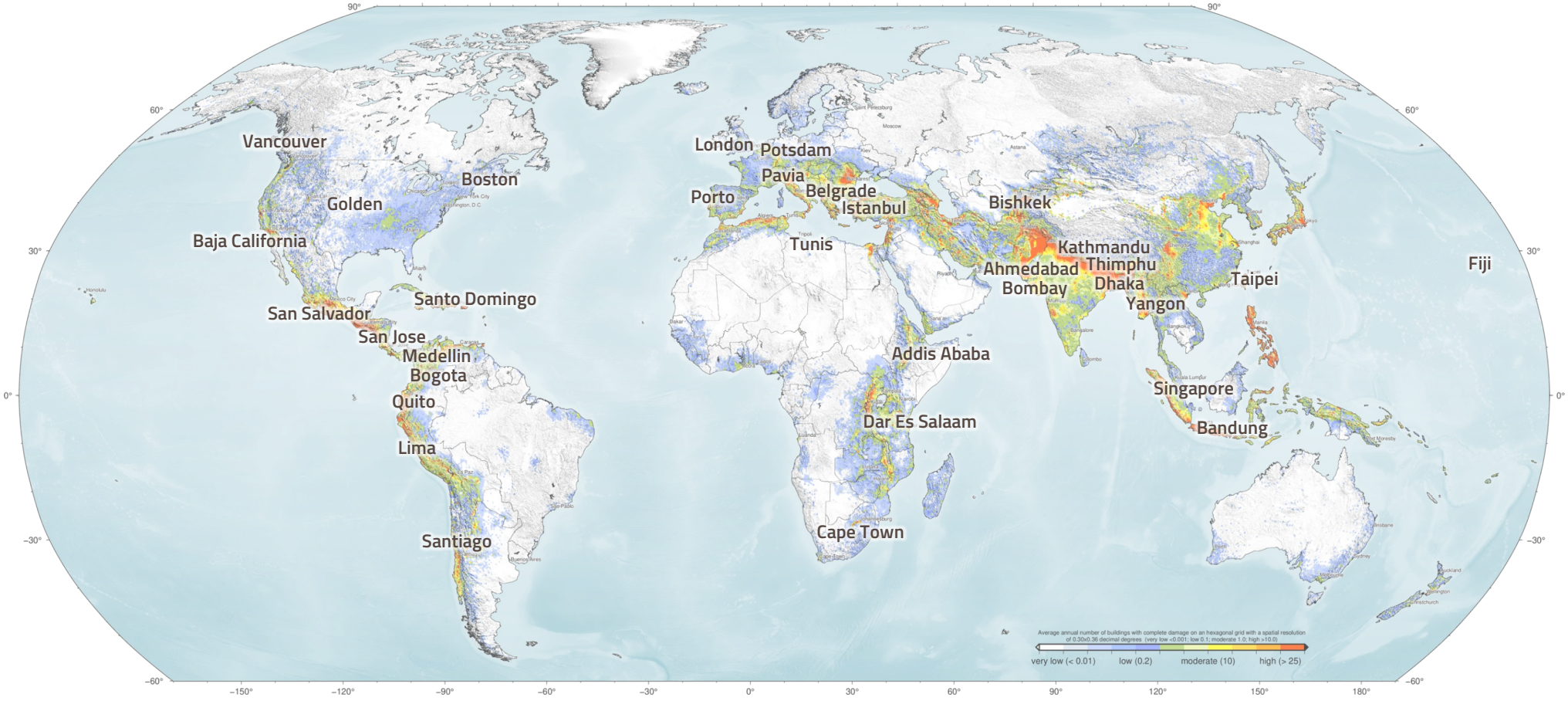


Defining Vulnerability Classes

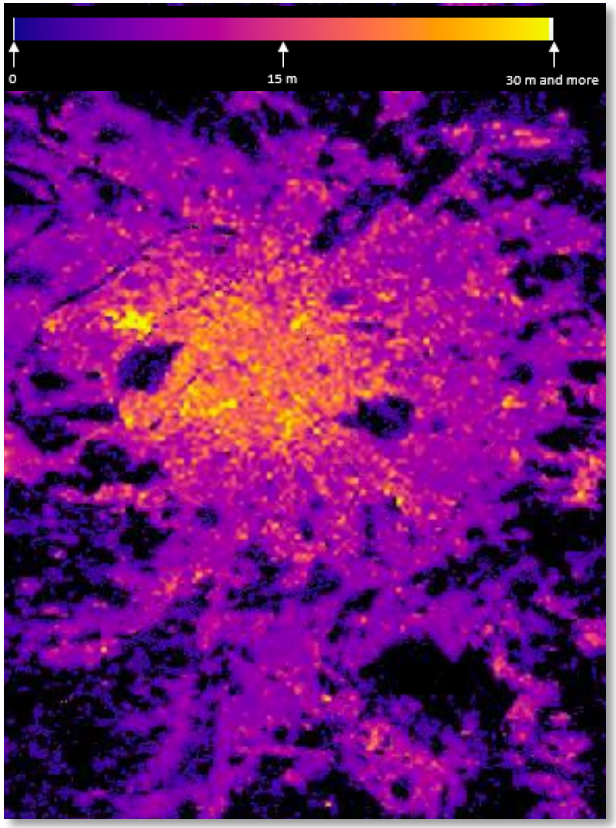
Working with local experts to develop and improve mapping schemes



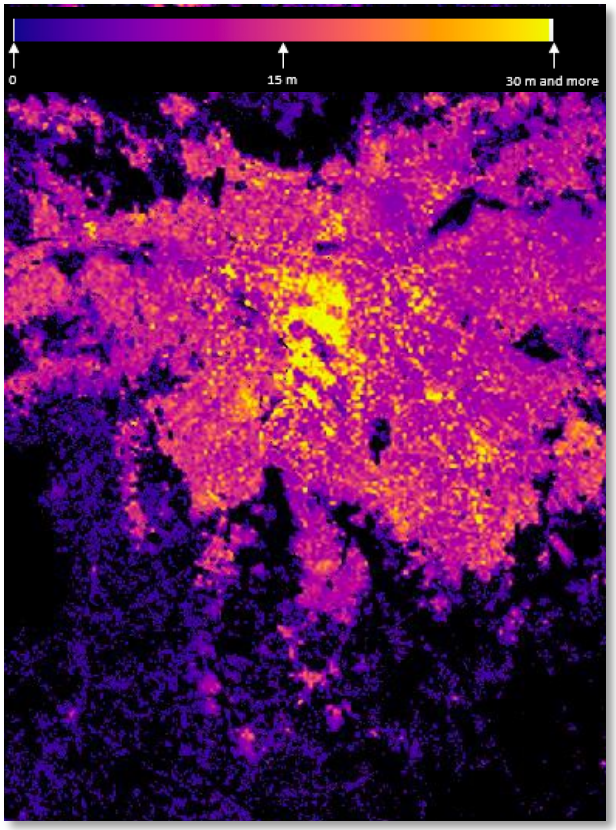
Defining Vulnerability Classes

Incorporation of building height from satellite imagery

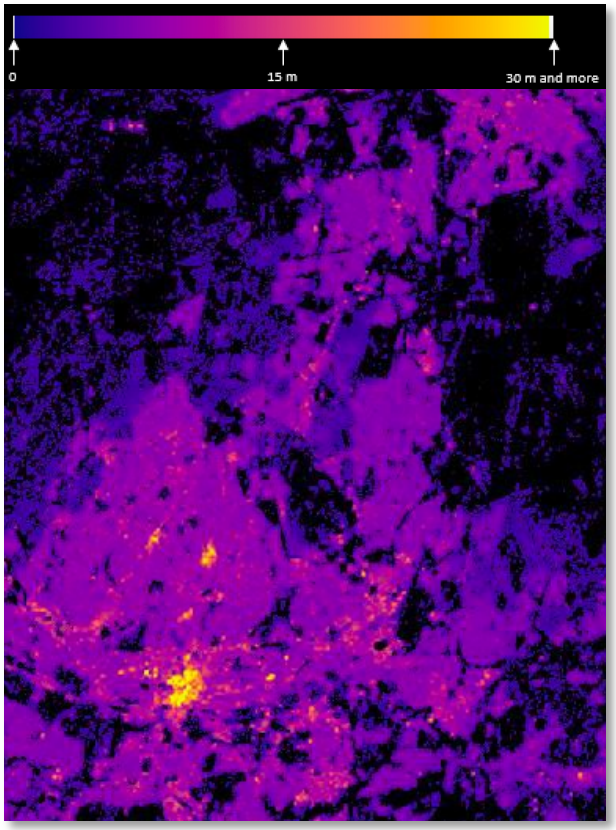
Paris, France



Sao Paulo, Brasil



Johannesburg, South Africa



Defining Vulnerability Classes

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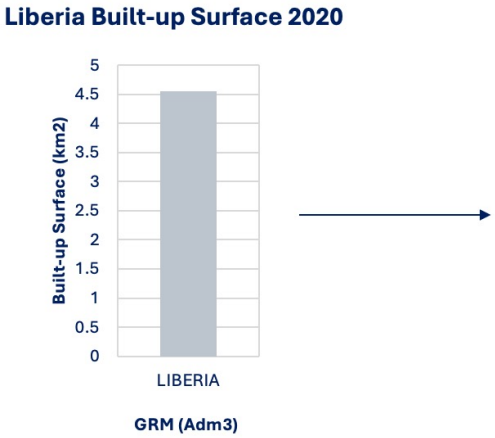
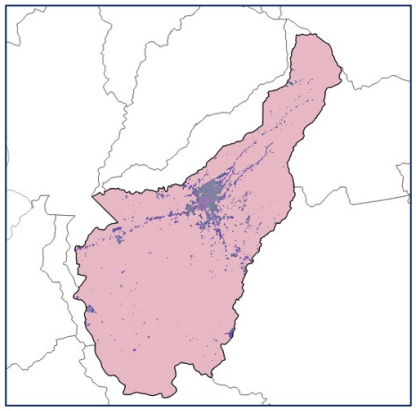
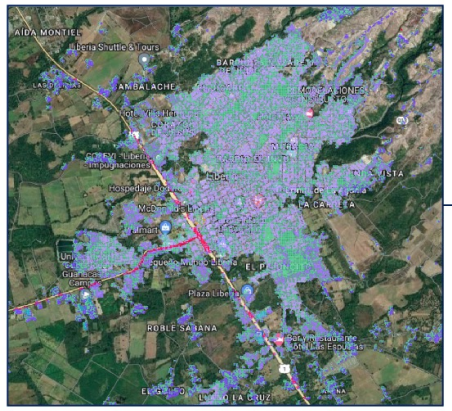
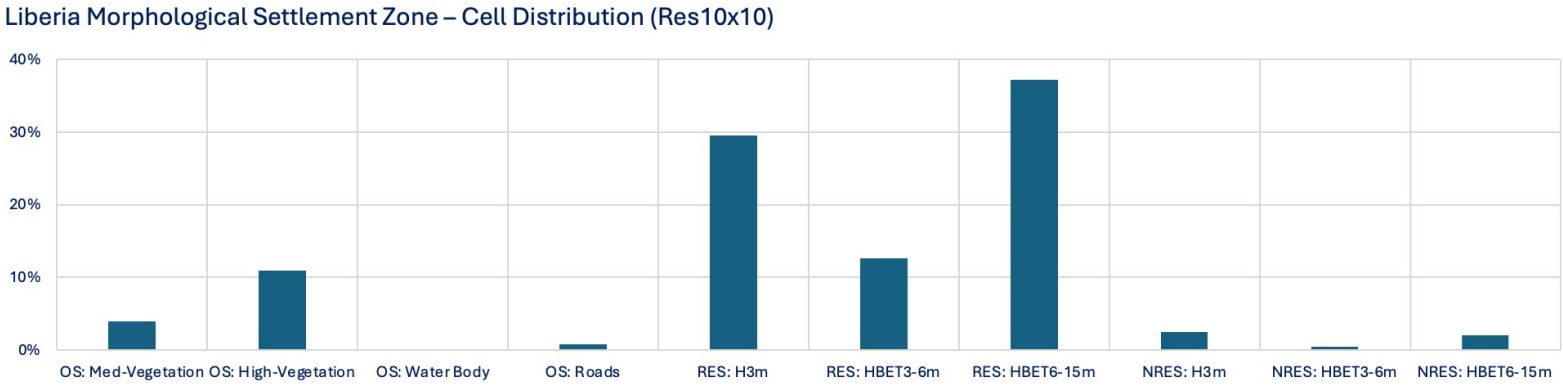


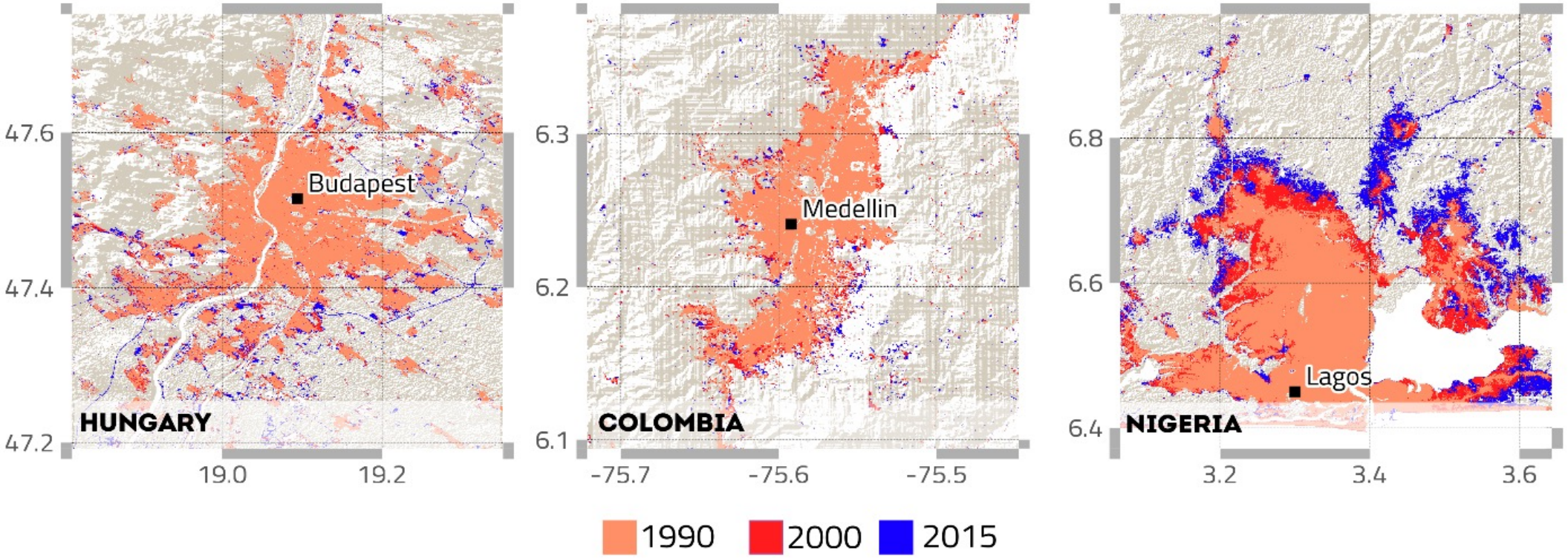






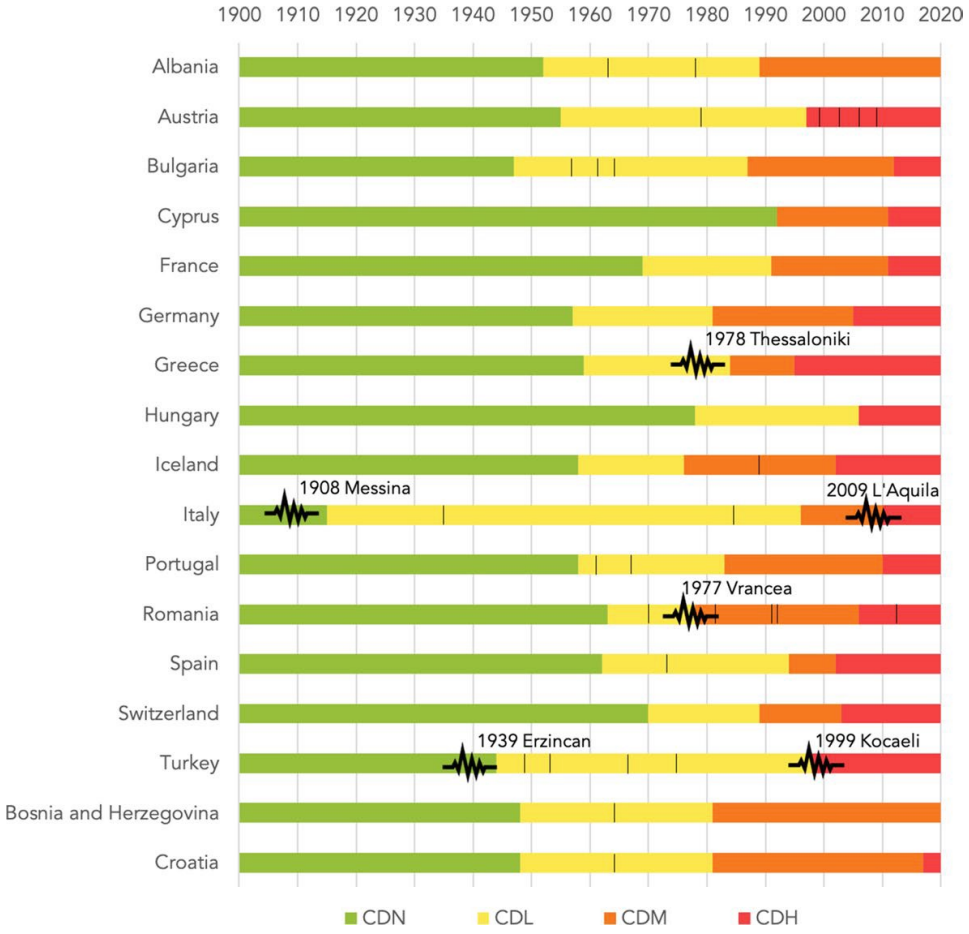
Defining Vulnerability Classes

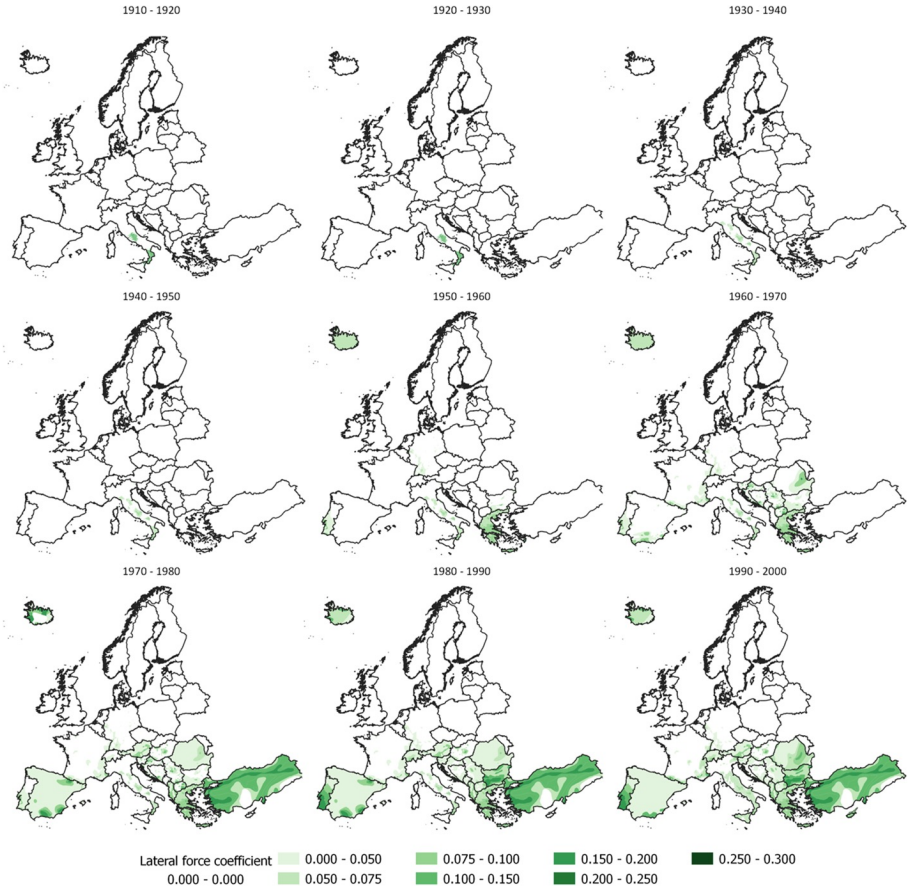
Incorporation of satellite imagery to assign building age (or epoch of construction)



Incorporating Design Regulations

Considering the year of design regulation and the associate seismic zonations





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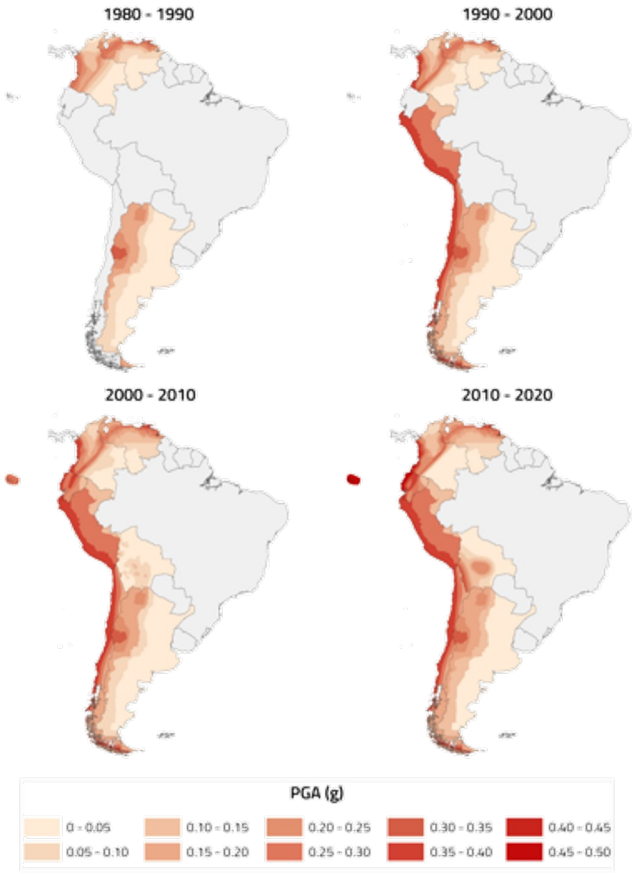
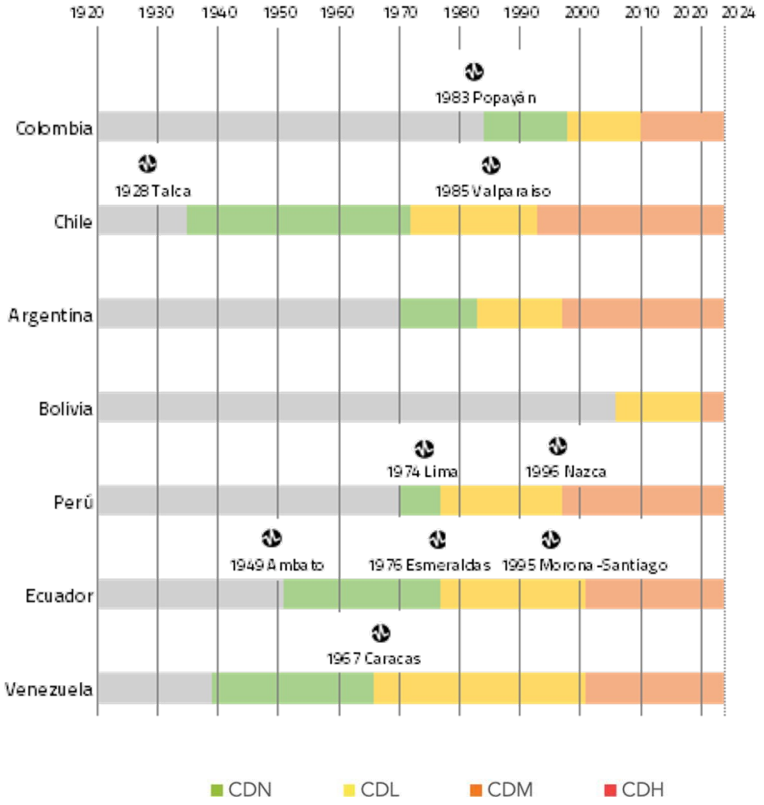
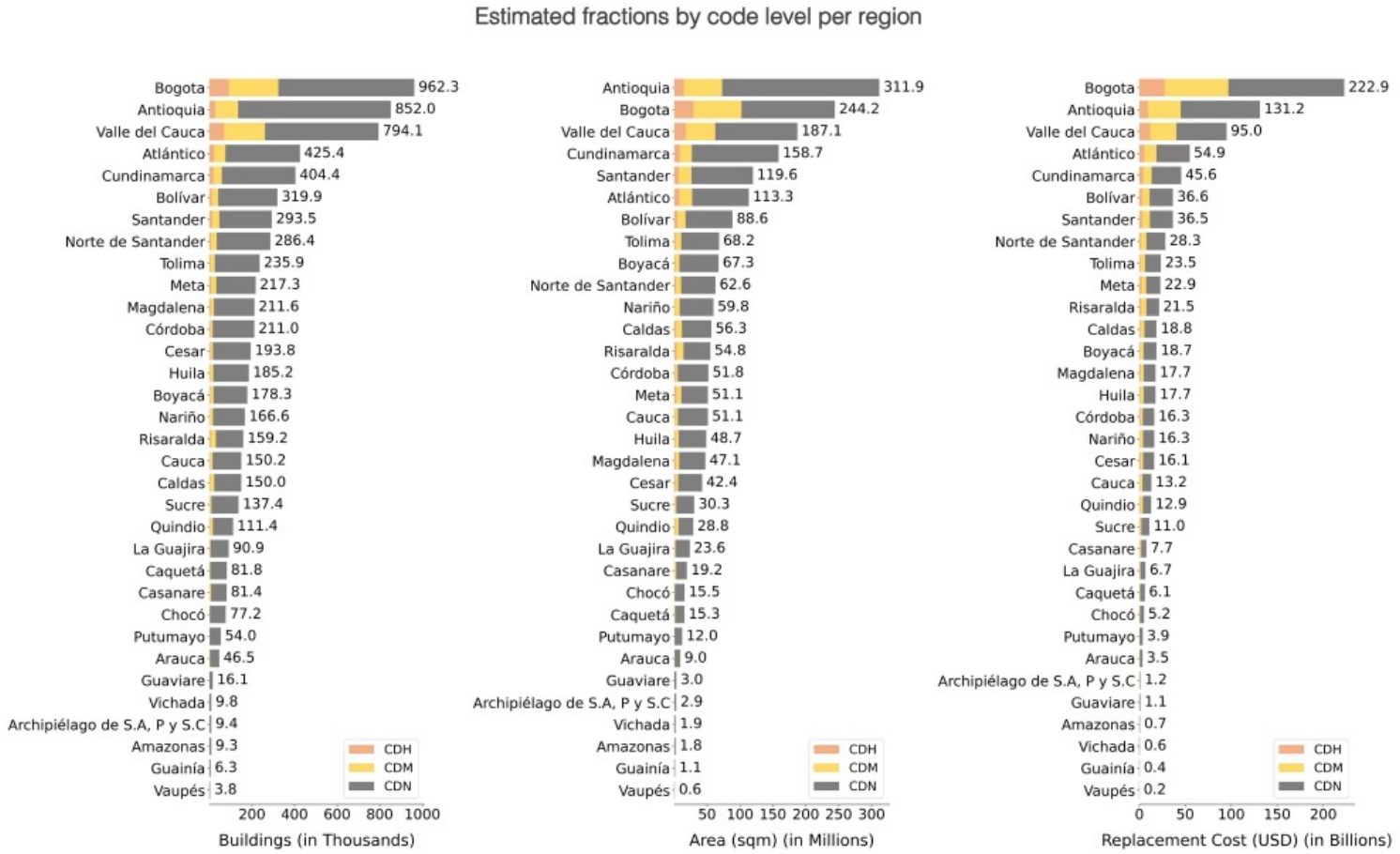




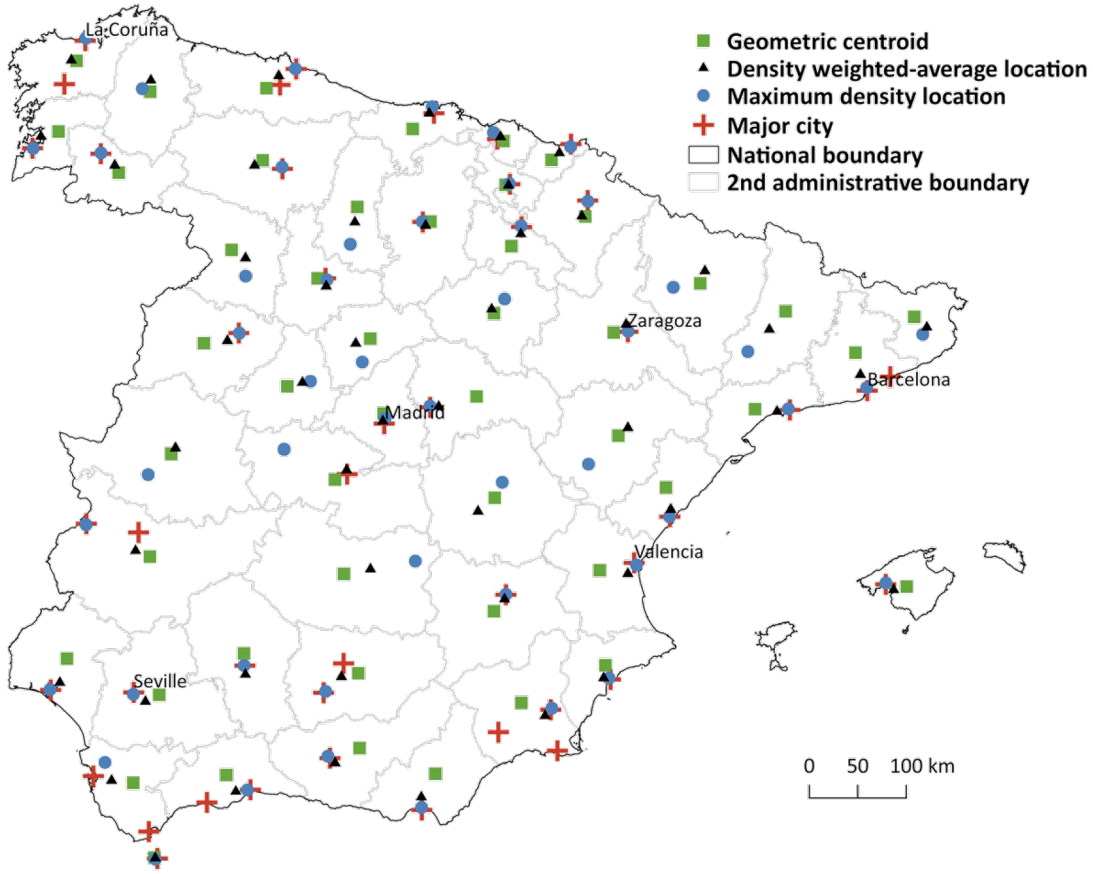
Incorporating Design Regulations

Distribution of buildings, area and replacement cost across different code levels for Colombia



Location of Buildings

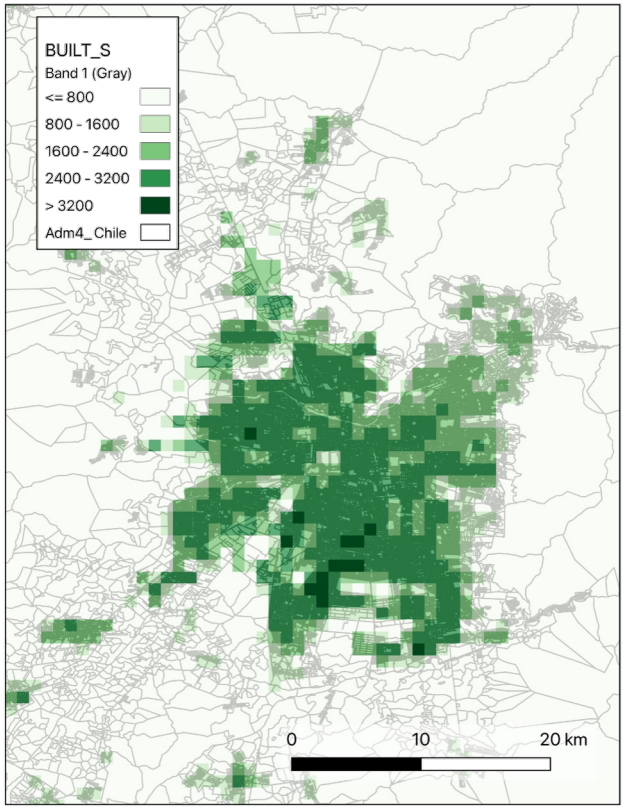
The current exposure model for Spain is at the first administrative level. Either the data is aggregated at a given site, or spatially disaggregated using auxiliary datasets. For the latter approach, different techniques and datasets can be pursued to minimized the uncertainty and bias.



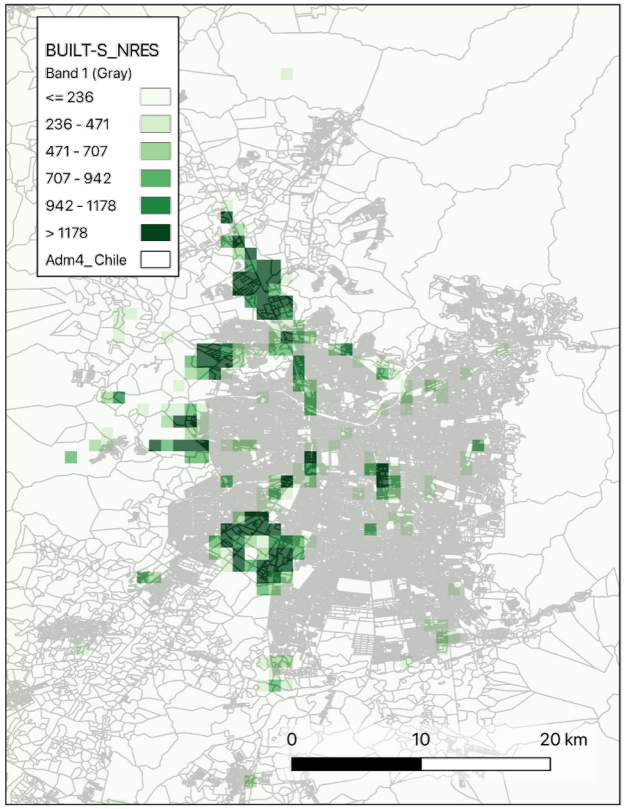
Location of Buildings

Incorporation of national data and vulnerability improvements due to projects

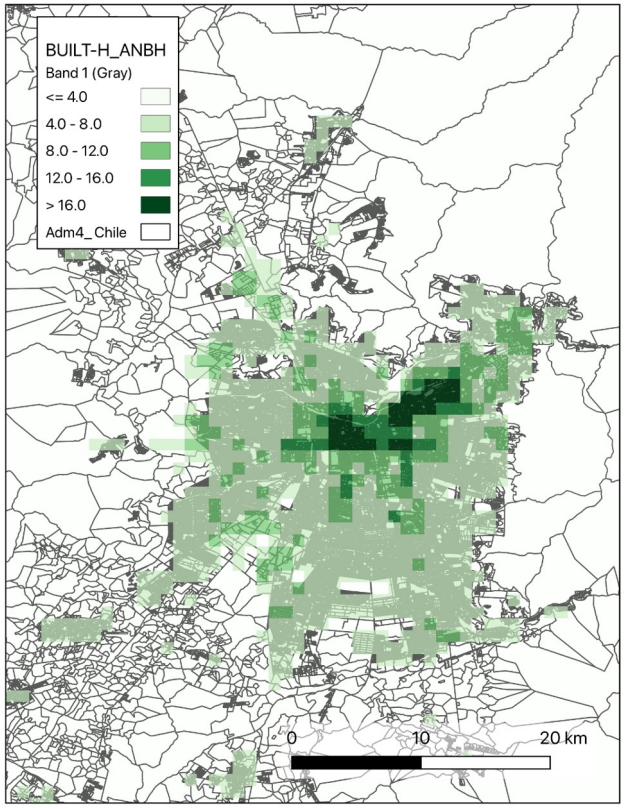
Built-up Surface



Built-up Surface (Non-residential)



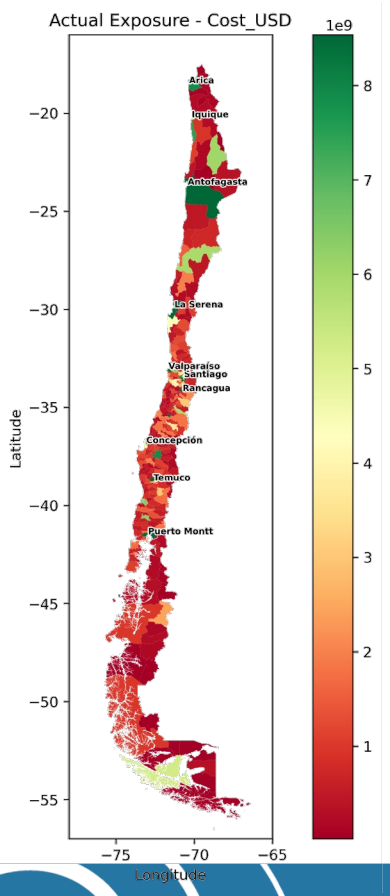
Building Height



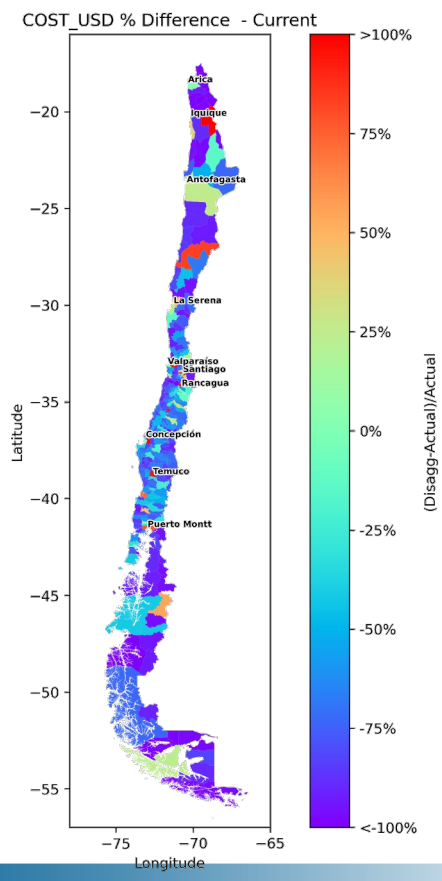
Location of Buildings

Application of different spatial disaggregation approaches (example for Chile)

Actual



Using population



Location of Buildings

Application of different spatial disaggregation approaches (example for Chile)

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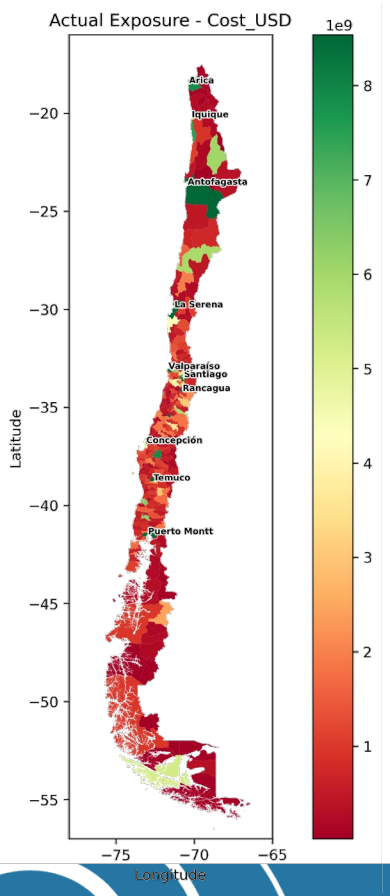
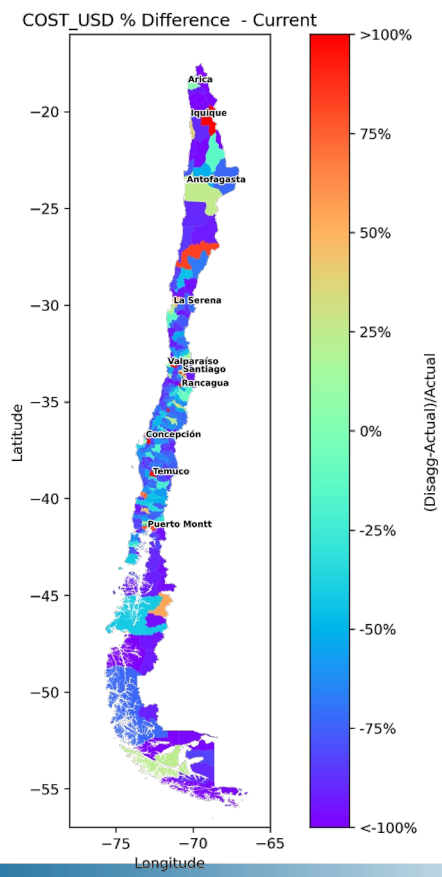
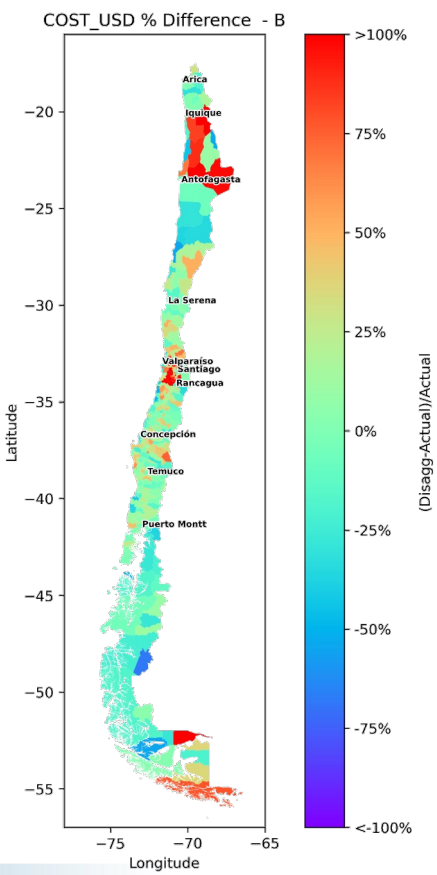


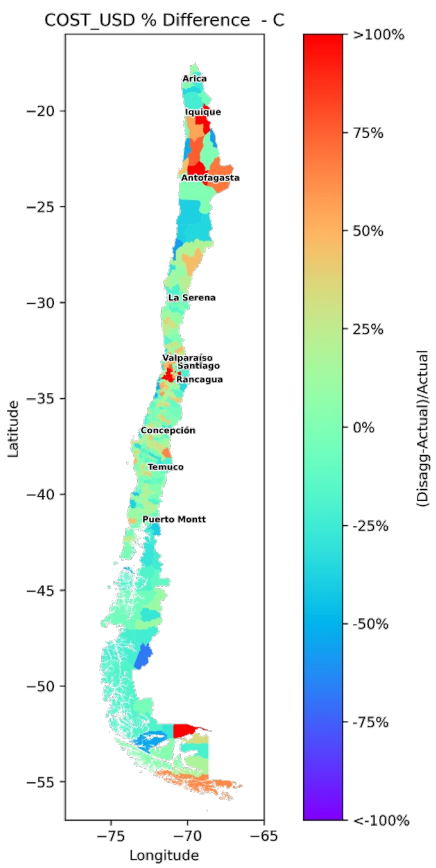
Using population



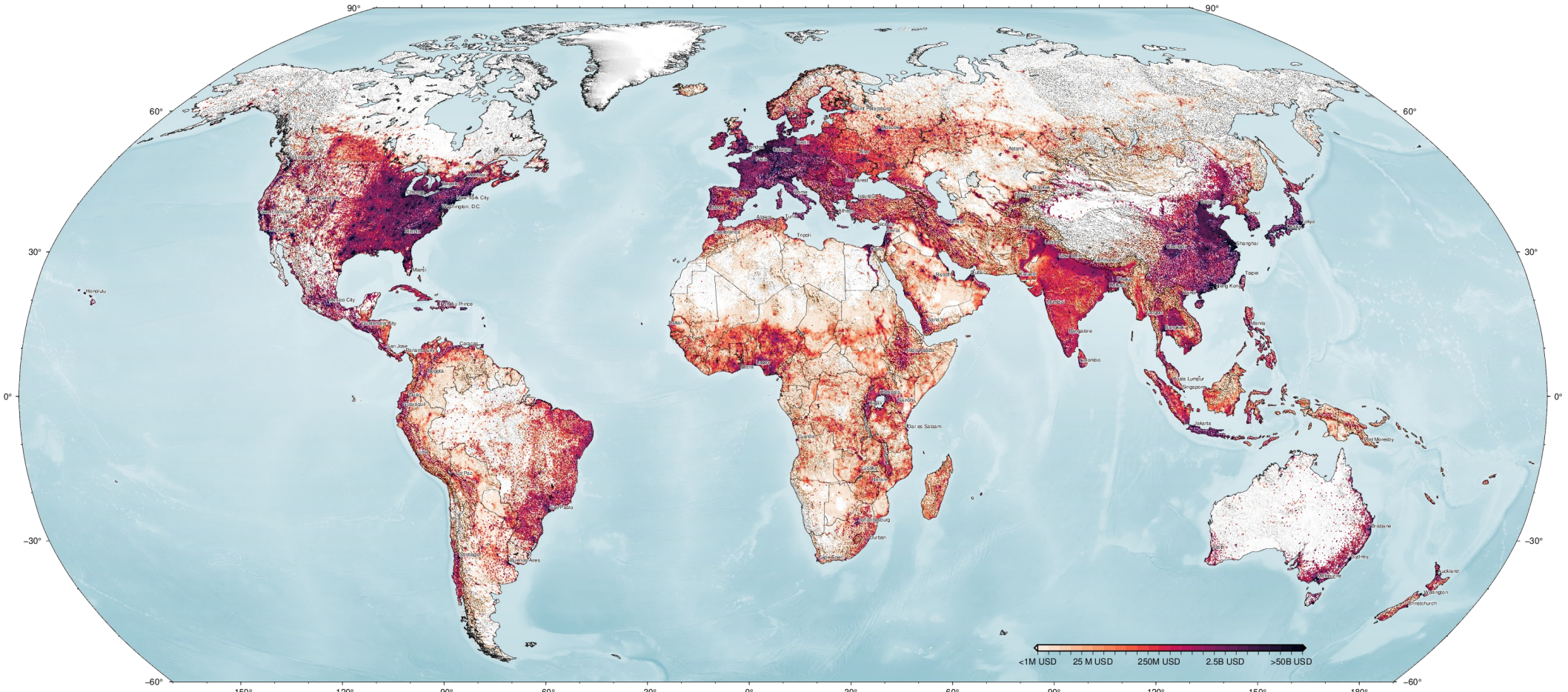
Using built up area



Using built up area and building height



GEM's Global Exposure Model

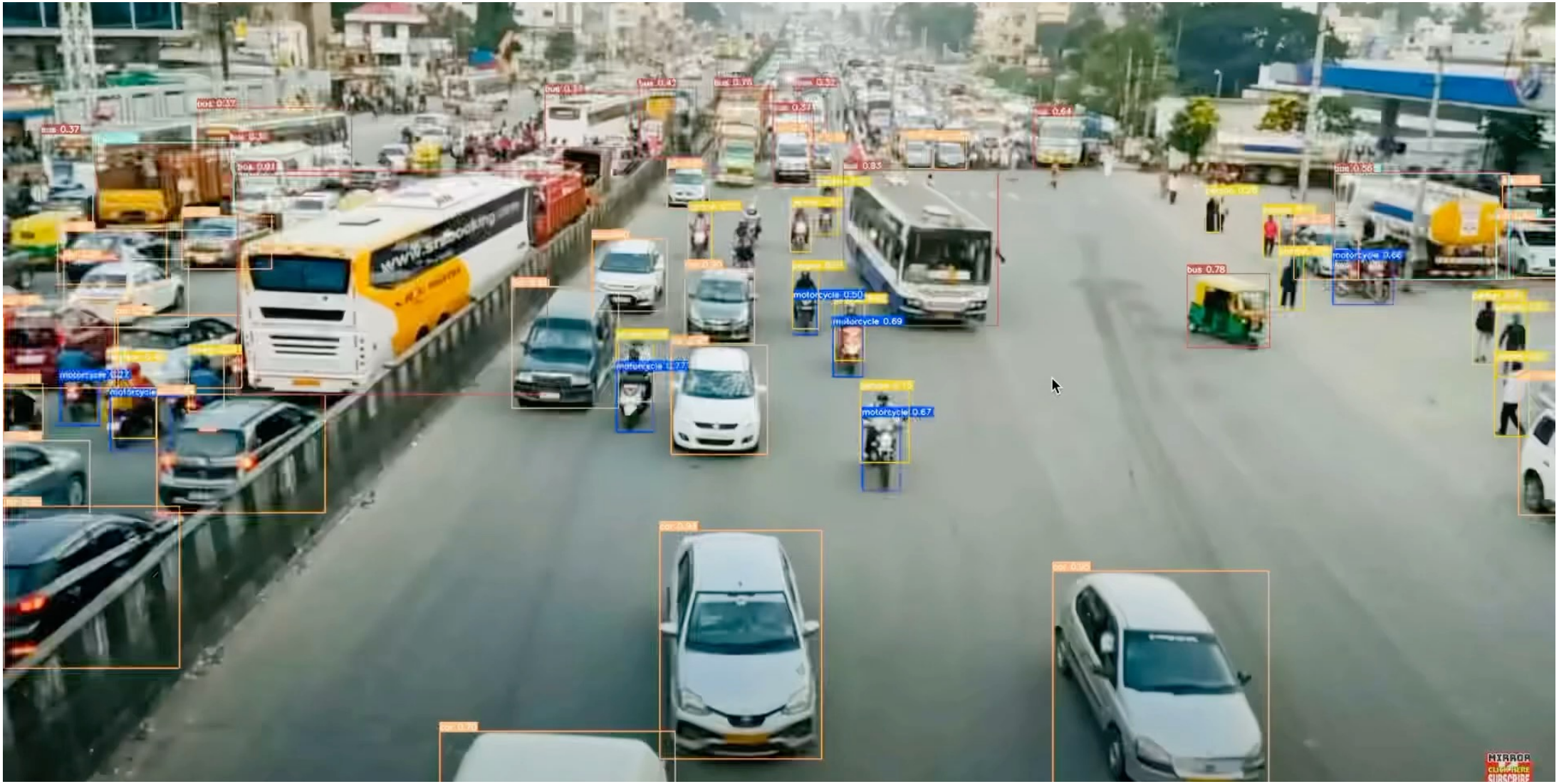


Economic value of residential, commercial and industrial buildings on an evenly spaced hexagon grid with a constant spatial resolution of 0.30x0.36 decimal degrees.

Some Future Developments

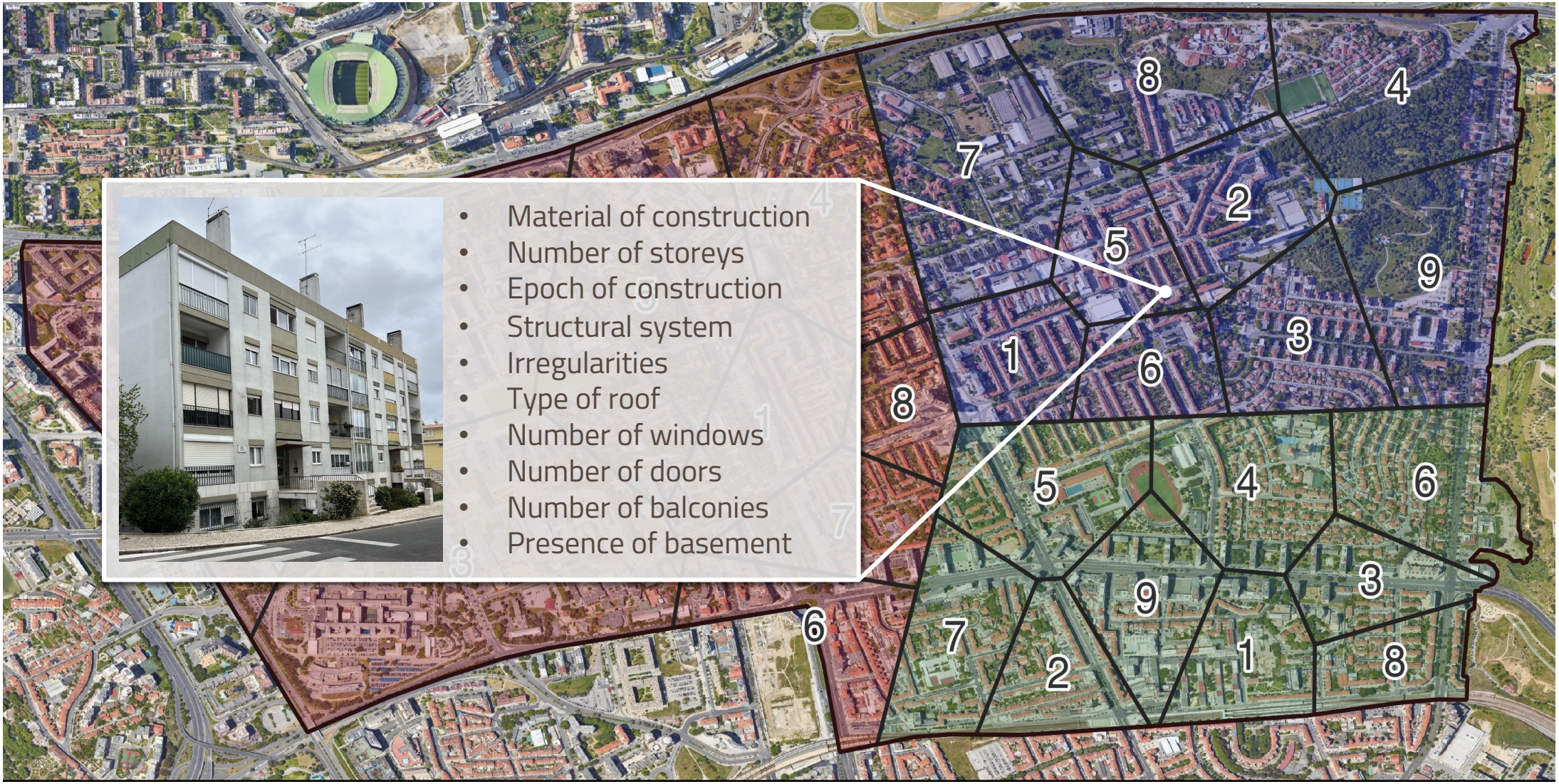
Exposure Modelling with ML/AI

Exposure Modelling with ML/AI

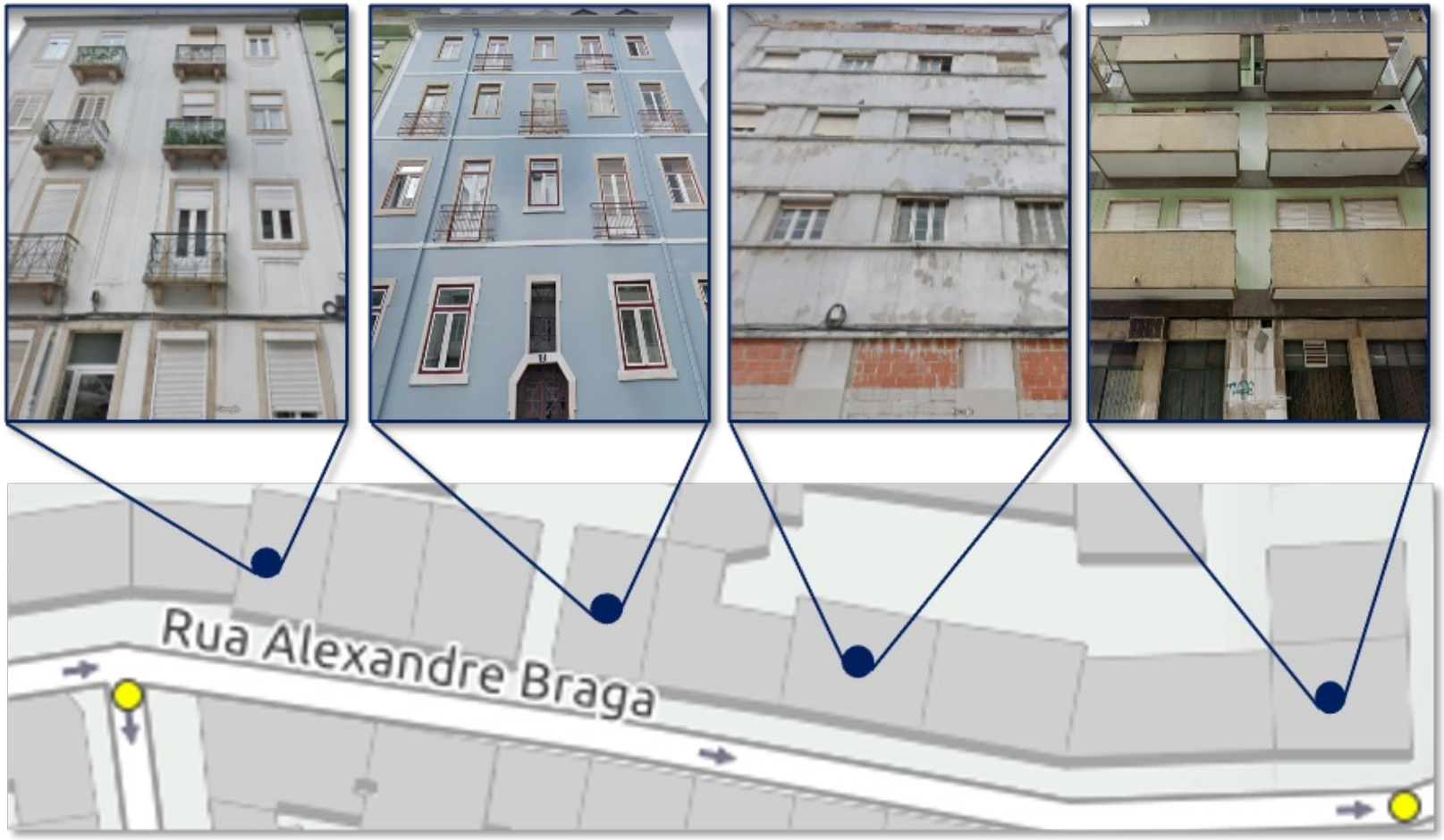


Exposure Modelling with ML/AI

Exposure Modelling with ML/AI

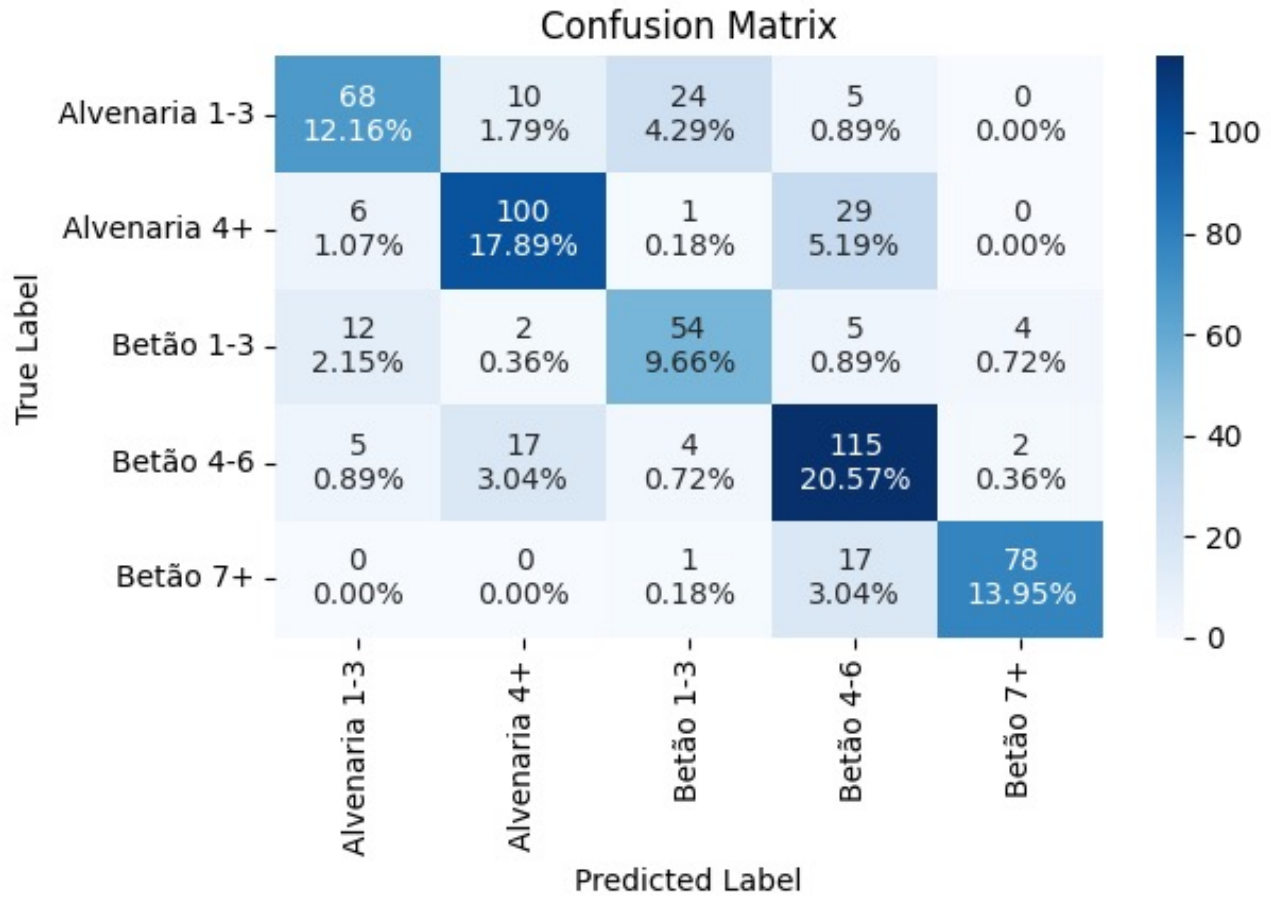


Exposure Modelling with ML/AI



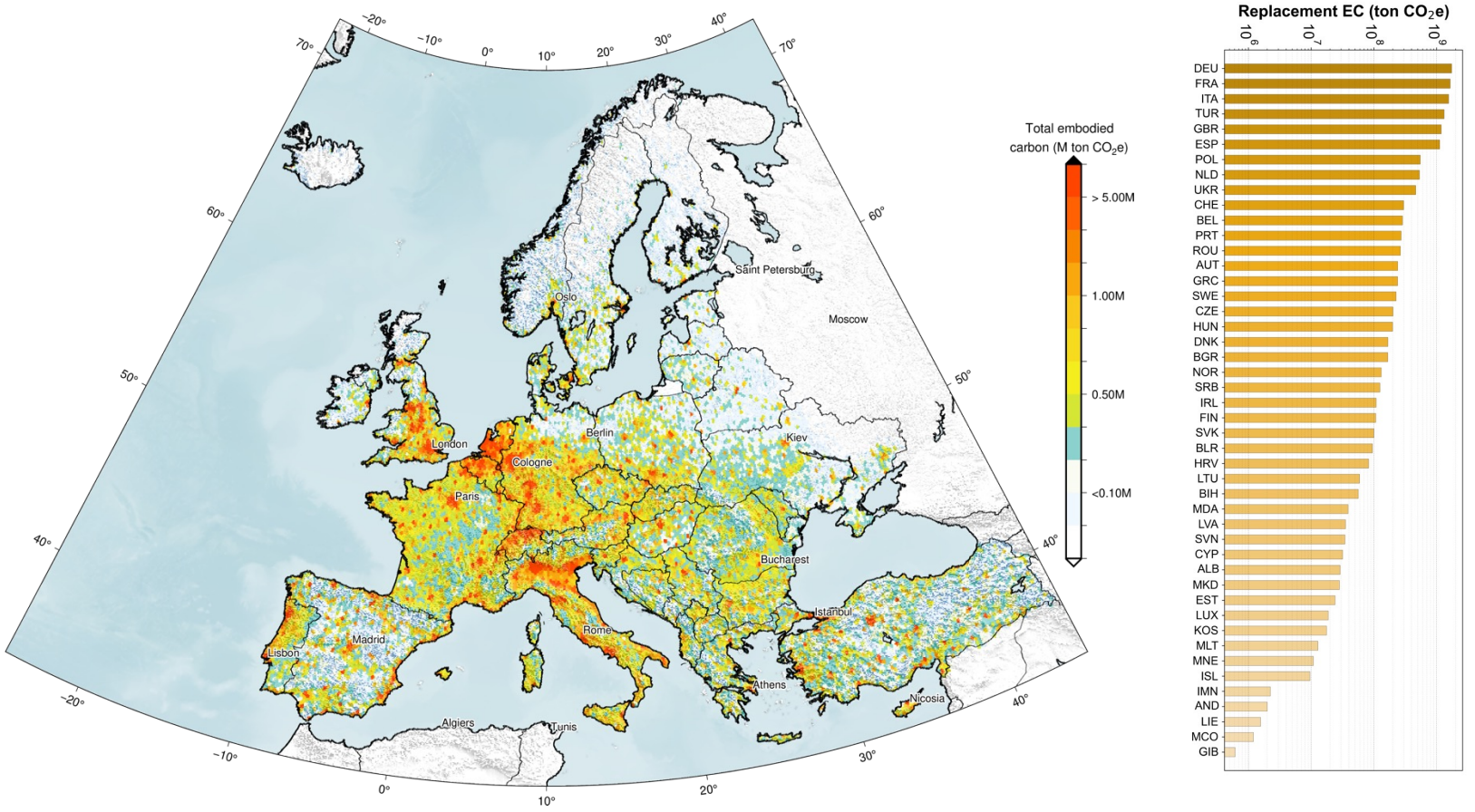
Exposure Modelling with ML/AI

The algorithm predicted the building class in more than **86%** of the cases



Incorporating Sustainability in Exposure Modelling

Estimation of the embodied carbon in the building stock in Europe



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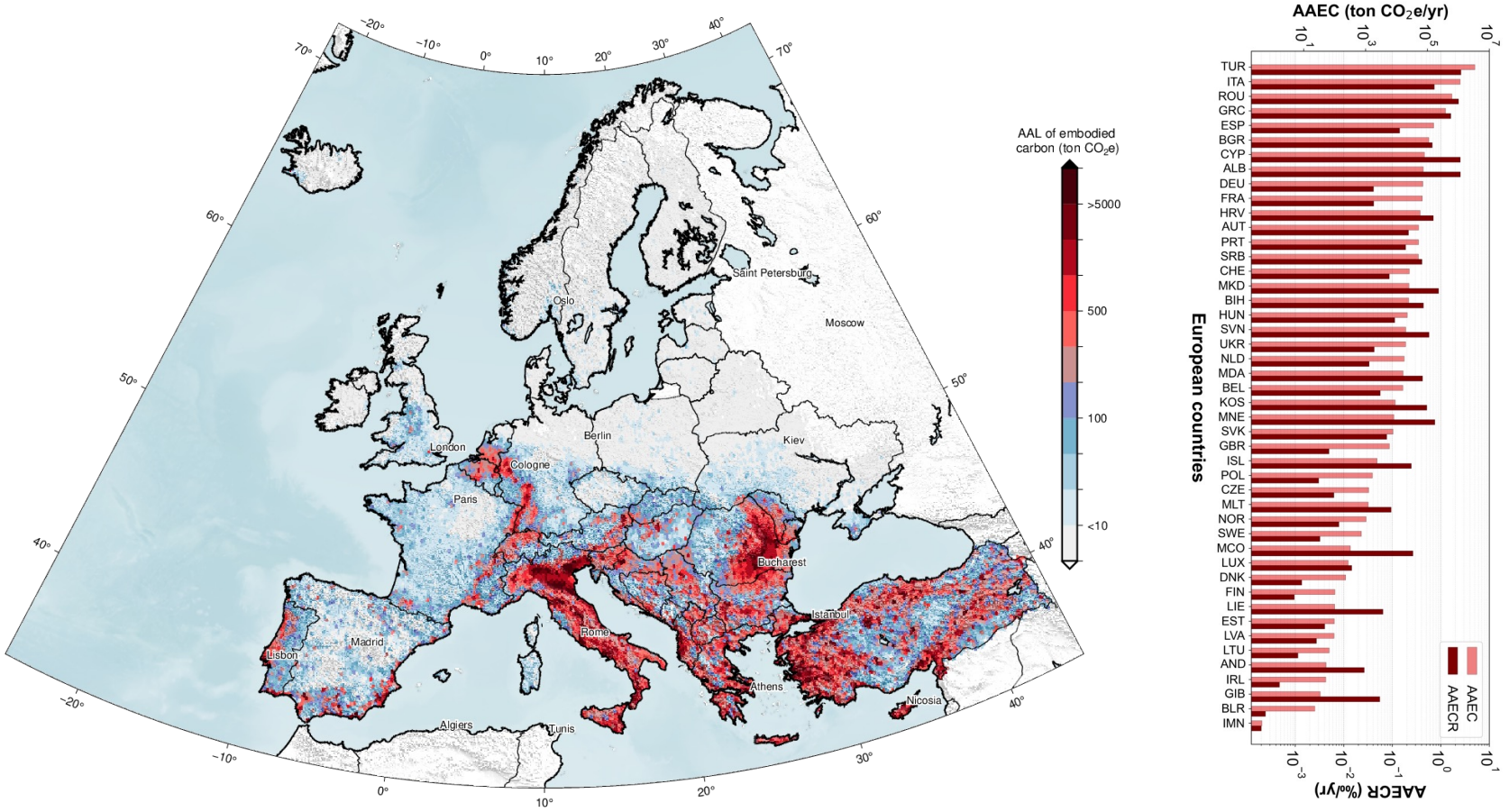

FINAL REMARKS

- Exposure models are fundamental for several multi-hazard risk analysis and to support the development of risk reduction measures.
- Several challenges still remain in the estimation of the number of buildings, their location, costs and vulnerability classes.
- It is fundamental to ensure that the same exposure model is used for the assessment of impact due to different hazards, to avoid unnecessary bias.
- New technologies such as machine learning and existing datasets can support the development of exposure models, or the enhacement of current datasets.

Thank you

and thanks to all the co-authors

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