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The Portuguese coastal areas under climate change – Results from the National Roadmap for Adaptation 2100

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INTRODUCTION

- ✓ Some of the most disruptive effects of climate change are projected to be felt along the coastal areas
- ✓ Changes in the water levels, due to **SLR**, **tides**, **storm surges** and **wave climate** may cause coastal erosion, flooding, damage in infrastructures, loss of life and habitats

→ Goals within the National Roadmap for Adaptation 2100

- Conduct a high-resolution probabilistic coastal vulnerability assessment for the Portuguese coastal areas
- Obtain large-scale results based on local high-resolution dynamical modelling
- Define a streamlined methodology to obtain accurate results near the coast
- Calculate "no-action" costs, define adaptation measures and strategies and calculate adaptation costs

DATA

Same GCMs

Sea Level Rise

Ensemble projections from up to **21 GCMs** for Historical, RCP4.5 and RCP8.5, respectively.

Tides

Local tide projections simulated using harmonic analysis by Antunes *et al.* (2007)

Waves

6-member ensemble generated using WW3 with ST4 package for Historical, RCP4.5 and RCP8.5 (data along the portuguese coastline at ~0.5º; LISCOAST)

ERA5 reanalysis (0.36º offshore)

In-situ data (Leixões, Costa Nova, Gova Gala, Lisboa, Sines, Faro)

Storm Surge

6-member ensemble generated using Delft3D-FLOW for Historical, RCP4.5 and RCP8.5 (data along the portuguese coastline at ~0.5º; LISCOAST)

Digital Terrain Models (DTMs)

Aerophotogrammetric (2008, 2015; 2018) + LiDAR (2011) + future projected (PaCR method)

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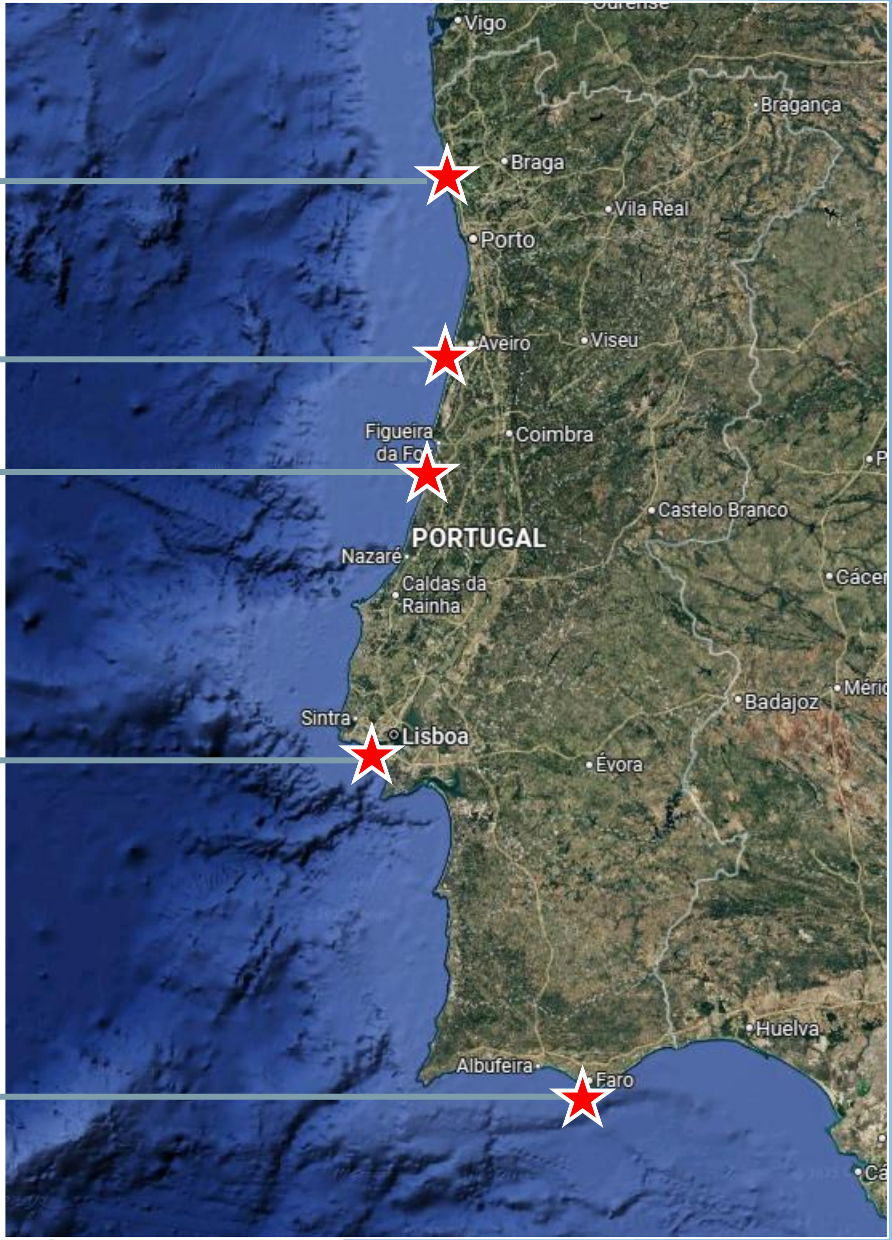
METHODOLOGY

→ Local Dynamical Modelling Key Locations

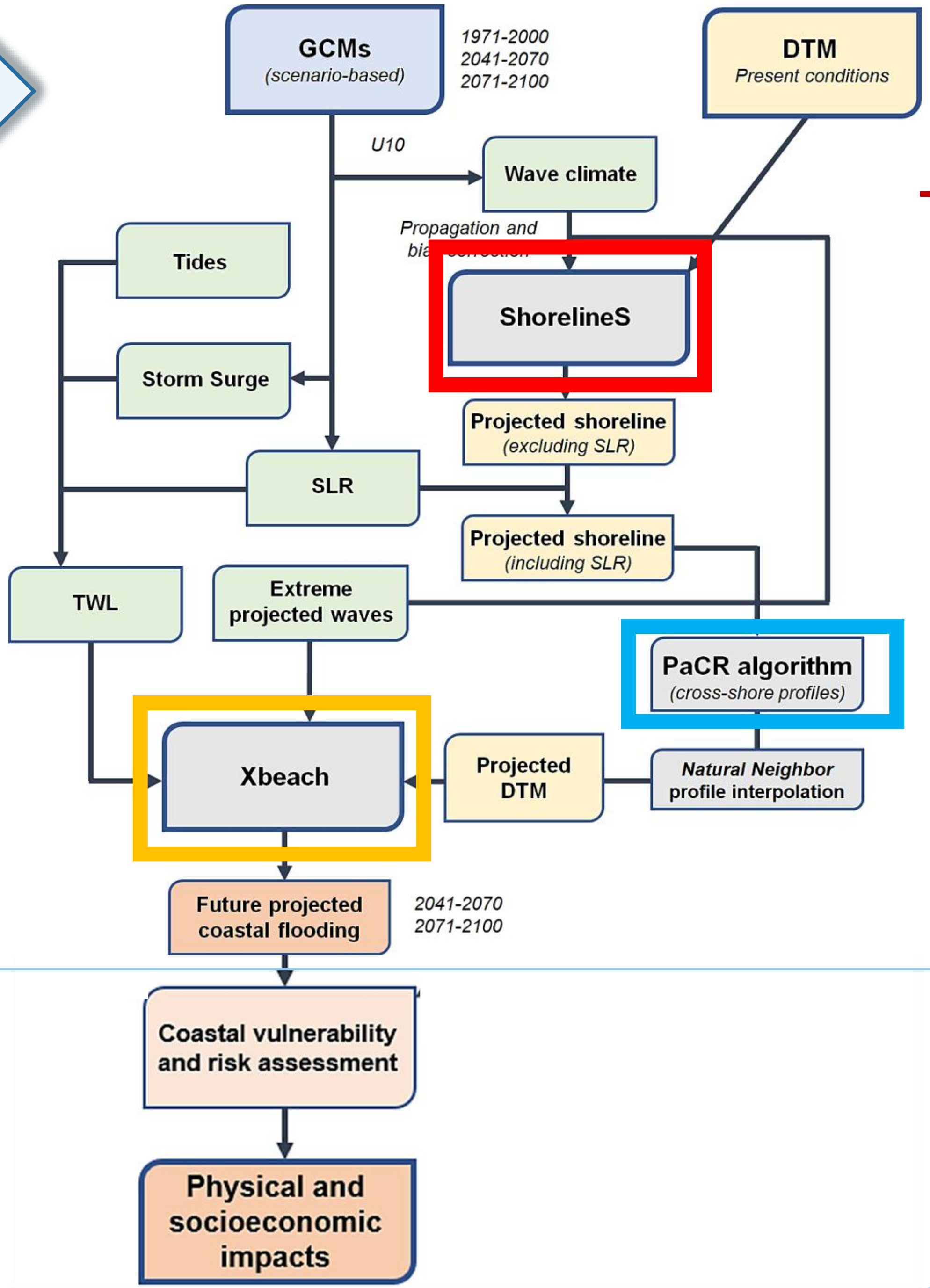


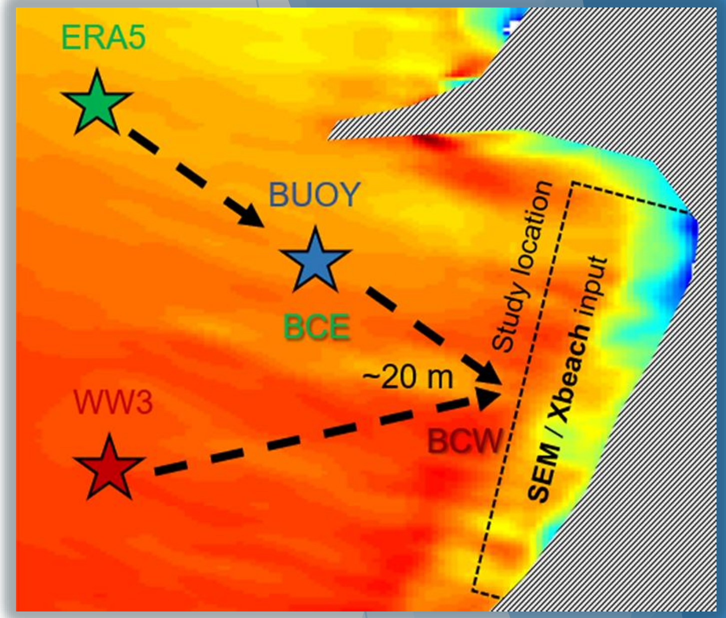
METHODOLOGY

WORKFLOW

Dynamic modelling at local scale
(5 key-locations)

Parametrical modelling at national scale
(1000 km of coastline)



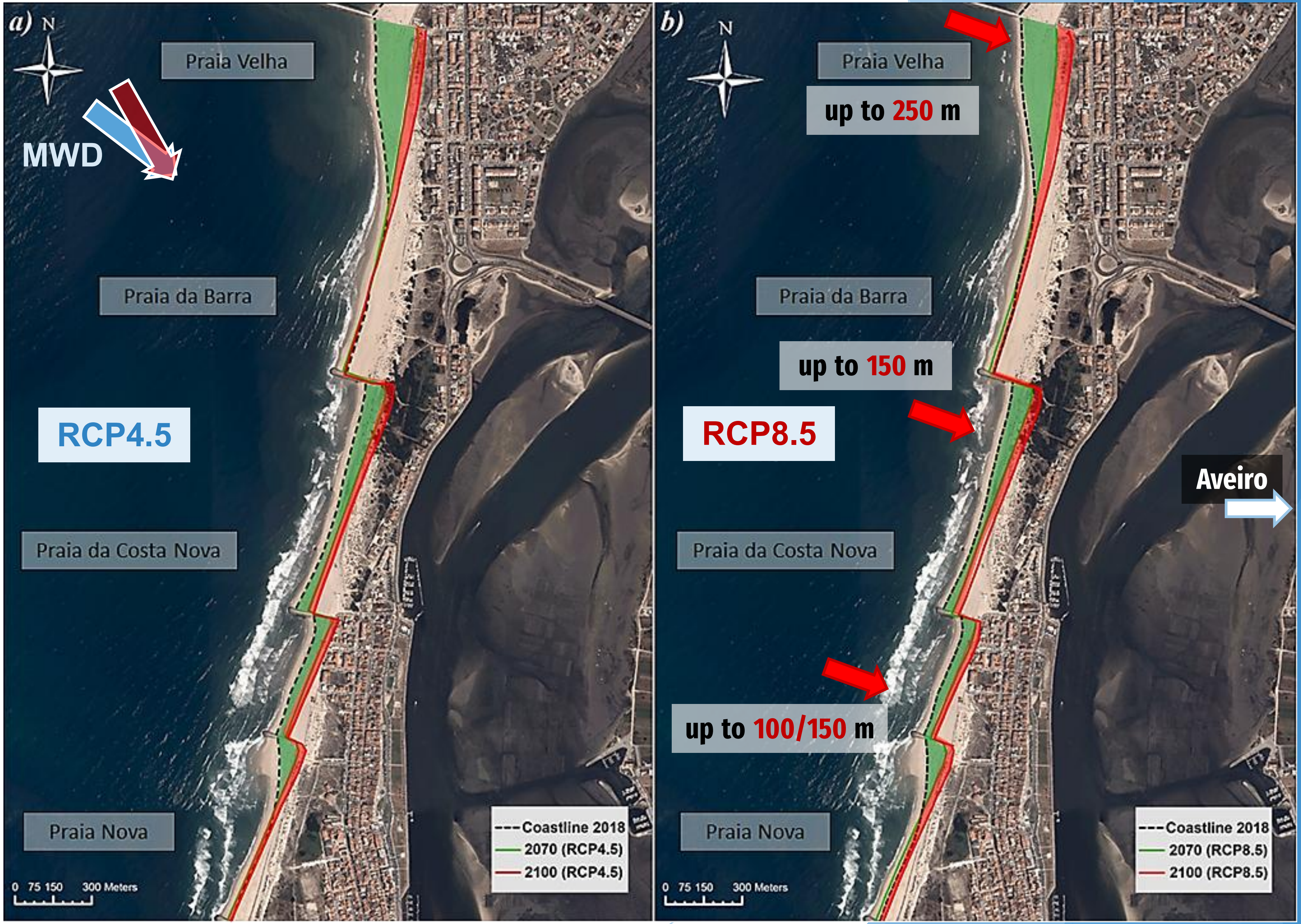


Propagation & correction

RESULTS

→ Shoreline Evolution

COSTA NOVA
(Northern Portugal)



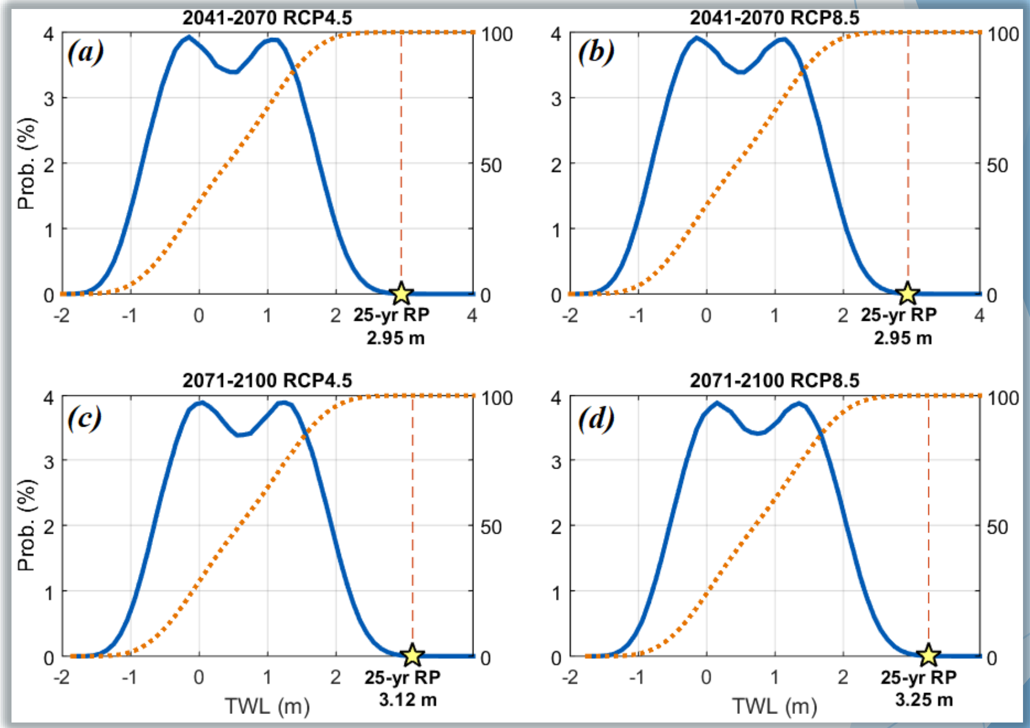
RESULTS

→ Coastal Flooding (predetermined events)

TWL (25-year RP) + wave events based on 99% percentile energy + future projected DTM

TWL = SLR + Tides + Storm Surge

- SLR → Mean estimate
- Tides → Tide projections for nearest harbor
- Storm Surge → Corrected storm surge



Wave events

$$E \approx T_p H_s^2$$

+ MWD

Future projected DTM

PaCR method using future projected shorelines

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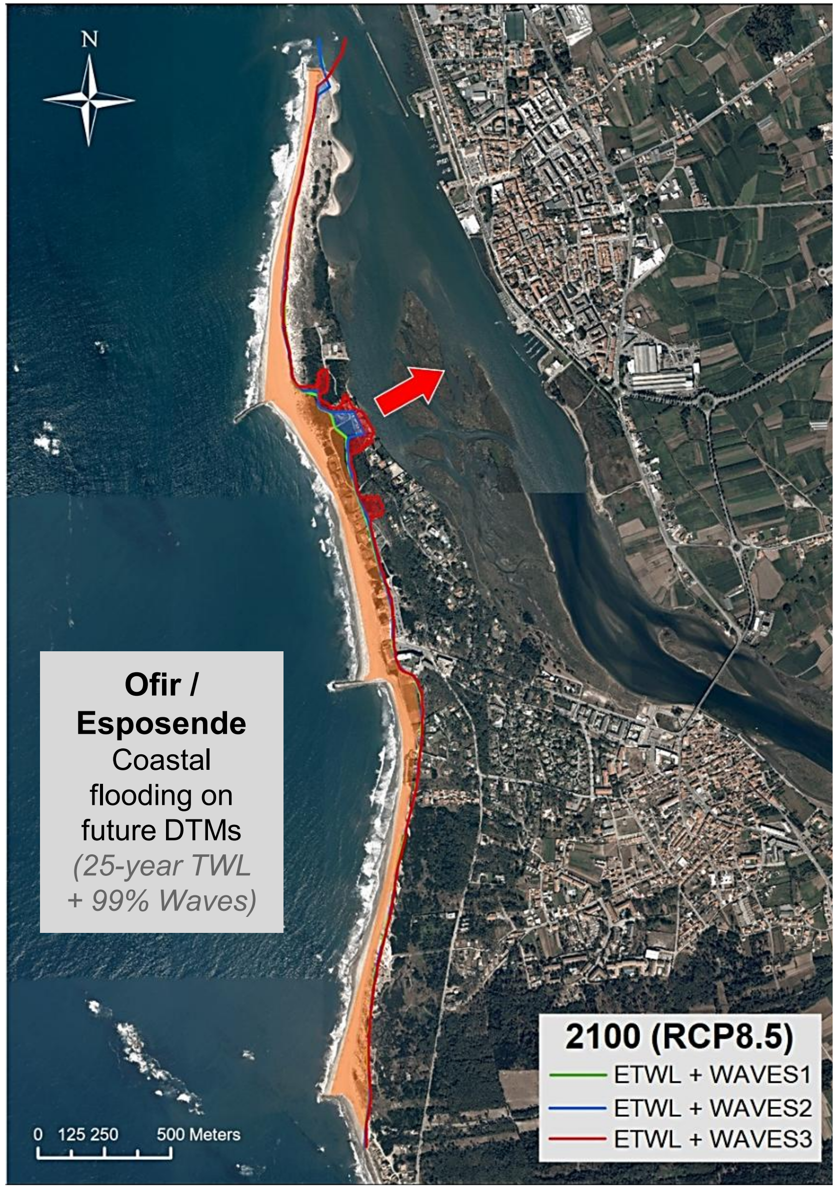
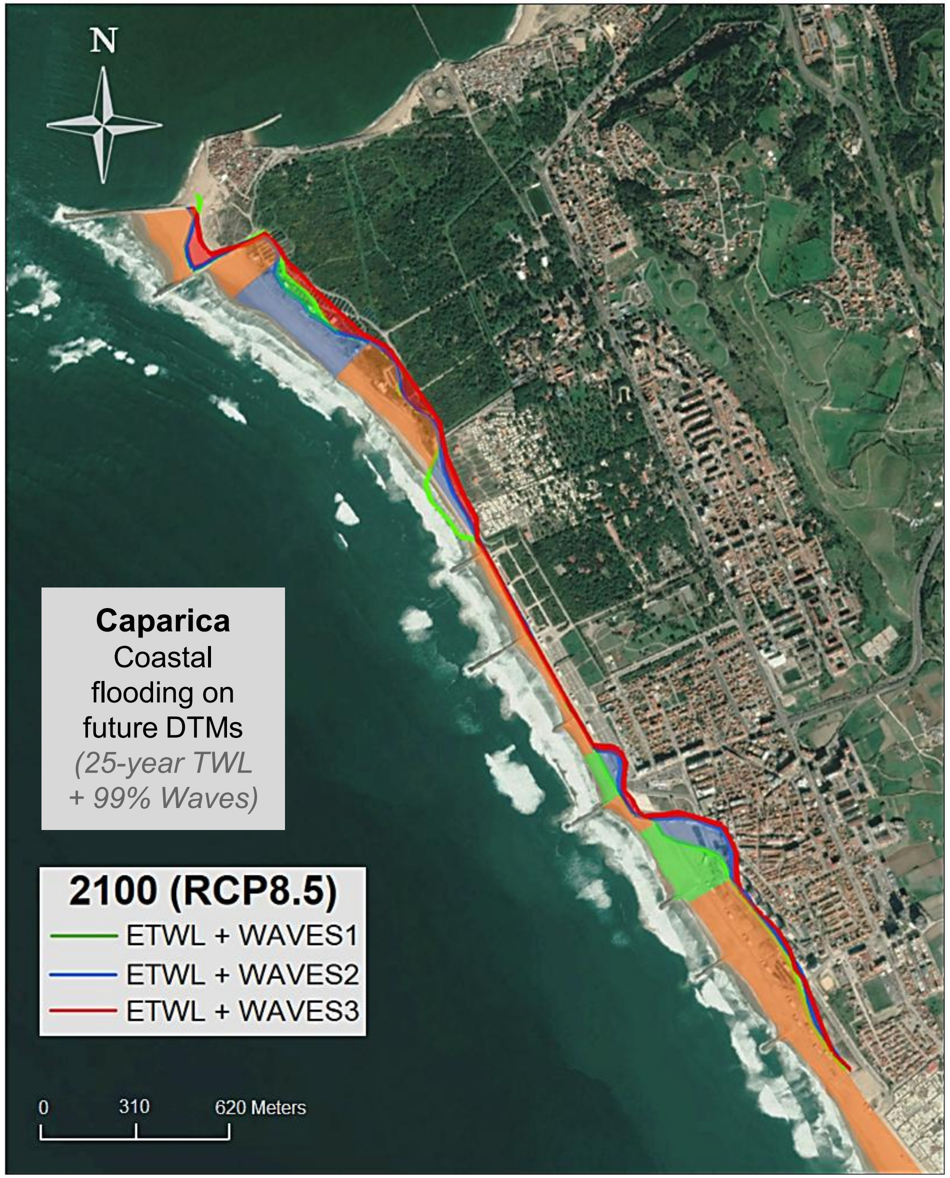
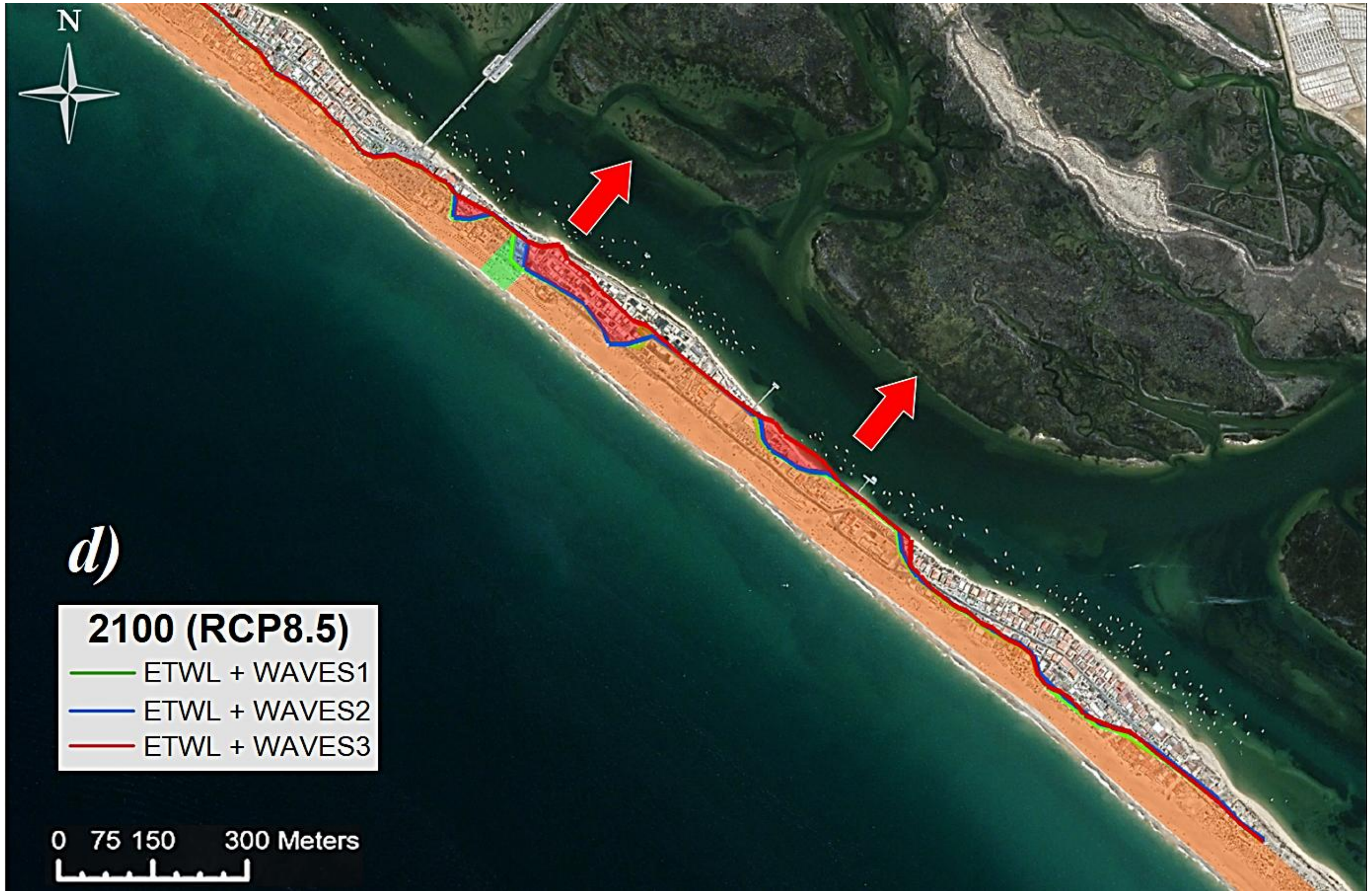
RESULTS → Coastal Flooding at key-locations (predetermined events)



RESULTS

→ Coastal Flooding (predetermined events)





RESULTS

CVI = Hazard x Physical Susceptibility

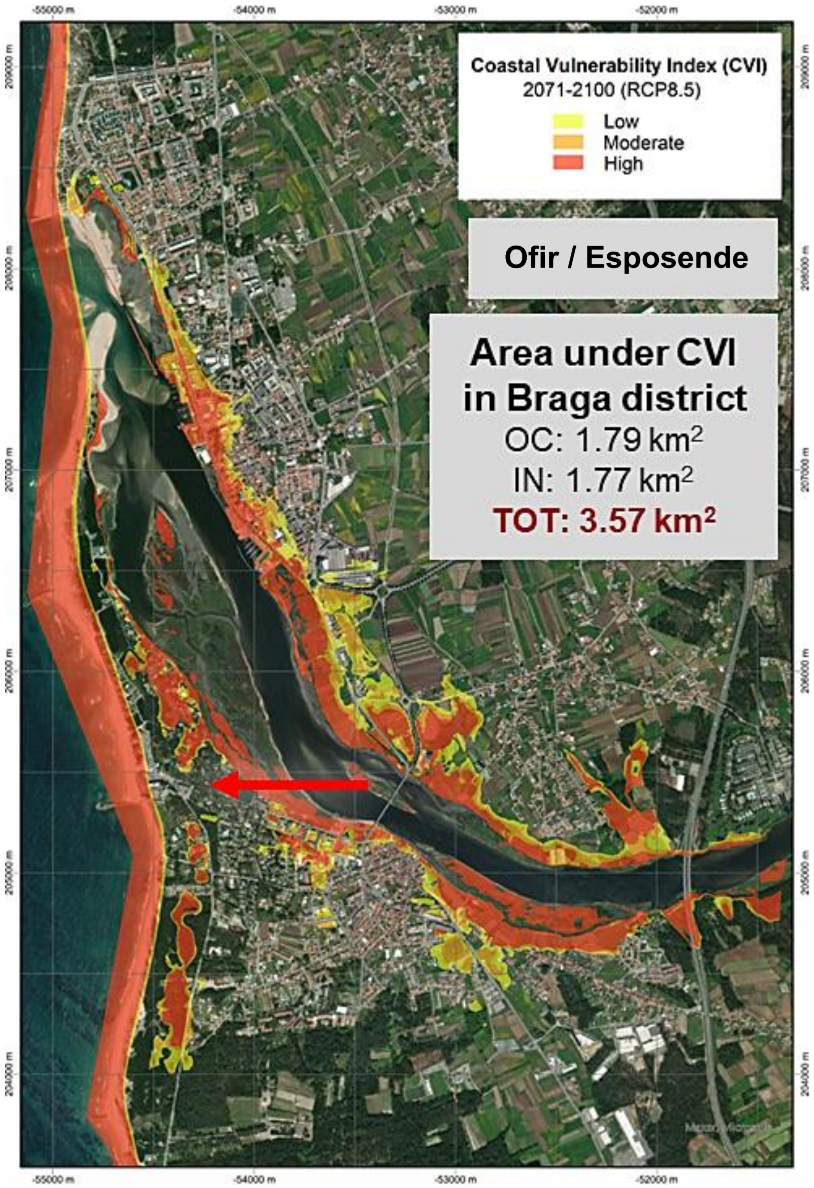
Hazard: Extreme TWLs

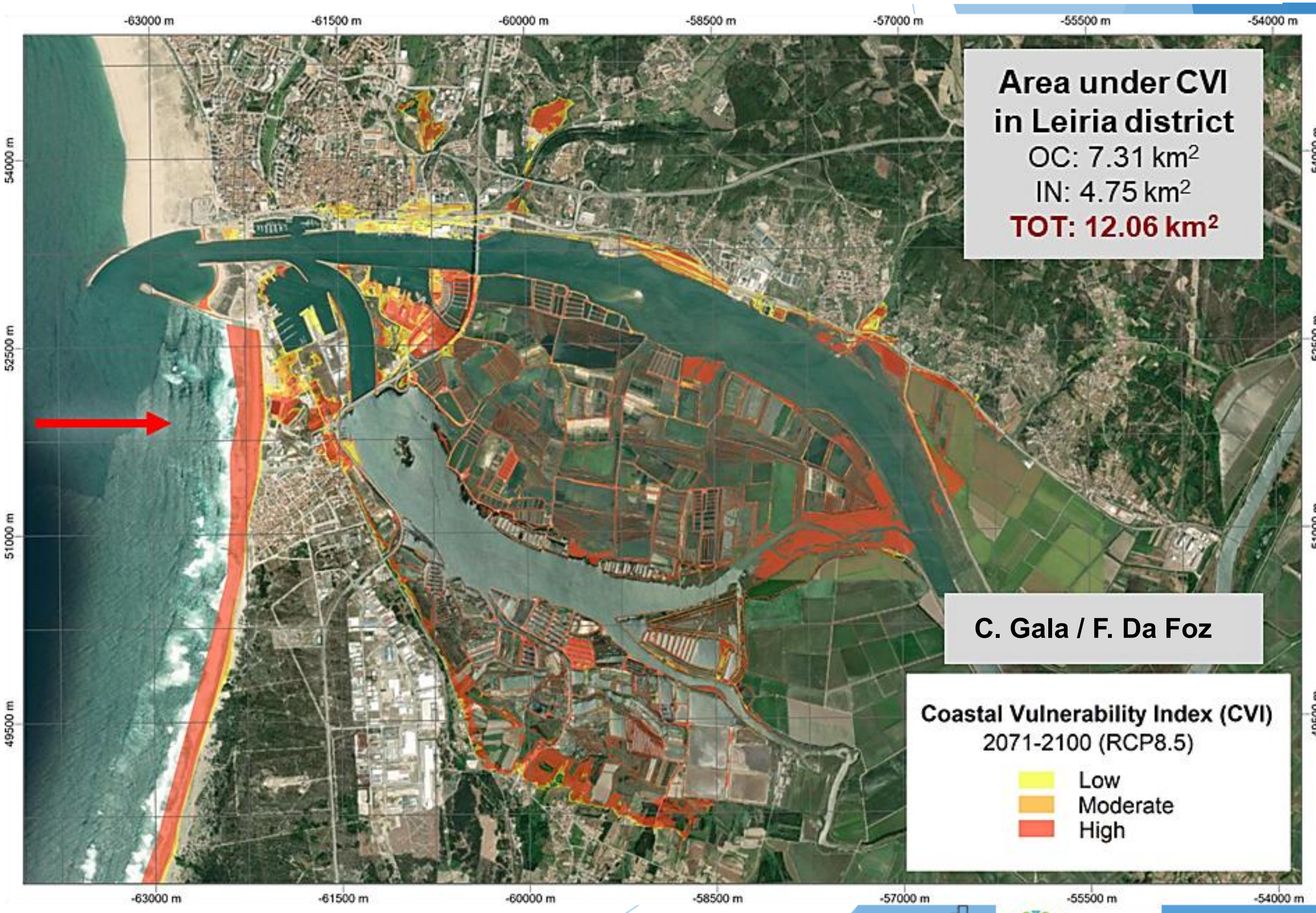
Physical Susceptibility: Projected DTMs

Low – Flooding with a return period of **100 years**

Moderate – Flooding with a return period of **25 years**

High – Flooding with a return period of **4 years**



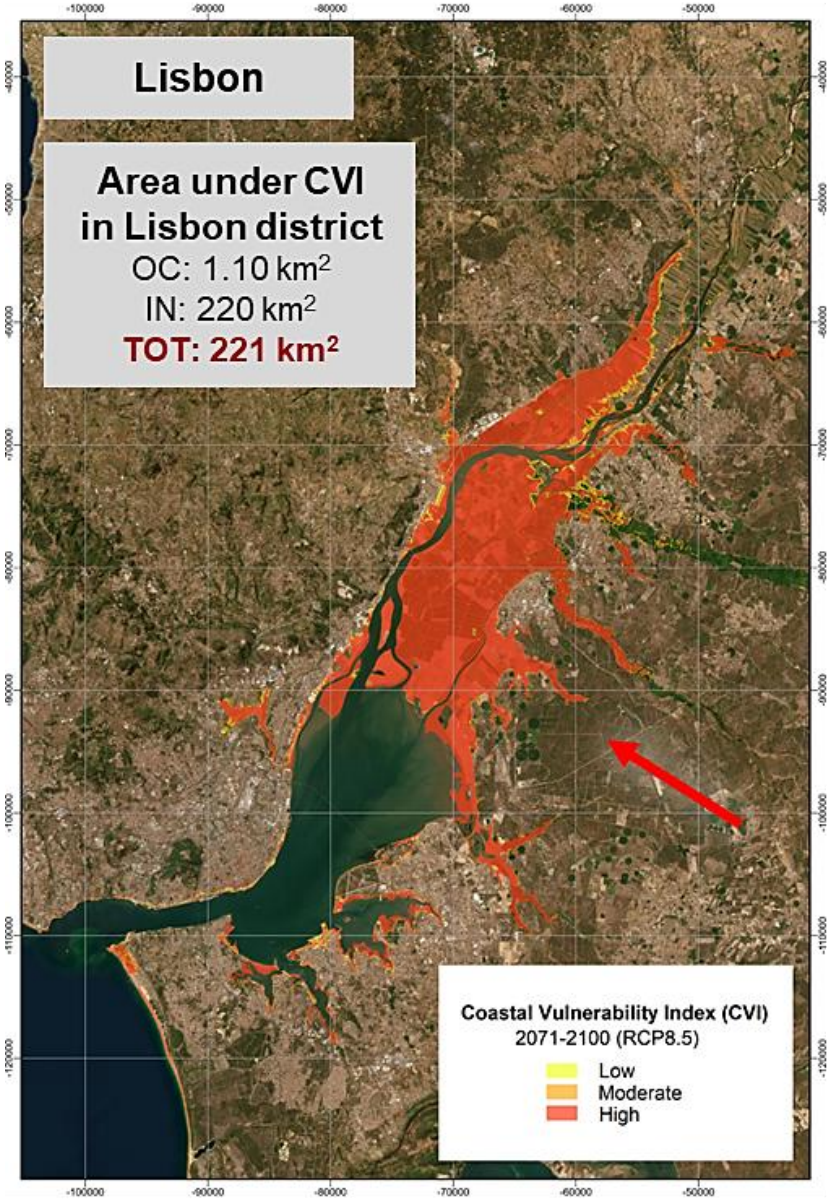


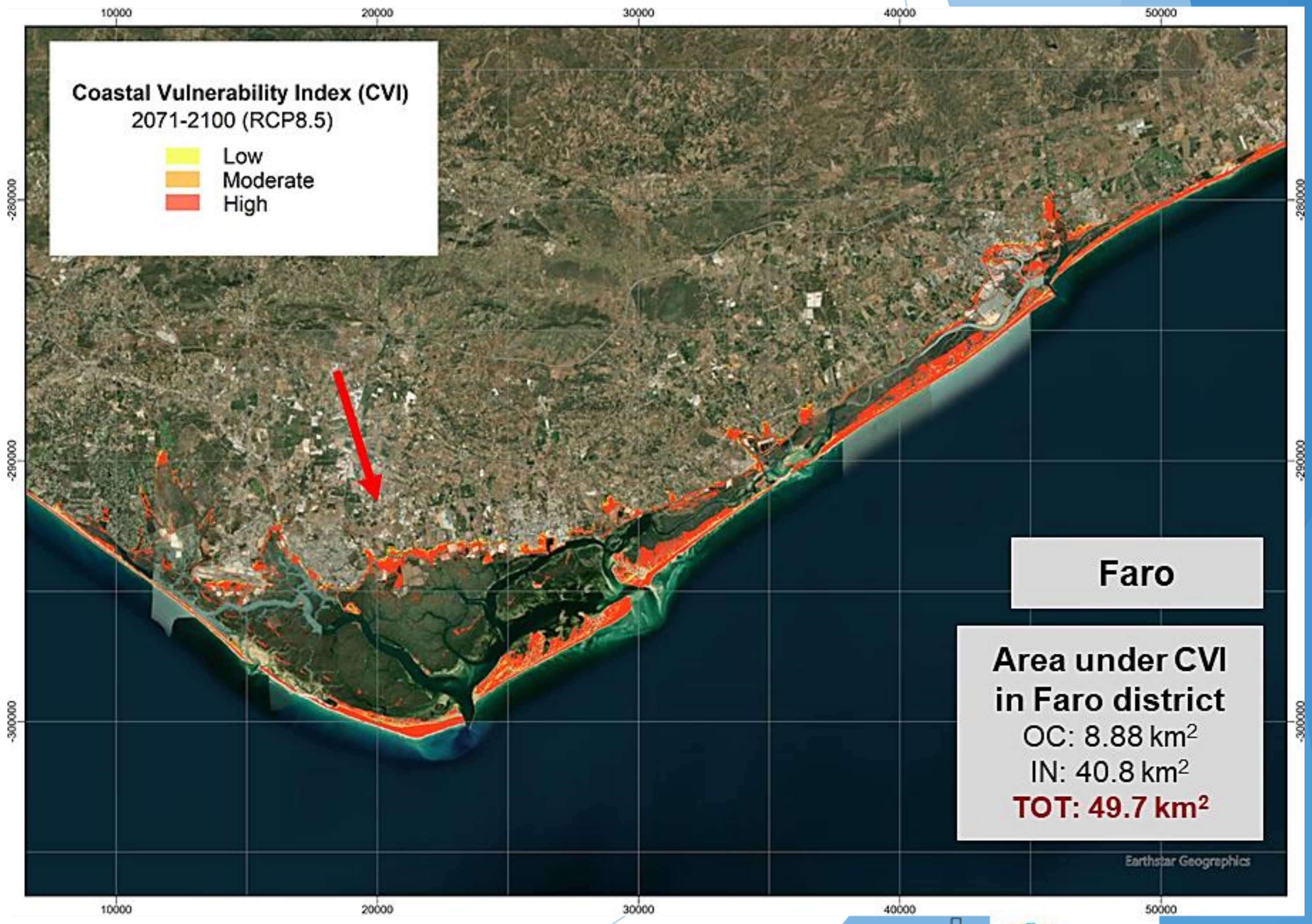
RESULTS

CVI = Hazard x Physical Susceptibility

Hazard: Extreme TWLs

Physical Susceptibility: Projected DTMs





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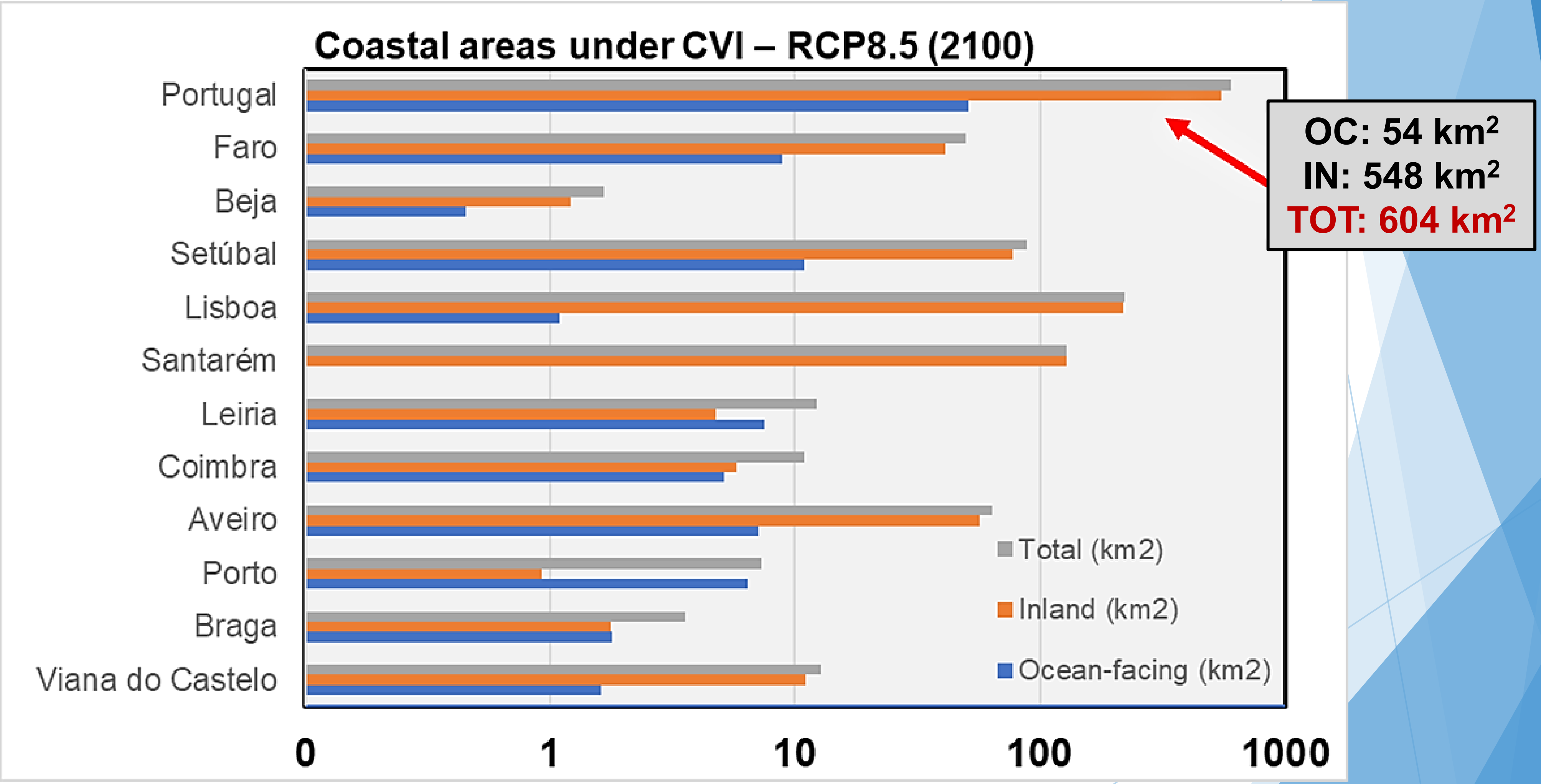
RESULTS

CVI = Hazard x Physical Susceptibility

Extreme TWLs — Projected DTMs



Nationwide eroded area between 1958 and 2021: **13.5 km²**

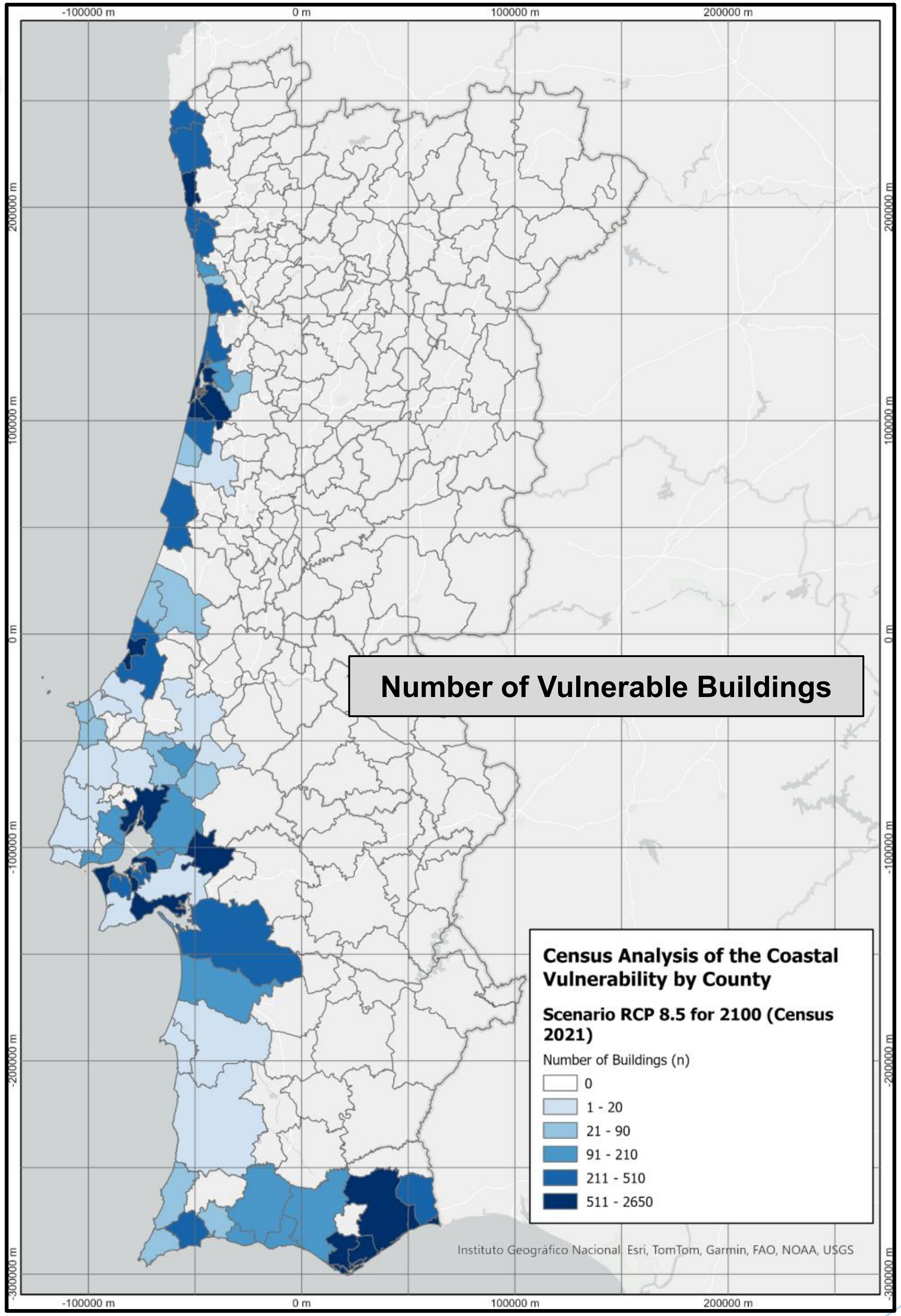
Note: vulnerable area does not imply permantenly lost area

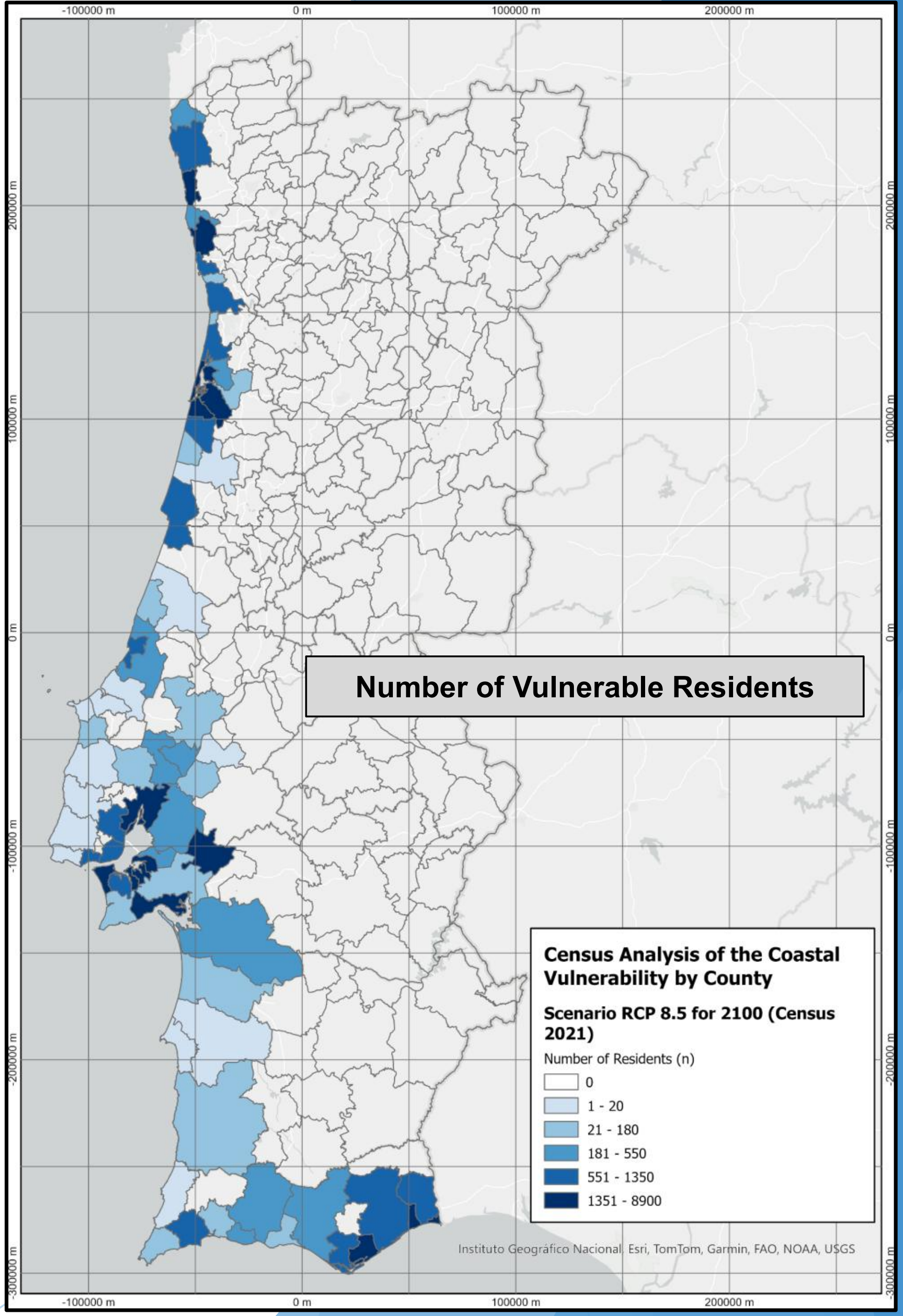
The rate is expected to increase 3x to 4x

RESULTS

Exposure (Demography)
2100 (RCP8.5)

Districts	Vulnerable Buildings	Vulnerable Residents
Viana do Castelo	721	1698
Braga	738	1588
Porto	1338	4196
Aveiro	**4796**	**10394**
Coimbra	335	756
Leiria	1240	1163
Santarém	448	677
Lisboa	1159	5476
Setúbal	**4578**	**16769**
Beja	19	21
Faro	**7838**	**17725**
Continental Portugal	**23210**	**60463**





RESULTS

Total Inaction Costs

$$VPT = V * A * C_A * C_L * C_V$$

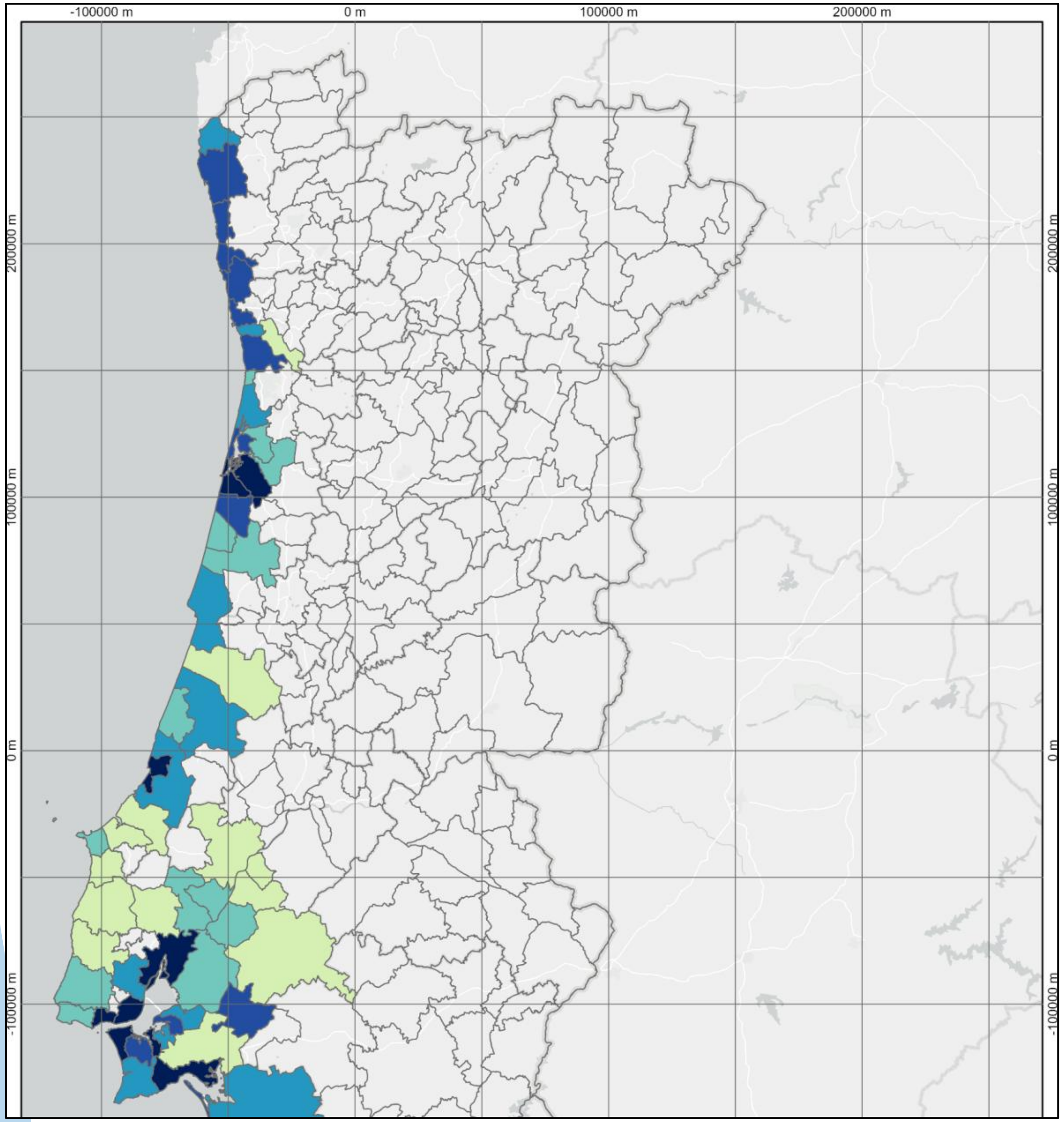
$$D_A = VPT(1 + TaxFEU + 23TaxIMI)$$

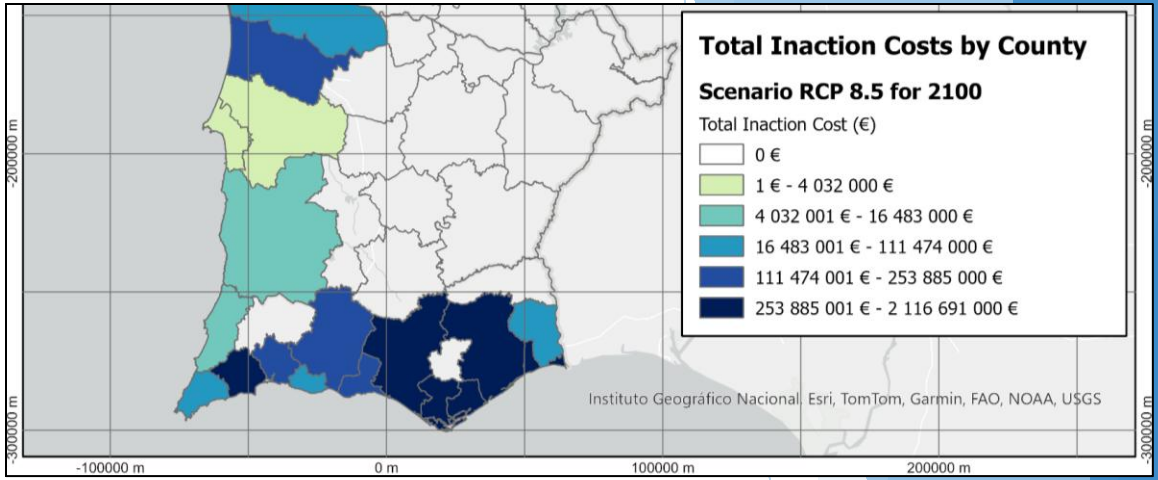
$$\begin{cases} DPP = D_A * \left(\dfrac{\frac{1}{4} * AV(n1) + \frac{1}{2} * AV(n2) + 1 * AV(n3)}{ATotal}\right) \\ DTP = D_A * \left(\dfrac{AV(n1) + AV(n2) + AV(n3)}{ATotal}\right) \end{cases}$$

$$\begin{cases} TIC_{min} = FM * DPP \\ TIC_{max} = FM * DTP \end{cases}$$

RESULTS

Total Inaction Costs
2100 (RCP8.5)

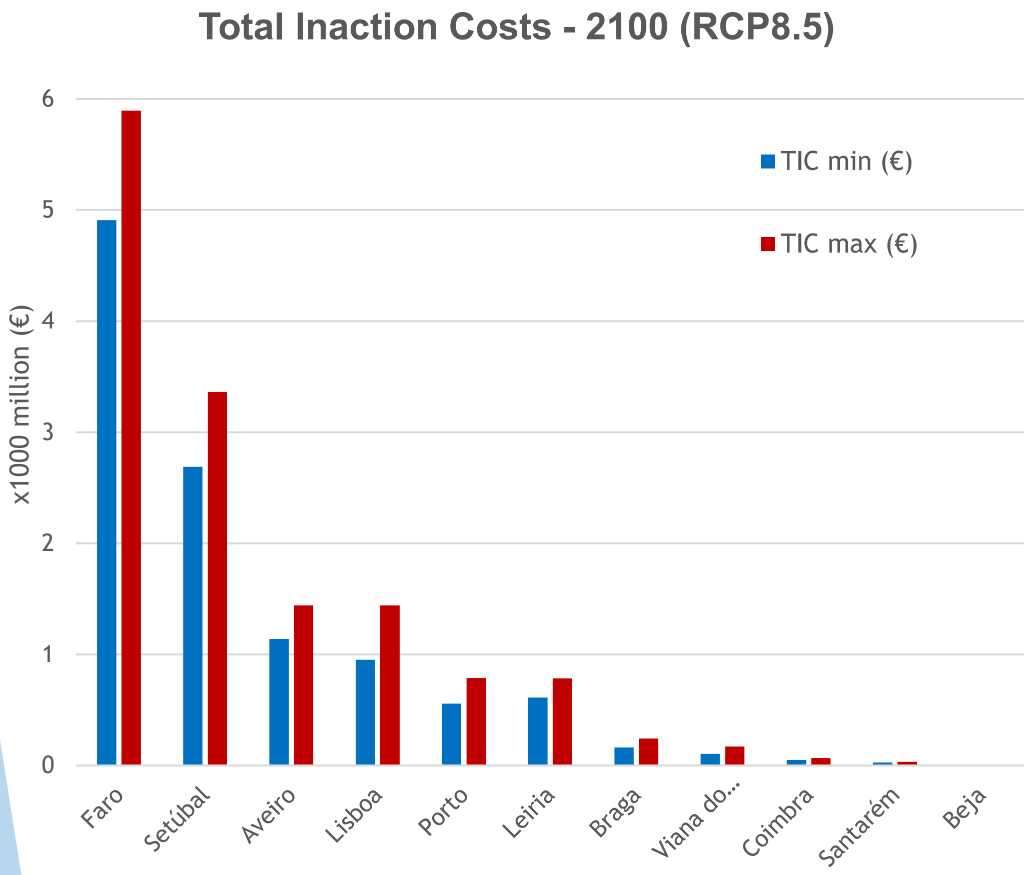


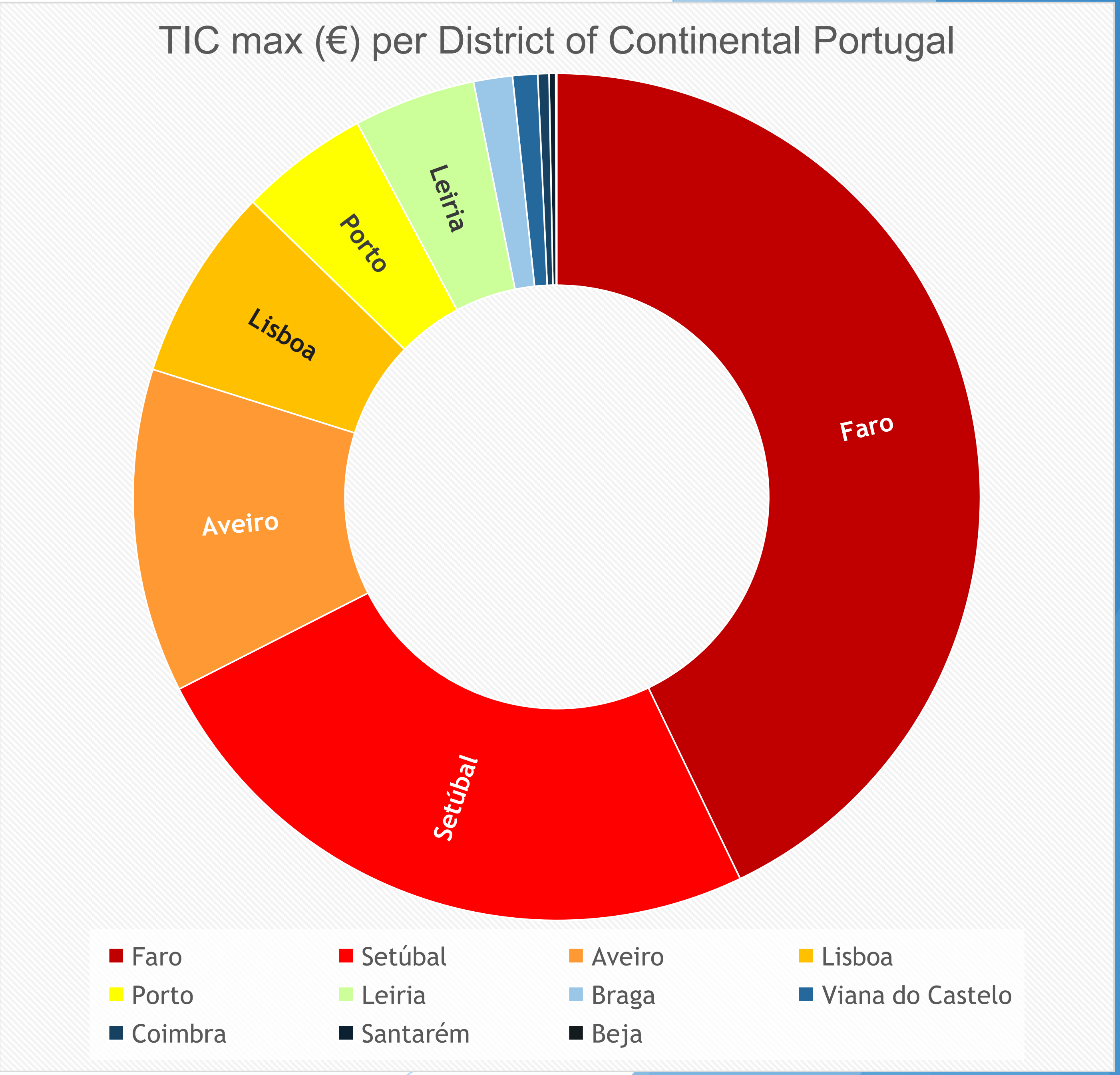


Districts	Total Inaction Cost (MAX)
Viana do Castelo	170.01 M€
Braga	243.59 M€
Porto	785.64 M€
Aveiro	**1440.25 M€**
Coimbra	65.61 M€
Leiria	783.43 M€
Santarém	32.28 M€
Lisboa	**1439.51 M€**
Setúbal	**3363.07 M€**
Beja	4.06 M€
Faro	**5895.30 M€**
Continental Portugal	**14,223 M€**

RESULTS

Total Inaction Costs
2100 (RCP8.5)





METHODOLOGY

Adaptation Costs

Costs associated to:

1) **Maintenance** of pre-existing structures
2) **Beach nourishment** according to Longitudinal Sediment Transport projections
3) **Structural accommodation** to support future projected extreme TWLs

Adaptation measures considered (according to APA's data):

1) Beach nourishment
2) Groins
3) Adherent structures
4) Breakwaters (ports/harbors)
5) Dykes
6) Cliff stabilization

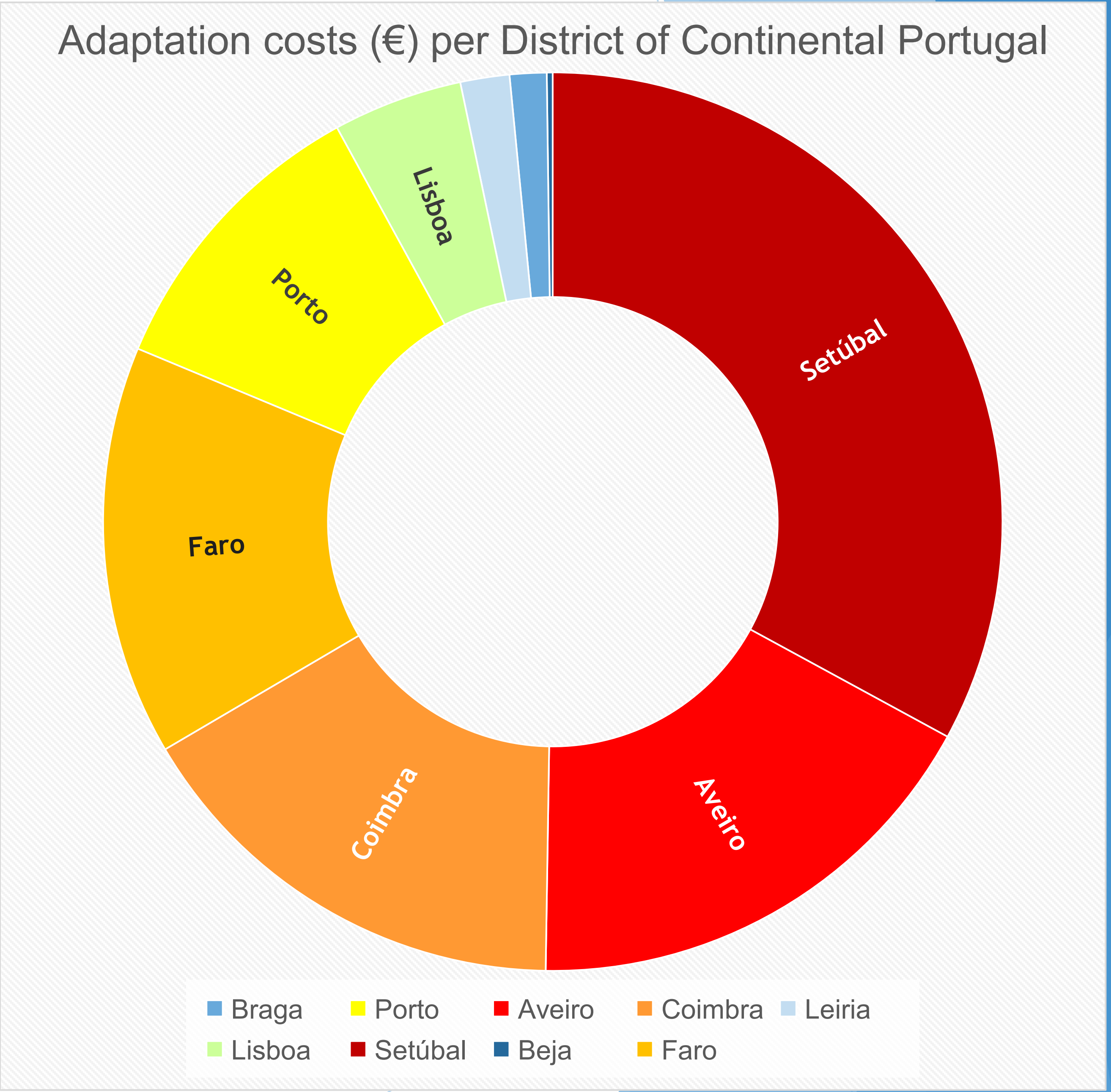





RESULTS

Adaptation costs (maintenance + accommodation)
2100 (RCP8.5)

Districts	Adaptation costs
Viana do Castelo	134.90 M€
Braga	66.09 M€
Porto	535.61 M€
Aveiro	**830.57 M€**
Coimbra	**781.68 M€**
Leiria	86.55 M€
Lisboa	226.60 M€
Setúbal	**1587.43 M€**
Beja	9.92 M€
Faro	660.56 M€
Continental Portugal (ocean-facing coastlines)	**4,920 M€**



RESULTS

Inaction *vs* Adaptation costs

2100 (RCP8.5)

	Faro	Beja	Setúbal	Lisboa	Leiria	Coimbra	Aveiro	Porto	Braga	Viana do Castelo
Inaction Costs	€5,895,300,000	€4,060,000	€3,363,070,000	€1,439,510,000	€783,430,000	€65,610,000	€1,440,250,000	€785,640,000	€243,590,000	€170,010,000
Adaptation Costs	€660,560,000	€9,920,000	€1,587,430,000	€226,600,000	€86,550,000	€781,680,000	€830,570,000	€535,610,000	€66,090,000	€134,900,000

Inaction Costs   Adaptation Costs

FINAL REMARKS

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Ocean Engineering
Volume 302, 15 June 2024, 117661

Research paper

The future of the Portuguese (SW Europe) most vulnerable coastal areas under climate change – Part I: Performance evaluation and shoreline evolution from a downscaled bias corrected wave climate ensemble

Gil Lemos [a], Ivana Bosnic [b], Carlos Antunes [a], Michalis Vousdoukas [c], Lorenzo Mentaschi [d], Pedro M.M. Soares [a]

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https://doi.org/10.1016/j.oceaneng.2024.117661

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Ocean Engineering
Volume 310, Part 1, 15 October 2024, 118448

Research paper

The future of the Portuguese (SW Europe) most vulnerable coastal areas under climate change – Part II: Future extreme coastal flooding from downscaled bias corrected wave climate projections

Gil Lemos [a], Ivana Bosnic [b], Carlos Antunes [a], Michalis Vousdoukas [c], Lorenzo Mentaschi [d], Miguel Espírito Santo [a], Vanessa Ferreira [a], Pedro M.M. Soares [a]

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- WP1B 1 - Emergency Preparedness Analysis Forest Fire
- WP1B 2 - Risk analysis at a societal level

WP2. Climate projections and indexes

- WP2A - Climate Projections, Extremes, and Indices - Mainland Portugal
- WP2A - Climate Projections, Extremes, and Indices - Supplementary Material
- WP2E - Climate Projections, Extremes, and Indices - Portugal Autonomous Regions

WP3. Socioeconomic scenarios

- WP3A1 Emissions Scenarios, Narratives and Socioeconomic Trajectories

WP4. Sectoral impacts modelling

- WP4C1 Sectoral Impacts Modelling - Executive Summaries
- WP4C2 Sectoral impacts modelling - Hydrological Balance & Agroforestry
- WP4C3 Sectoral Impacts Modelling - Droughts
- WP4C4 Sectoral Impacts Modelling - Forest fires

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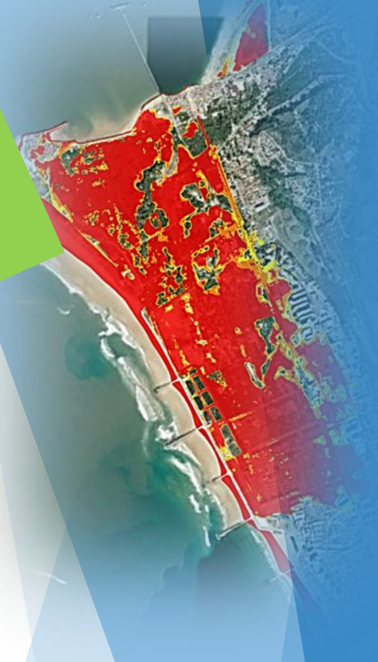

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