Smart Control of the Climate Resilience in European Coastal Cities

Decision-Support Tools and Living Lab Sustainability to Inform Climate Policy-making

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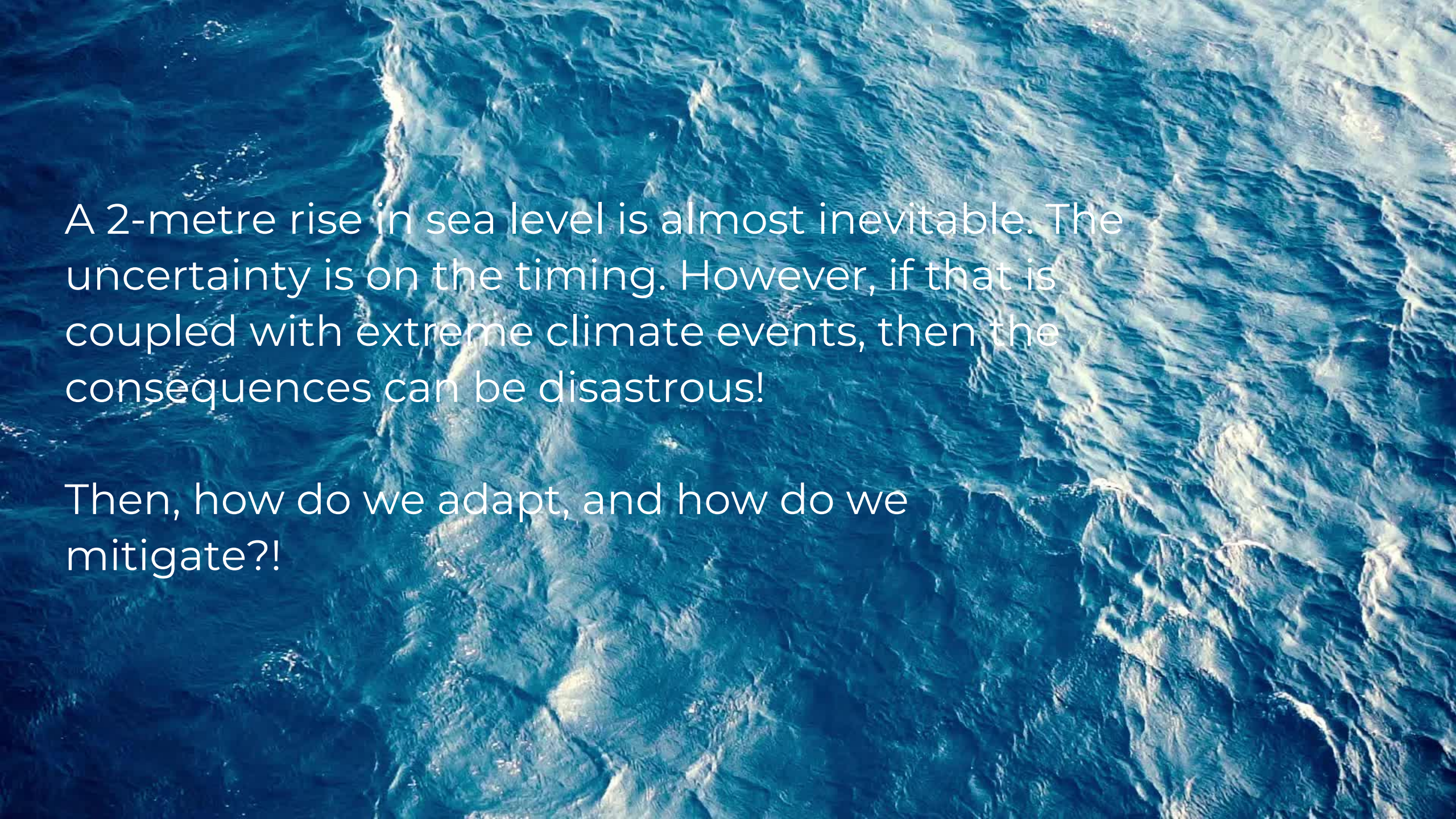
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007142



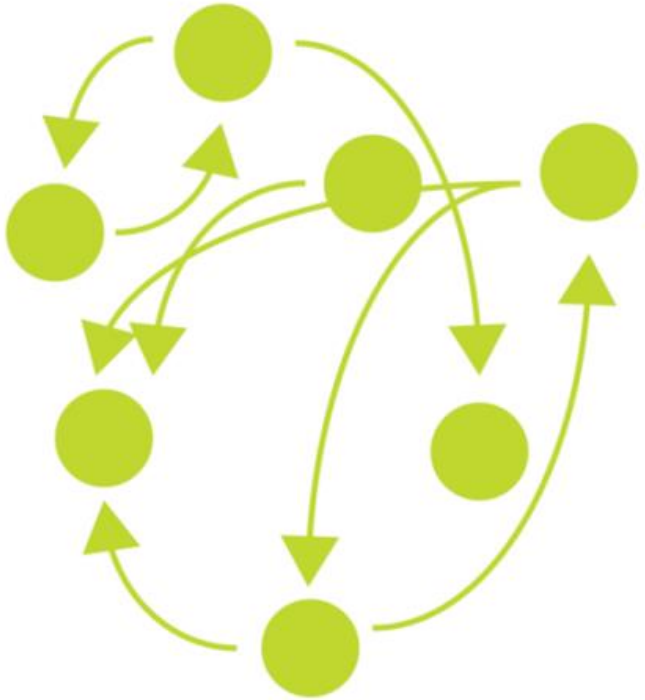
A 2-metre rise in sea level is almost inevitable. The uncertainty is on the timing. However, if that is coupled with extreme climate events, then the consequences can be disastrous!

Then, how do we adapt, and how do we mitigate?!


Developing regional **systematic transformative** solutions on climate resilience, mainstreaming **nature-based solutions, living labs,** and **smart technologies**
EU Mission: Adaptation to Climate Change

Traditional thinking

Systems thinking



Why systematic transformation?!

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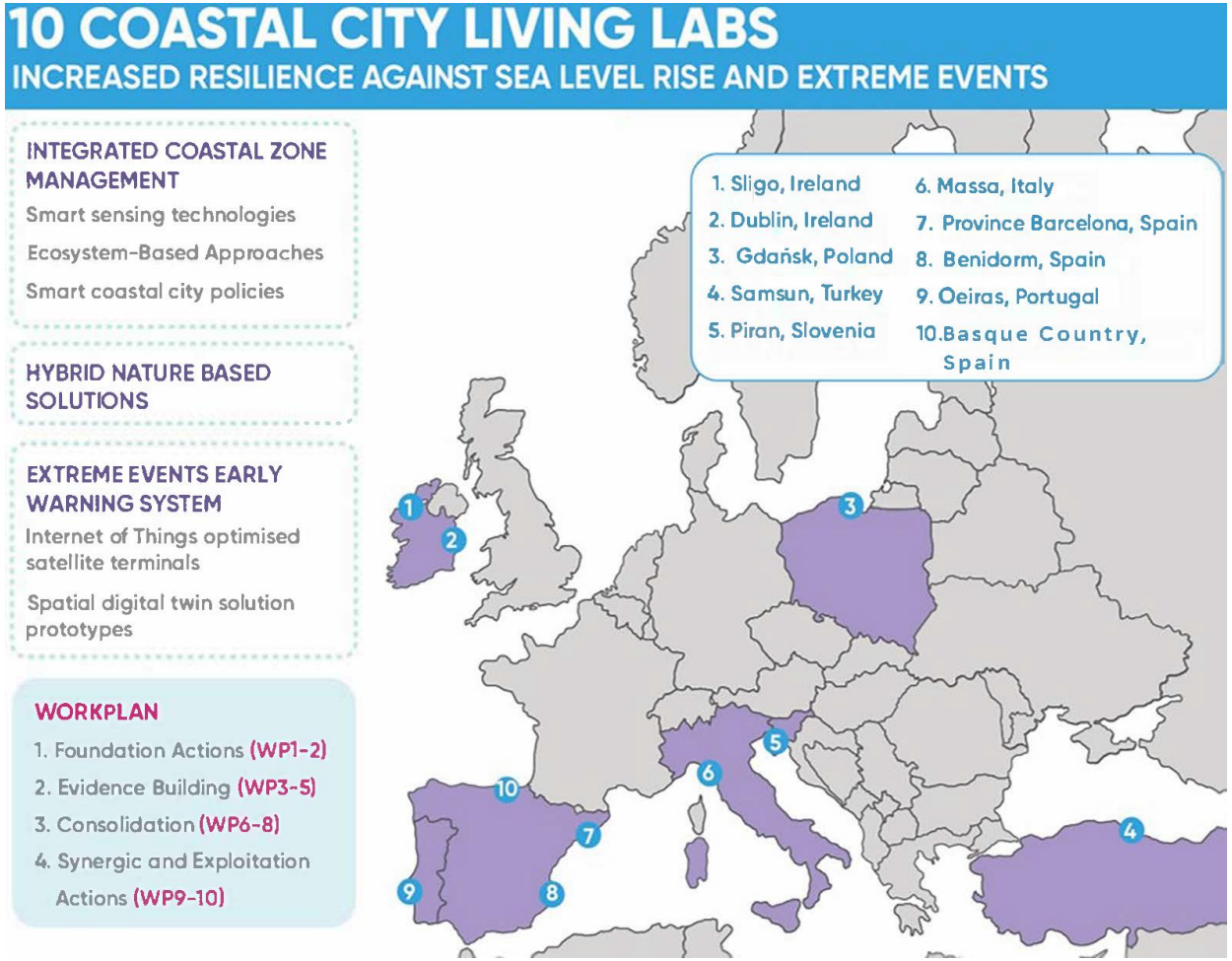
***S**mart **Co**ntrol Of the climate **R**esilience in **E**uropean coastal cities*



Integrated approached to increase resilience

The overall aim SCORE is to design, develop, monitor and **validate robust adaptation measures** in coastal and low-lying areas to protect them from increasing climate and sea level risks, including coastal flooding and erosion, to **enhance their overall long-term resilience**.

One of the key activities under SCORE is to **design, implement, and evaluate a novel framework of Coastal City Living Labs** (CCLL) that will enable citizens and stakeholders to co-create and co-design the solutions with scientists, researchers and engineers to make sure these are sustainable and acceptable by the society.

CCLL Visualisation

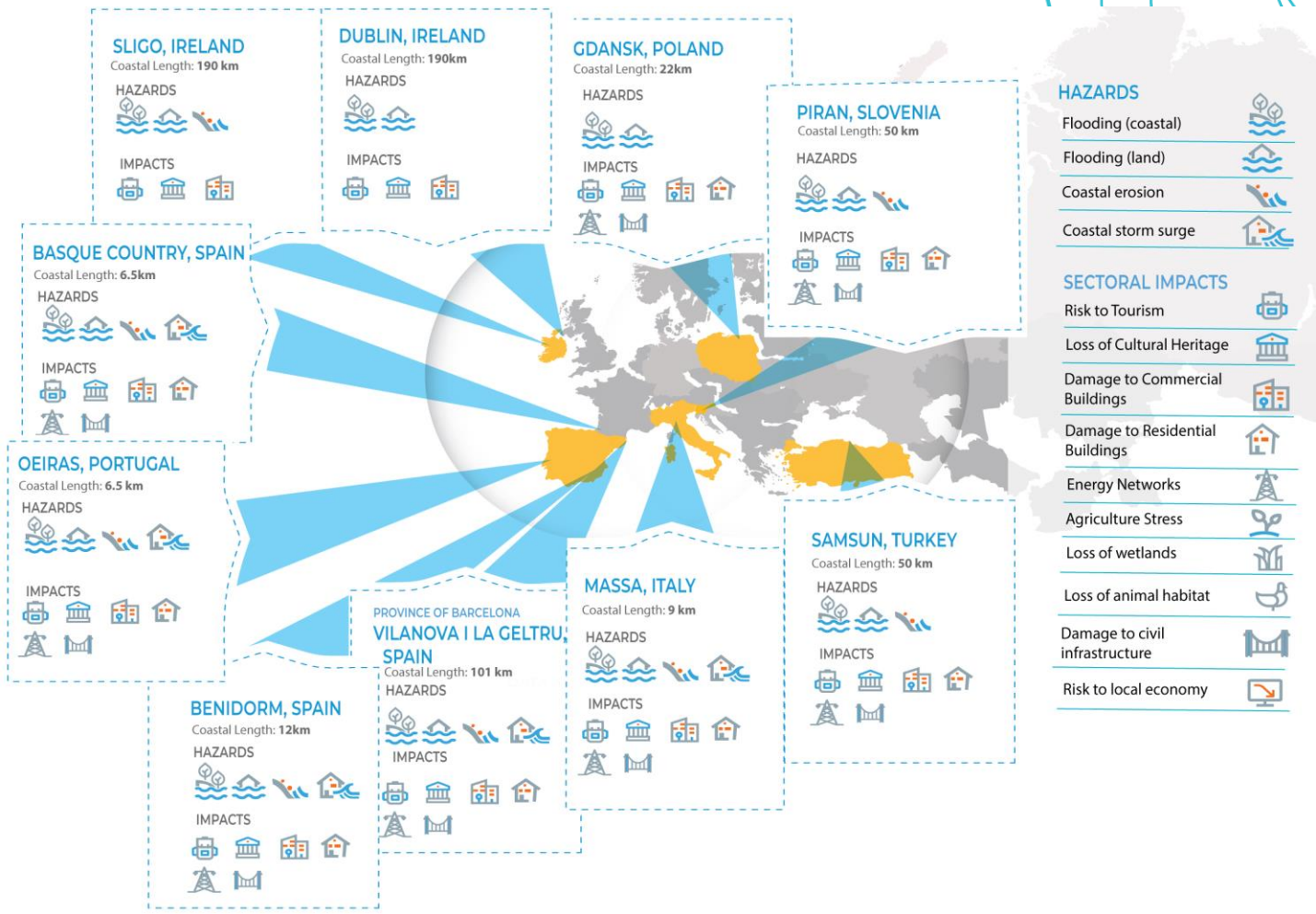
Find more about our CCLL challenges and risks on: **score-eu-project.eu/coastal-city-living-labs/sligo/**

Challenges and risks

- Potential storm surge
- Coastal flooding and erosion
- Dune erosion
- Sligo coastal archaeological sites are vulnerable to coastal erosion
- Heritage venues were closed due to flooding and archaeological sites were washed away entirely and lost forever
- Risks to tourism and beaches

Planned Ecosystem Based Approaches (EBAs)

- Establishment of vegetated buffer areas in dune systems as hybrid NBS
- Testing buffer zones with several vegetated areas
- Testing several coastal protection bioengineering solutions



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How can Living Labs Support Climate Policymaking?

- Living Labs (or LLs) **can address various barriers** to related to climate adaptation (e.g., lack of dialogue, limited knowledge, low uptake in policy, etc).
- LLs are based on the concept of **collaborative governance and co-production of knowledge**, which are critical for effective climate adaptation.
- LLs have aided **decision-making in the face of climate uncertainty**, as they bring together diverse stakeholders and interdisciplinary techniques.
- LLs have served as standards for **scaling-up NBS for dealing with climate risks** because they promote a user-centric approach in which information and skills can be efficiently shared.
- LLs encourage citizens to be proactively involved in designing and implementing **innovative schemes**, and can play a role in supporting **co-creative climate strategies**.

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Types of Participatory Decision Support Tools to inform Climate Policymaking in Living Labs

- **Multi-Criteria Decision Analysis** (Ranking Different Climate Strategies based on Stakeholder Perceptions)
- **Cost-Benefit Analysis** (Comparing Costs and Benefits of a Climate Strategy, using Stakeholder Insights)
- **Fuzzy Cognitive Mapping** (Mental Mapping of Stakeholder Perceptions to Inform Decision-Making)
- **Participatory Scenario Planning** (Engage Stakeholders in Developing Future Climate Scenarios and Policies)
- **Serious Games** (Allow Stakeholders to Test Different Climate Strategies in a Simulated Environment)
- **Citizen Science** (Collect Data from Citizens to Inform Climate Policy)
- **Participatory Budget and Citizen Assemblies** (Involve Citizens in Climate Policy and Funding Decisions)
- And more!

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How can Living Lab Sustainability Ensure Maximum Policy Impact?

- Using **pre-existing LL networks**, partnerships and collaborations to ensure continued policy impact
- Creating **long-term processes** and frameworks for embedding LL outputs in policy
- **Long-term LL funding** can ensure greater resources for policy changes
- Increased **stakeholder ownership and community stewardship** can ensure better decision-making processes and co-creation of solutions
- Building **data sharing policies**, **toolkits, open knowledge platforms**, and knowledge sharing networks.
- Setting up processes for **monitoring and evaluation of long-term impacts**, and informing dynamic policymaking.
- Greater opportunities for **scaling and institutionalization of solutions**, since they are already tested in pilot LLs, and other LLs could be more willing to try them.

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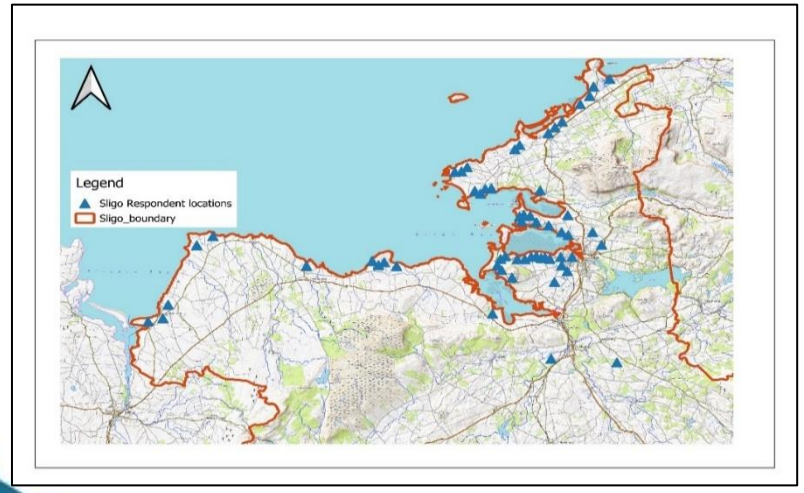
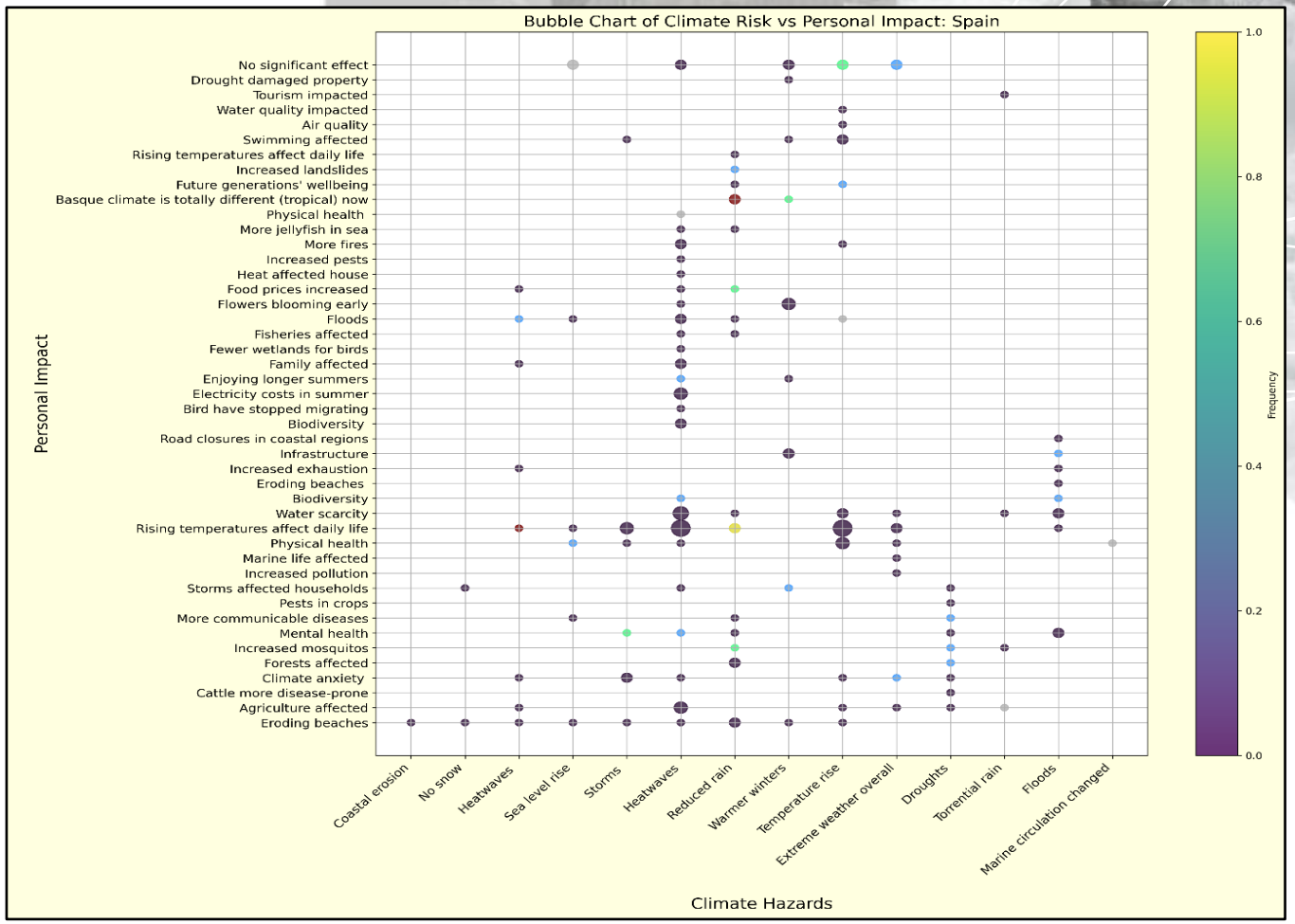
Public Perceptions of Climate Risks, Vulnerability, and Adaptation Strategies



170 participants surveyed across Sligo County (Ireland) and Basque Country (Spain) to map most common climate hazards and personal impacts.



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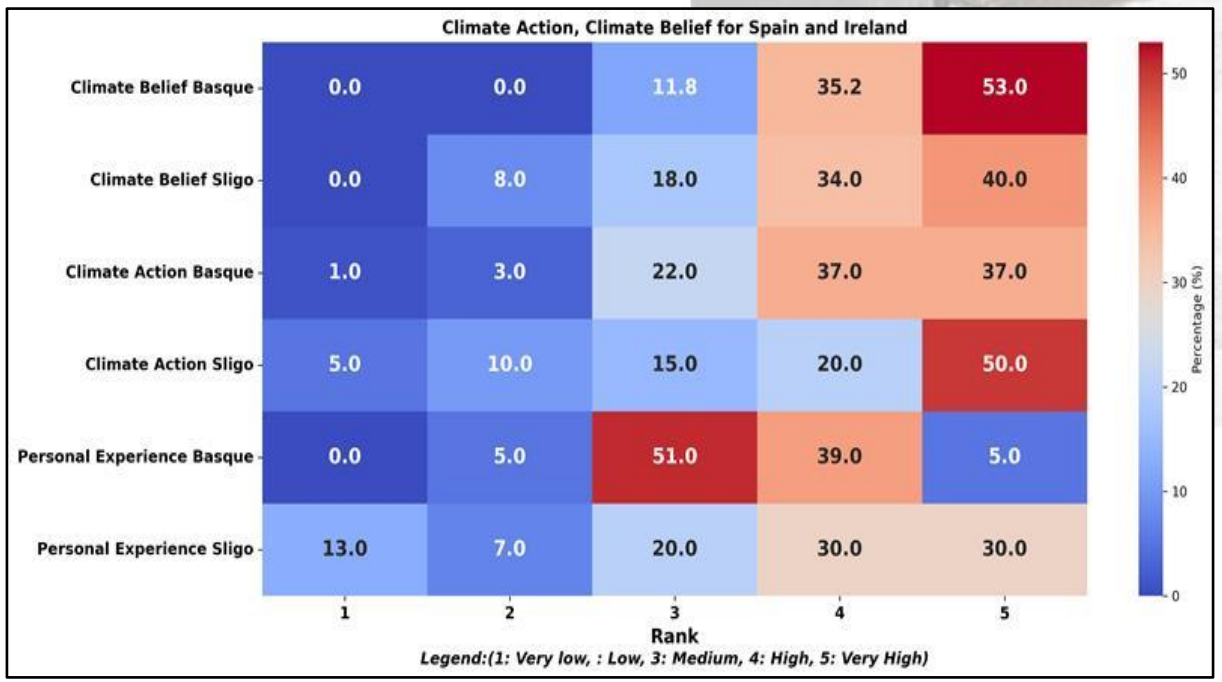
Increasing evidence of belief in climate change and personal experience of climate hazards, fuelling willingness to engage in climate action, which is hindered by lack of effective citizen engagement policies.



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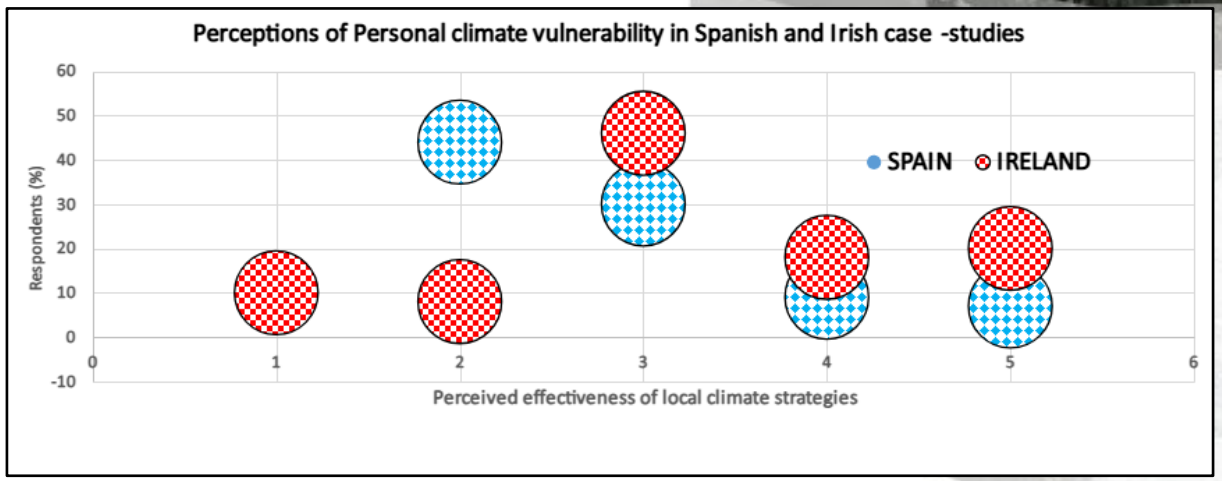
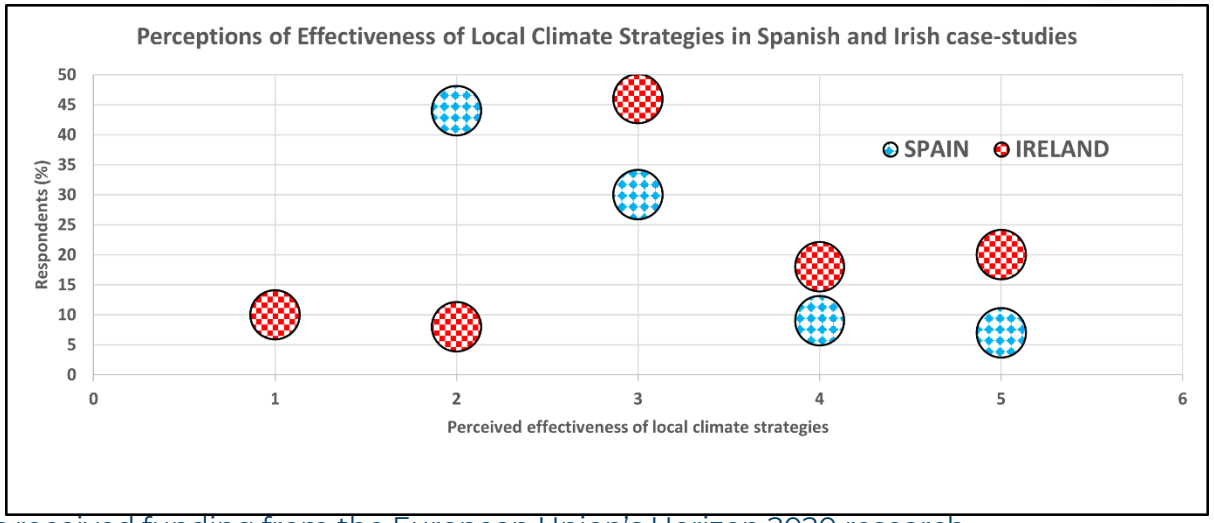
80% population believes local climate strategies are not effective, and 40% population feels climate vulnerable.





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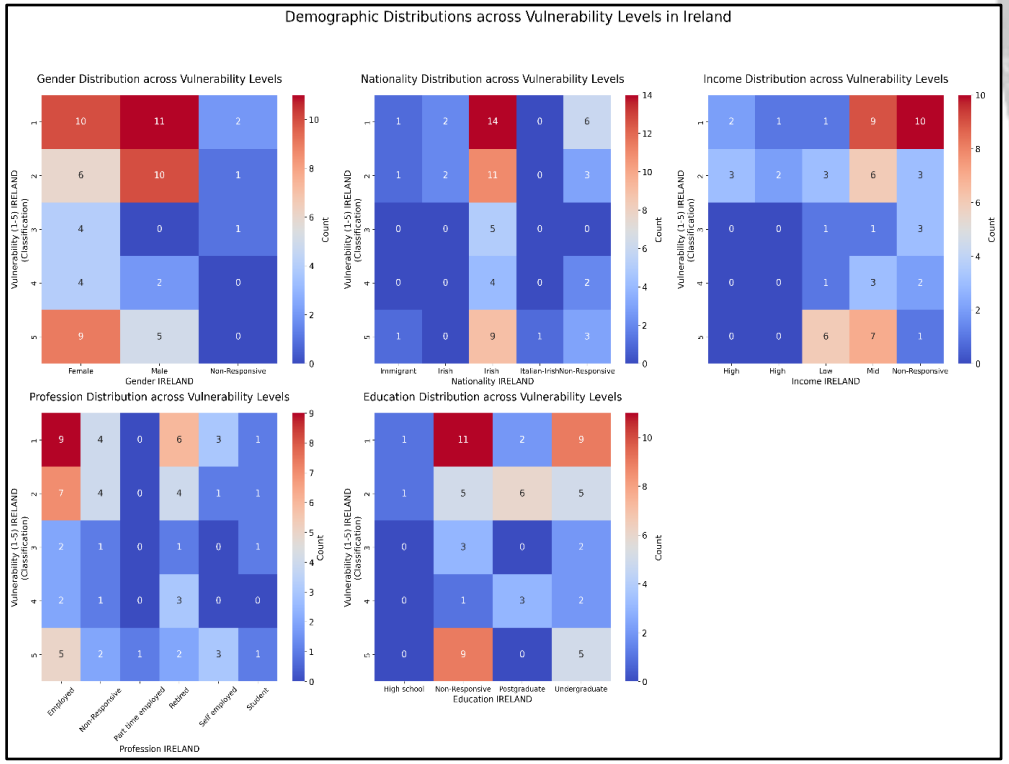
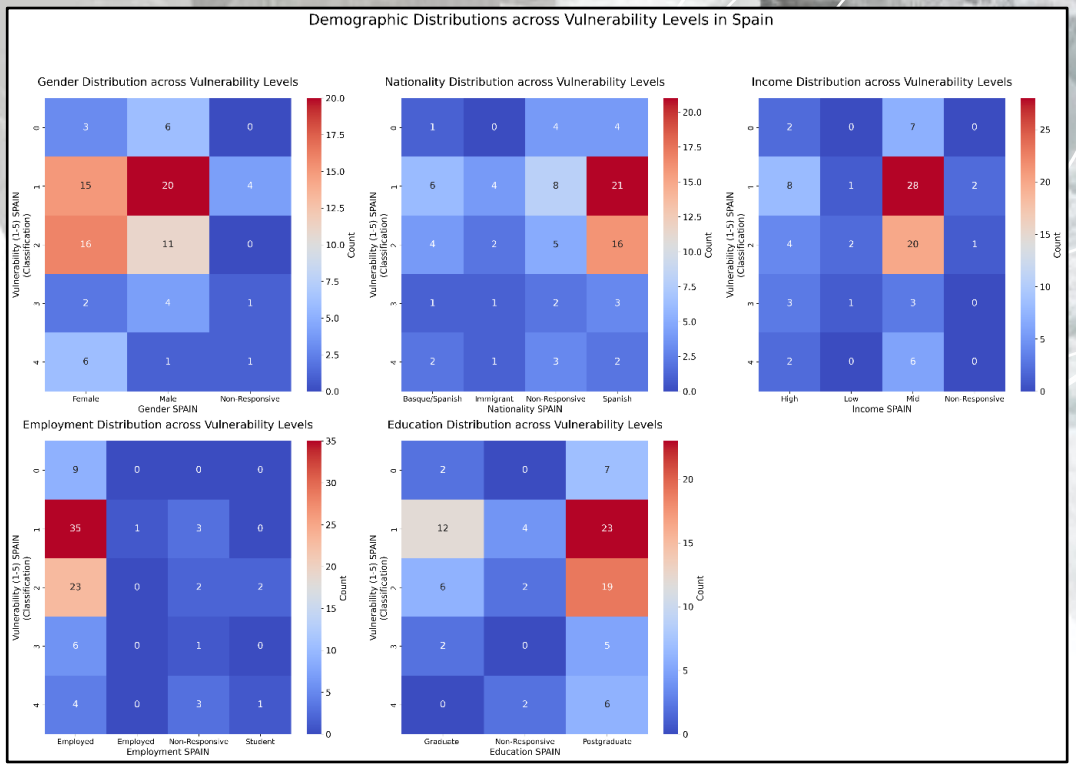
Surveys indicated that low-income groups, women, senior citizens, immigrants, and less educated individuals feel more climate vulnerable; indicating the need for targeted interventions.





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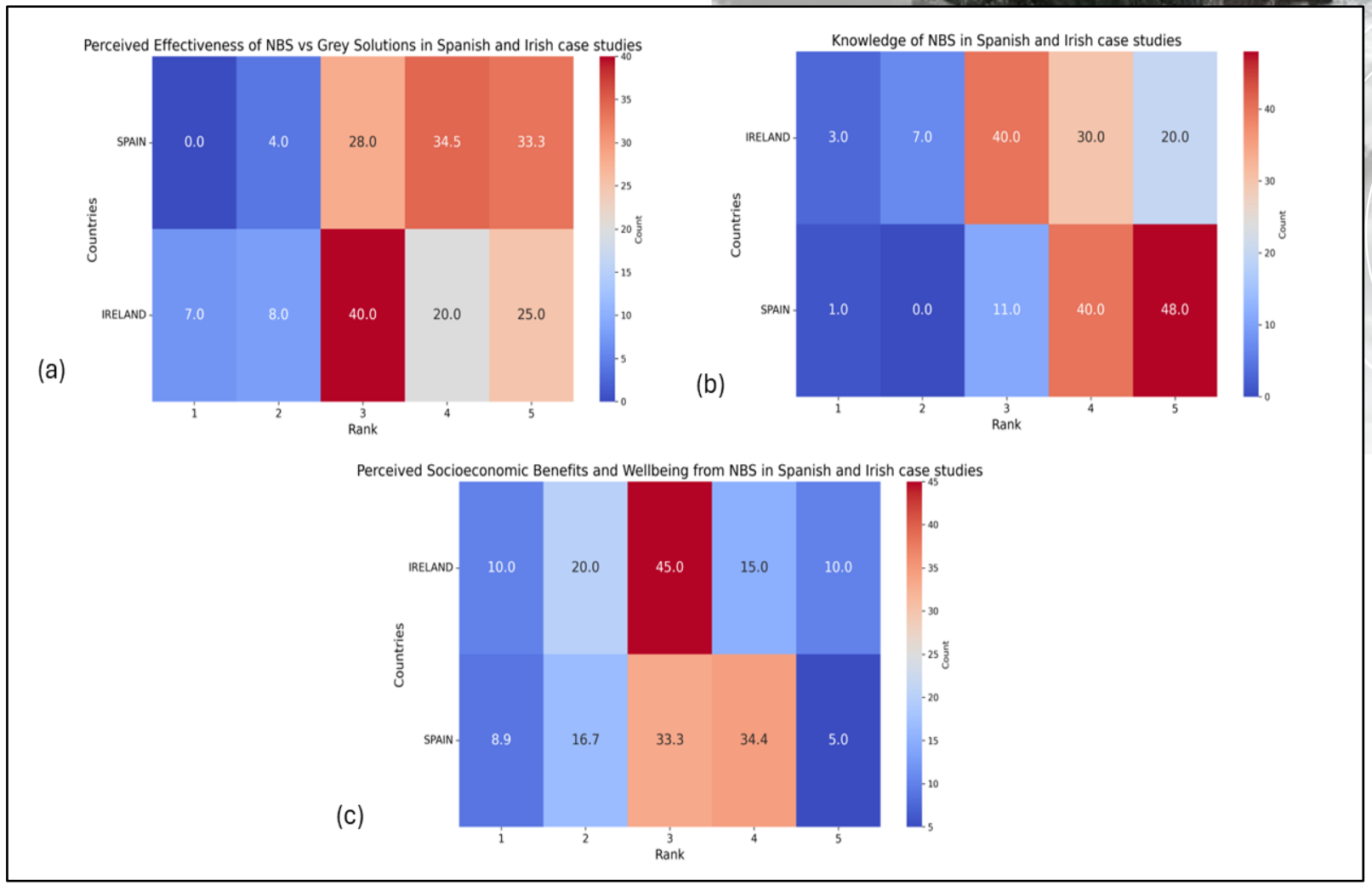
Perceived Effectiveness of NBS compared to grey solutions was very high; socioeconomic benefits of NBS were considered high, as well as NBS' ability to improve community wellbeing.



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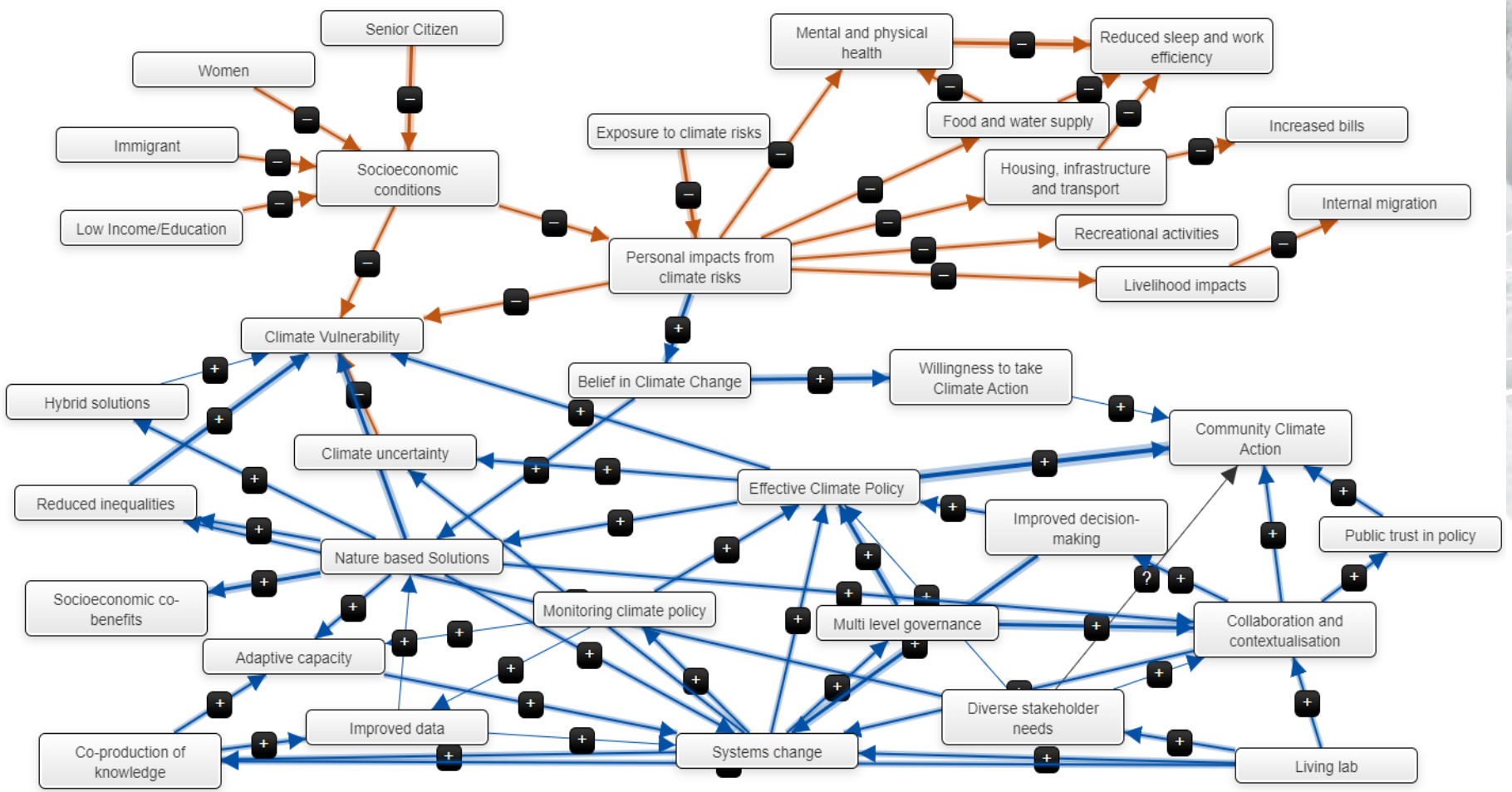
Fuzzy Cognitive Maps: Four Key Types of Variables Identified for Systems Changes and Decision Support including Socioeconomic Variables, Governance Variables, Behavioural Variables and Research Variables.



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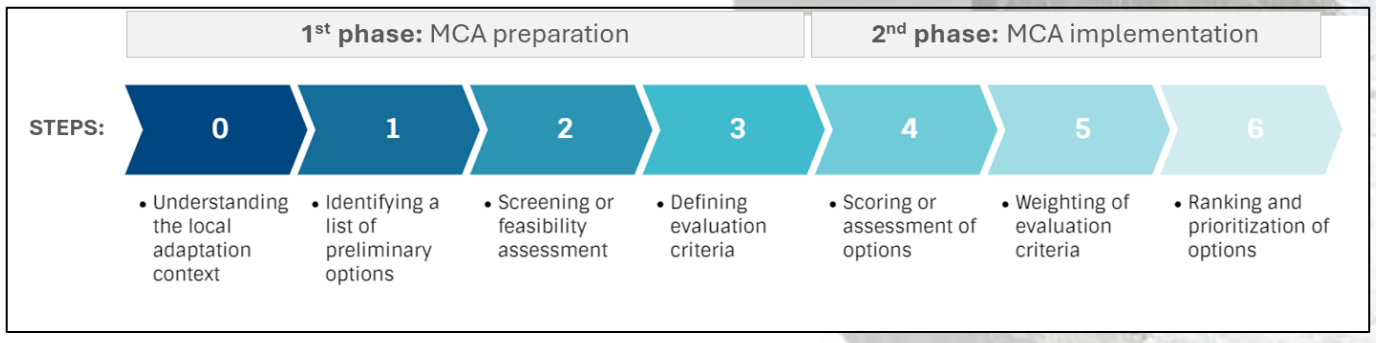
Multi-Criteria Analysis of EBA strategies for coastal hazard risk reduction: Methodology & Study Areas



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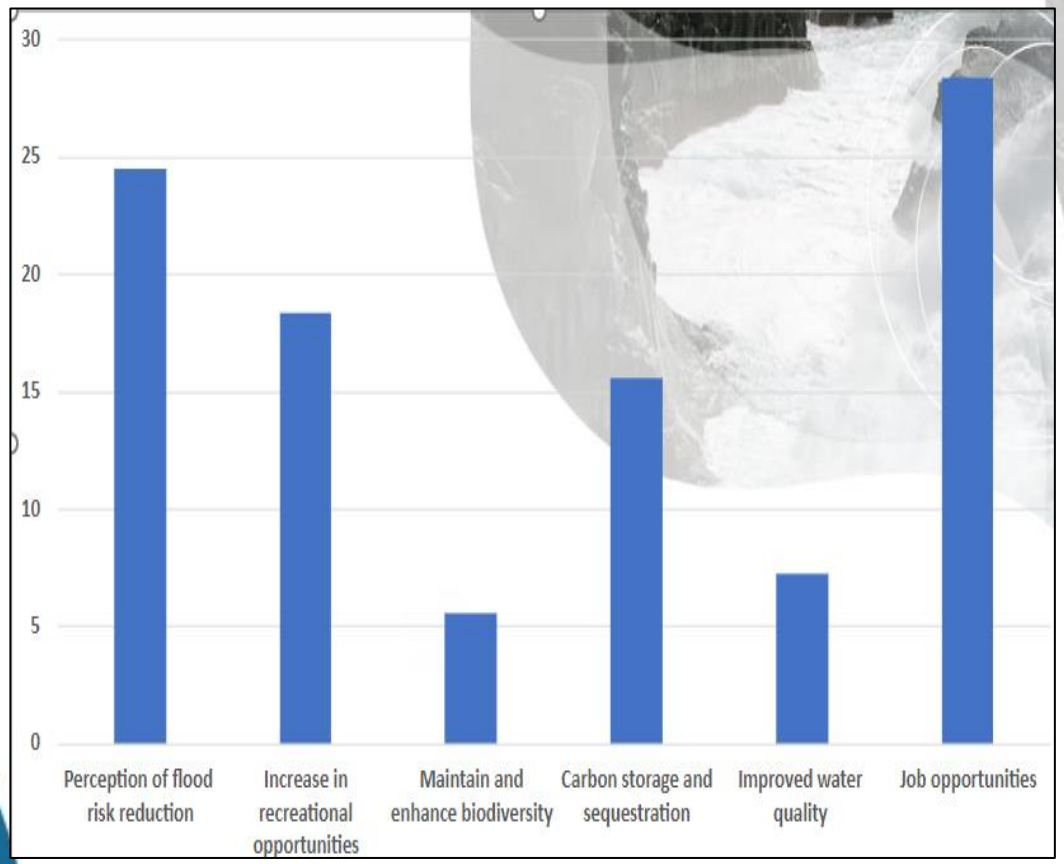
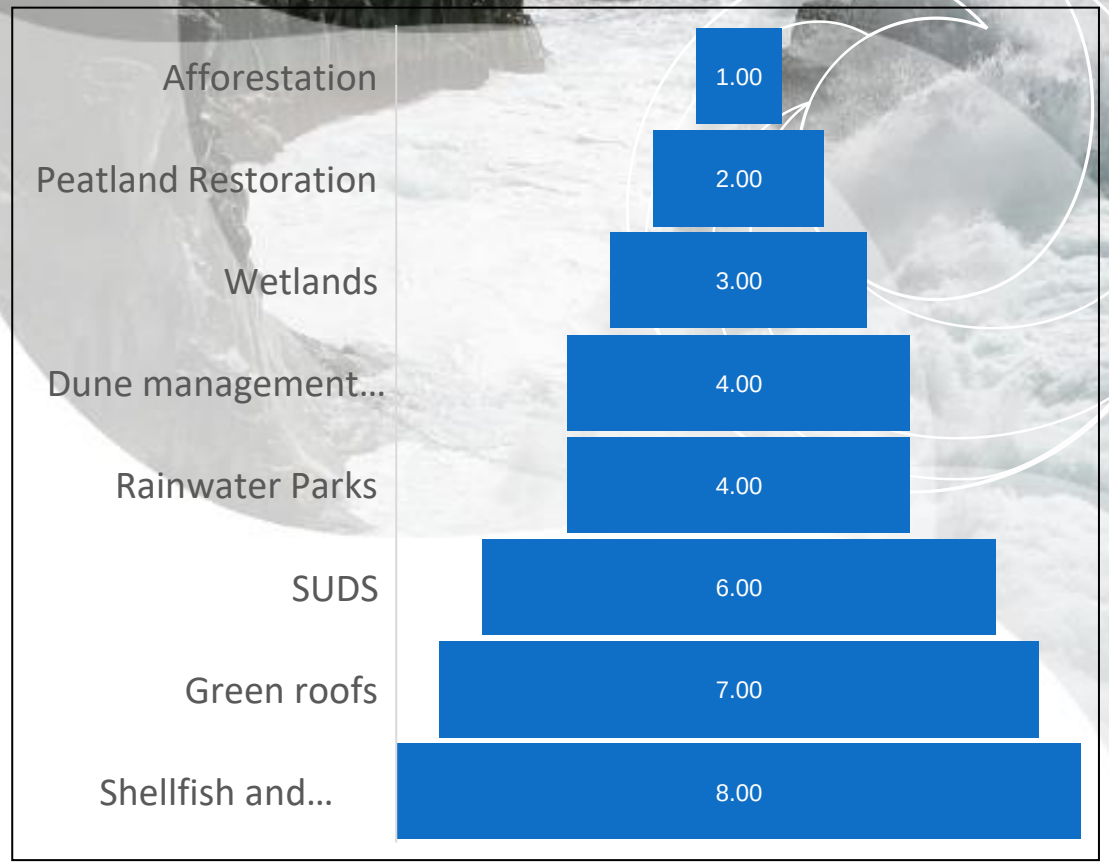
Results for Sligo County: 8 EBAs ranked based on Feasibility Criteria and CO-BENEFITS





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Results from across Europe:
DECISION SUPPORT FRAMEWORK FOR EBA SELECTION

CCLL	Study area	Hazard(s)	Top-3 prioritised EBAs
Oarsoaldea (Spain)	Specific location (floodplains of the Oiartzun river basin; Pasaia bay/port and its surrounding urban areas; old centres of the four municipalities)	Inland flooding, coastal flooding, landslide, heatwaves	1st Green spaces 2nd Planting of trees 3rd Riparian reforestation
Piran (Slovenia)	Specific location (historic town of Piran at top of the peninsula)	Coastal flooding, droughts, heatwaves	1st Historic wells and water reservoirs 2nd Sustainable permeable pavements 3rd Green spaces
Vilanova i la Geltrú (Spain)	Specific location (Intermittent river "Torrent de la Piera")	Inland flooding	1st Combination of measures (renaturalisation, restitution of the original riverbed depth, increase in riverbank height) 2nd Renaturalisation and stabilisation of riverbed and slopes 3rd Restitution of the original riverbed depth
Massa (Italy)	Specific location ("Marina di Massa")	Coastal flooding, storm surge, coastal erosion	1st Floodplain enlargement 2nd Riparian reforestation 3rd High water channel
Dublin (Ireland)	Specific location (Dun Laoghaire decarbonization zone)	Coastal flooding, storm surge, coastal erosion	1st Floodable Park 2nd Saltmarsh restoration 3rd Green infrastructure
Oeiras (Portugal)	Specific location ("Eixo Verde Azul" – The Green and Blue Axis, in the Jamor River)	Inland flooding	1st Planting indigenous vegetation 2nd Floodplain enlargement 3rd Maintenance of the river network
Gdansk (Poland)	Specific location (Wrzeszcz District; old historic central area; Orunia district)	Inland flooding, storm surge	1st Water parks and retention ponds 2nd Green spaces 3rd Planting of trees
Samsun (Turkey)	Specific location (Kizilirmak Delta in the Black Sea coast)	Coastal flooding and coastal erosion	1st Floodplain enlargement 2nd Bank restoration/naturalisation 3rd Seagrass meadow introduction/restoration
Benidorm (Spain)	**Various sites in the municipality near intermittent rivers, beaches, and urbanizations**	**Coastal flooding, inland flooding, coastal erosion**	**1st Floodable Park** **2nd Riparian reforestation** **3rd Planting of trees**

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Cost-Benefit Analysis of Sand Dune Management to Prevent Coastal Erosion in Sligo County

- **STEP I:** Determined area gain/loss and future projections of shoreline erosion on three beaches.
- **STEP II:** Built ecological maps of three beach-sites through fieldwork and local reports.
- **STEP III:** Gathered data on costs of dune management and monetary benefits from dune management (i.e. coastal protection, carbon capture, recreational value of beach and dune systems).

Analysed the cost-benefit ratio, and found the benefits from management to be nearly 7 TIMES HIGHER than the costs.

Ecosystem Services	Value per ES (euros/ m^2)	Cost of dune management (euros/m^2)	Comparing Benefits vs Costs (ratio)
Coastal Protection	9.76	1.80	5.42
Carbon Capture	0.011		0.006
Recreation	2.13		1.2

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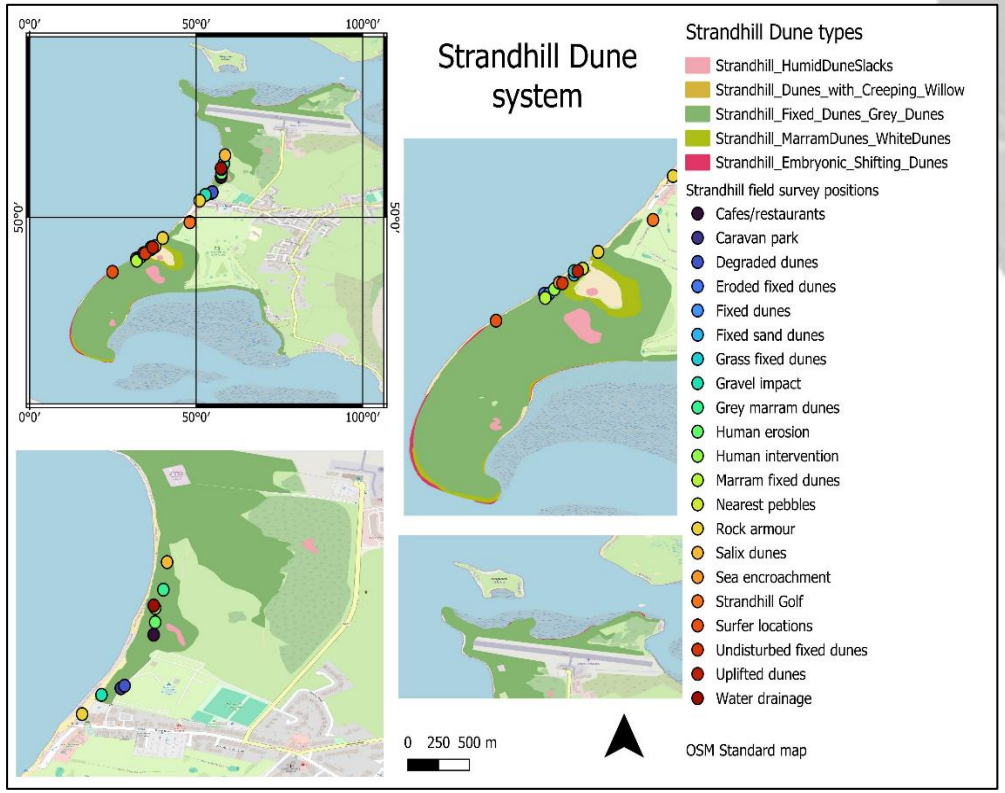
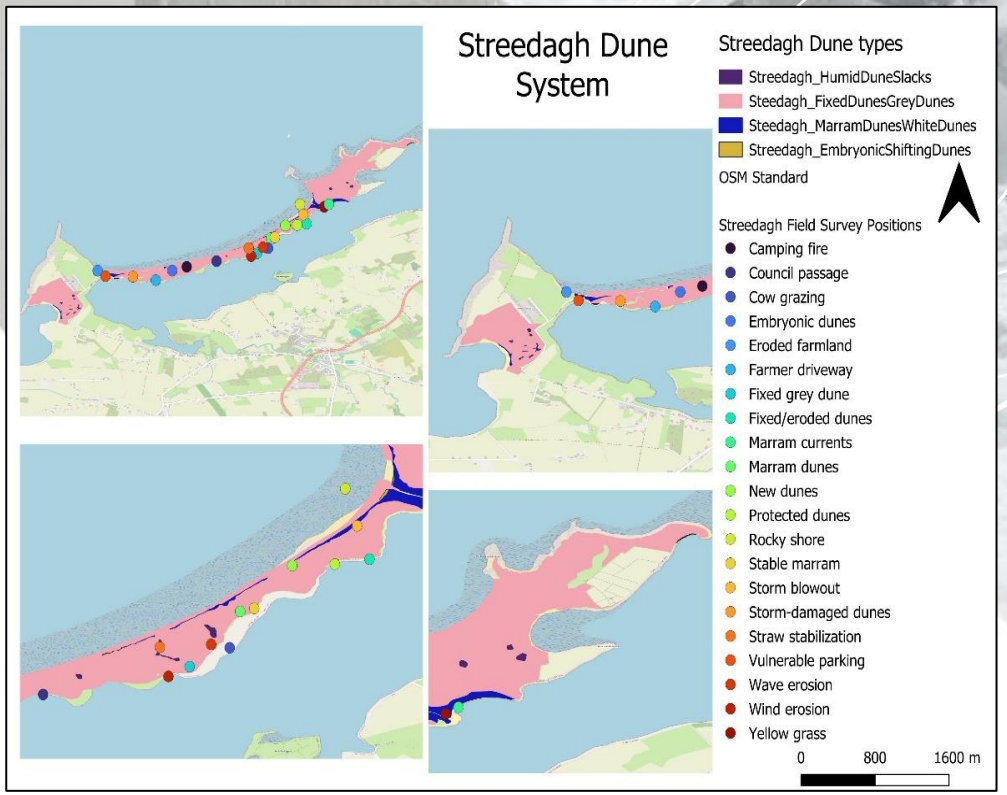
Ecological Mapping of Beach Sites





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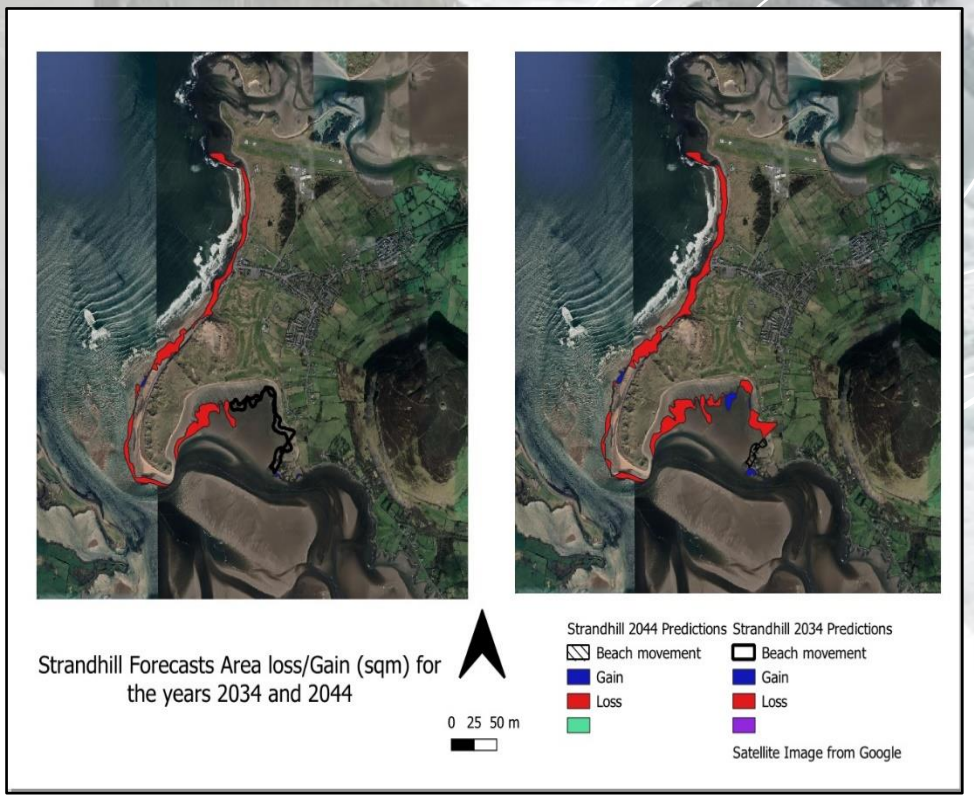
Strandhill Beach Area Loss Mapping: Current & Future Scenario

2003-2024: *-691,957m2;*
2024-2044: *-547,412m2*

Results indicate that Strandhill could lose most of its beach area by 2044, without any interventions, and is the most eroded beach in our case study.



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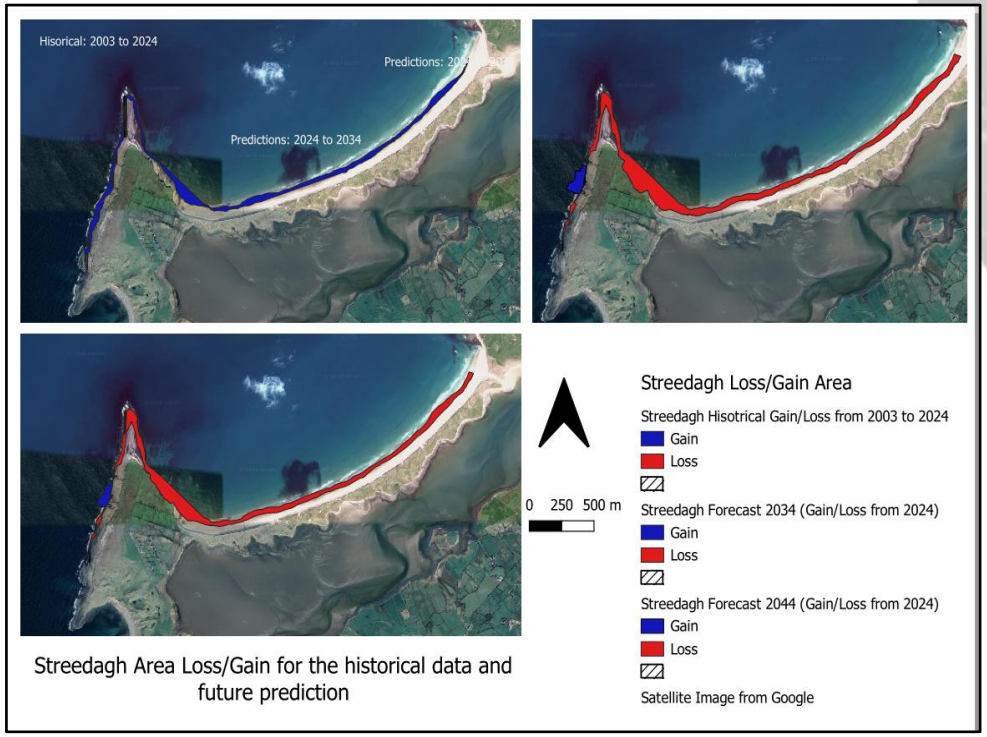
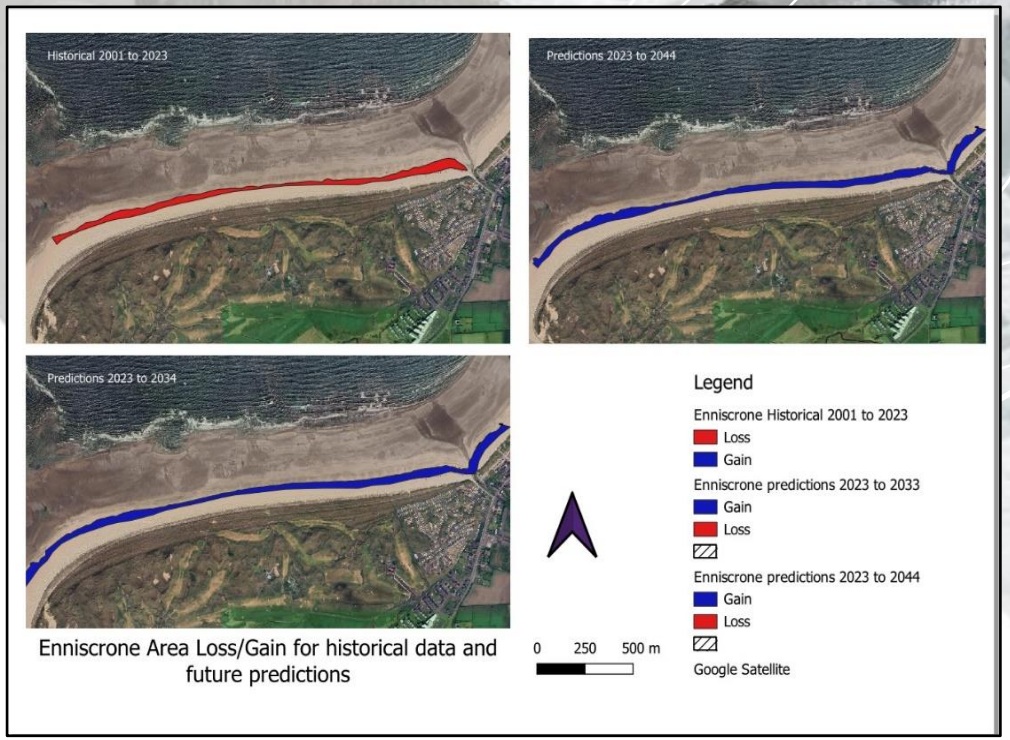
Streedagh and Enniscrone Beaches Area Change Map: Current & Future Scenario

Results indicate that while Enniscrone would have accretion, as a result of a healthy dune system, Streedagh beach could experience significant erosion.



Streedagh Area Loss/Gain for the historical data and future prediction



Enniscrone Area Loss/Gain for historical data and future predictions

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Monetary Values of Key Ecosystem Services from Sand Dune Management

Coastal Protection

Beach site	Historical area change (m^2; 2003-2024)	Future area change (m^2; 2024-2024)	Value change (euros; 2003-2024)	Value change (euros; 2024-2044)	Value change based on 2024 present values, using a 3% discount rate (euros; 2024-2044)
Strandhill	-691,957	-547,412	-6,753,500	-5,342,741	-2,968,189
Streedagh	+124,816	-318,566	+1,218,214	-3,109,204	-1,727,835
Enniscrone	**-56,895**	**+173,027**	**-555,295**	**+1,688,743**	**+938,190**

Carbon Capture

Beach site	Dune area (2024; m^2)	Value (euros; 2024)	Dune area change (m^2; 2024-2044)	Value change (euros; 2024-2044)	Value change based on 2024 present values, using a 3% discount rate (euros; 2024-2044)
Strandhill	132,000	1,465	-105,600	-1,161	-627
Streedagh	160,000	1,760	-92,800	-1,020	-563
Enniscrone	**300,000**	**3,300**	**+51,000**	**+561**	**+306**

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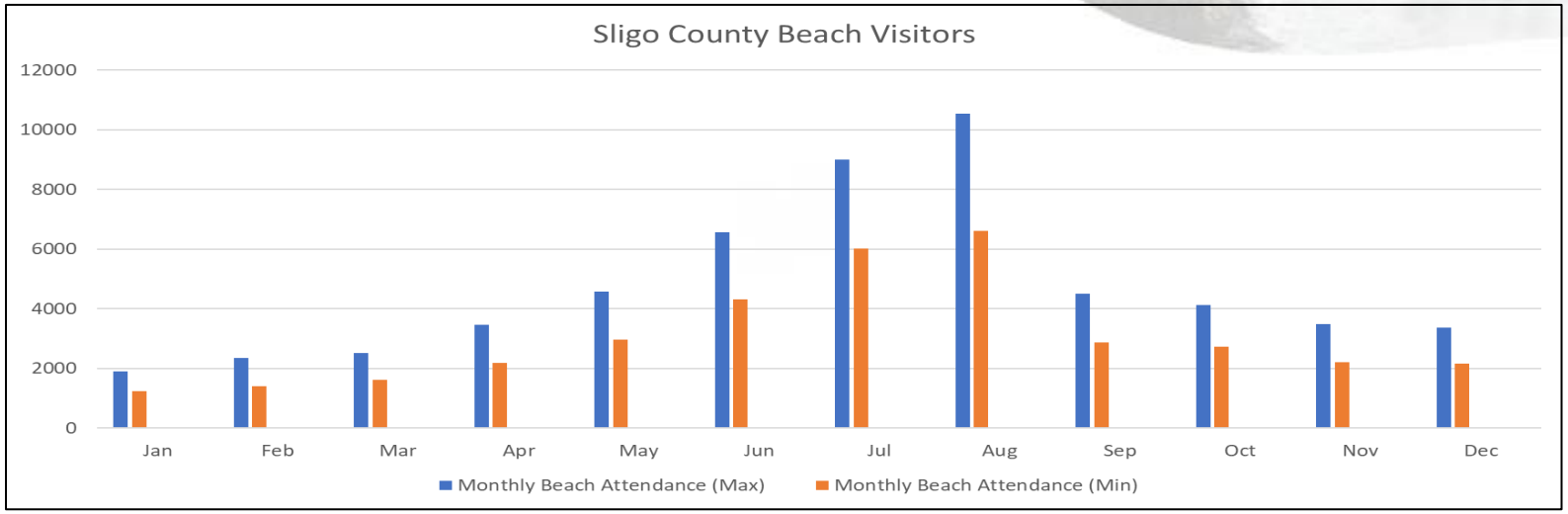
Monetary Values of Key Ecosystem Services from Sand Dune Management

Recreation

Beach site	Actual visitors/year	Actual value/year (euros)	Potential visitors at any given time	Potential value at any given time (euros)	Actual visitors (2024-2044)	Actual value with DR of 3% (euros; 2024-2044)	Changes in visitors/year (2024-2044)
Strandhill	72,660-112,650	1,743,840-2,703,600	62,857	1,508,568	-74,292	-960,005	NA
Streedagh	21,798-33,795	523,512-811,080	22,182	532,368	-16,146	-210,419	-4,447
Enniscrone	43,596-67,590	1,046,304-1,622,610	142,987	3,431,668	+9,465	+122,309	+975

Beach Visitor Numbers (Average, Per Beach)



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Examples of Policy Recommendations from Decision Support Tools in Living Labs

- Despite high belief in climate change and increasing willingness to engage in climate action, **majority of the public isn't mobilised** to engage with climate strategies, limiting their contribution.
- **Targeted interventions** aiming to improve the adaptive capacity in vulnerable groups (i.e. immigrants, women, senior citizens, children, low-income groups, low-educated groups, etc) are needed even in richer parts of Europe.
- Measures like **nature-based measures, communication campaigns, behavioural changes, early warning systems, multi-level governance, decision-support,** were most successful in improving adaptive capacity.
- Inefficient stakeholder engagement can also lead to maladaptation. **When local needs are not prioritised**, adaptation efforts can lead to gentrification, displacement of locals, support greenwashing of corporate actions, etc.
- Residents are increasingly willing to pay for protection of coastal ecosystems and improvement of ecosystem services like coastal protection, recreation, biodiversity, archaeological heritage, etc; however, landowners often may not be on board. **Better stakeholder engagement can help.**

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Examples of Policy Recommendations from Decision Support Tools in Living Labs

- **NBS implementation has been limited due to** financial constraints; lack of data on efficacy of NBS; lack of municipality willingness to try new strategies; and competition for space in dense urban areas**. Recommendations** include adapting existing infrastructure; improving understanding of local contexts; clearer guidelines on NBS implementation; improving monitoring and maintenance of NBS; improving technological capacity.
- **Improving NBS uptake in policy**: (i) incorporating NBS across policy programmes; (ii) embedding NBS in financing/regulations, (iii) generating knowledge about localised NBS, (v) supporting collaborative governance and decision-making, (vi) strengthening capacity for self-management/
- **Strategies to improve coastal management**: improving accessibility of databases on historical erosion damage and protection works; involving diverse stakeholders in decision-making; intervening with multidisciplinary solutions that provide socioeconomic co-benefits; investing in local knowledge; monitoring the effectiveness of solutions; and making evidence-based decisions.
- **Ways to ensure better stakeholder representation**: engaging a diverse range of stakeholders through targeted campaigns and facilitators; incorporation of diverse perspectives based and a mutual recognition of benefits; combining academic insights with real-world applications; building long-term relationships based in transparency and accountability, removing barriers to engagement by ensuring adequate financial support.

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Example of Living Lab Sustainability Maximising Policy Impact in Sligo, Ireland

- **Stakeholders using Results**: Cost Benefit Analysis results being used by local golf clubs, local authorities, environmental NGOs.
- **Climate Action Plan:** LL Results being included in local Sligo County Council's Climate Action Plan 2024-2029, and results submitted to SCC through policy briefs.
- **EBA/NBS implementation:** Using results of MCA/CBA exercise to implement better sand dune management in Sligo County.
- Continued **Citizen Science** activities set up through the municipality (i.e. CoastSnap, Low Cost Sensors etc).
- Continued **Stakeholder Engagement Events** and Living Lab workshops as part of other EU projects, to ensure continued co-creation of solutions.
- Widespread dissemination of open-access **Publications and Reports** to ensure continued impact of LL findings.
- **MOOCs** and online material available online for researchers, policymakers, and all.

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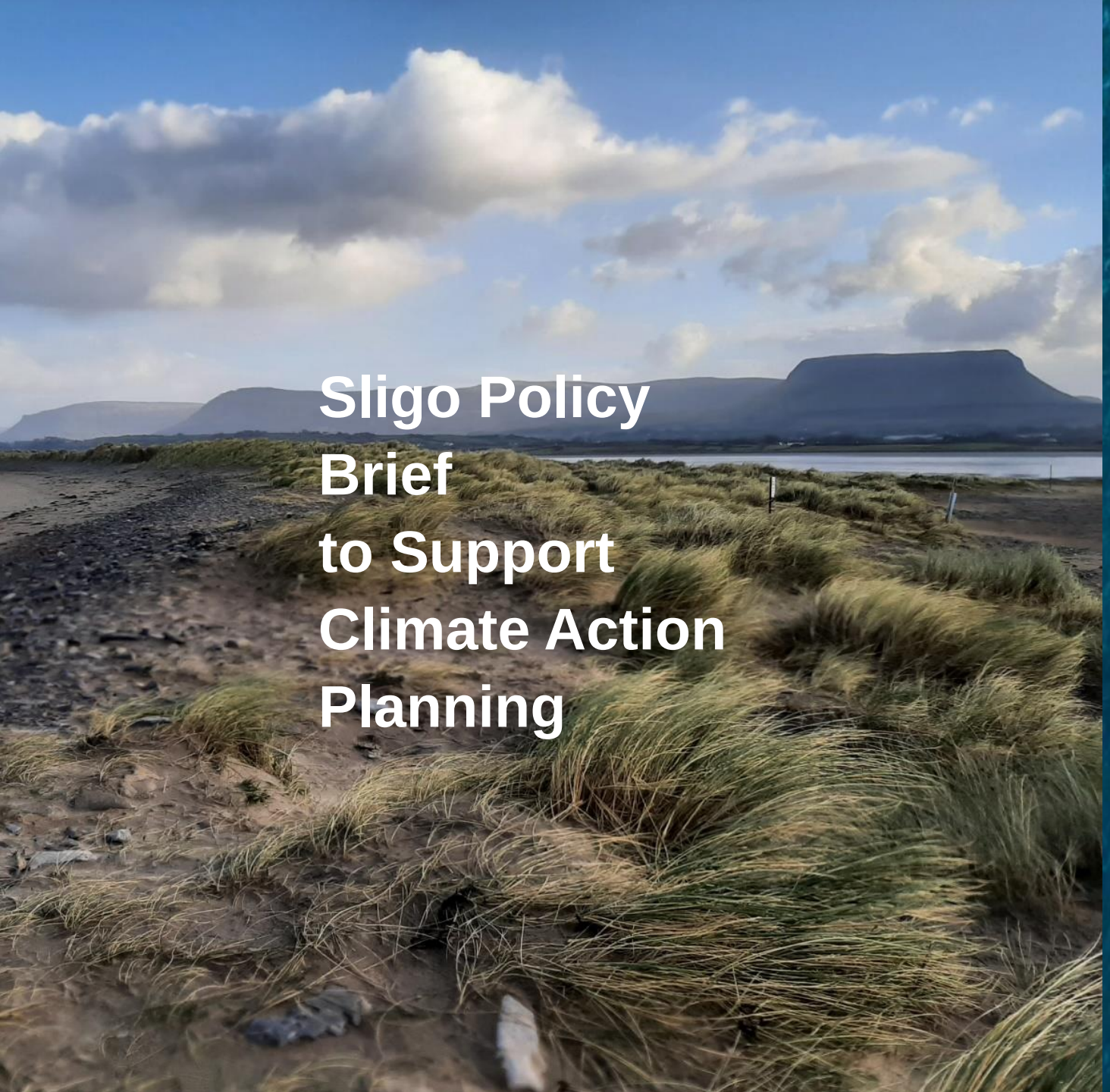

Sligo Policy Brief to Support Climate Action Planning

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POLICY BRIEF PRESENTED TO SLIGO COUNTY COUNCIL JUNE 2023 - Building Climate Resilience in Sligo County through Ecosystem-based Adaptation, Smart Technologies, and Coastal City Living Lab

SCORE ATU Sligo Team,
Smart EARTH Innovation HuB (EARTH-HB):
Earth-HB@atu.ie

When will a 2-metre rise in sea level occur, and how might we adapt?

- A 2-metre rise in sea level is almost inevitable. The uncertainty is on the timing, somewhere between one century and the next two thousand years depending onpolar ice sheet melting and which socio-economic pathway we follow. Exceeding 2meters of sea-level rise will fundamentally change European coastal zones.

- **PROTECT**, **CoCliCo** and **SCORE** have co-written a policy-brief about 2-m rise in sea level, which got presented in COP27. Find the full policy-brief: https://cloud.univ-grenoble-alpes.fr/s/J4WRBw4cbzd3biK

Hazard Maps

Within the SCORE project, a primary objective is to generate risk maps that are tailored specifically to each Coastal City Living Lab, considering their unique exposure and vulnerability to various risks. To build these tailored risk maps, our research teams have conducted extensive literature reviews, mapped the history of extreme local climate impacts, and identified key hazards associated with climate change and sea-level rise.

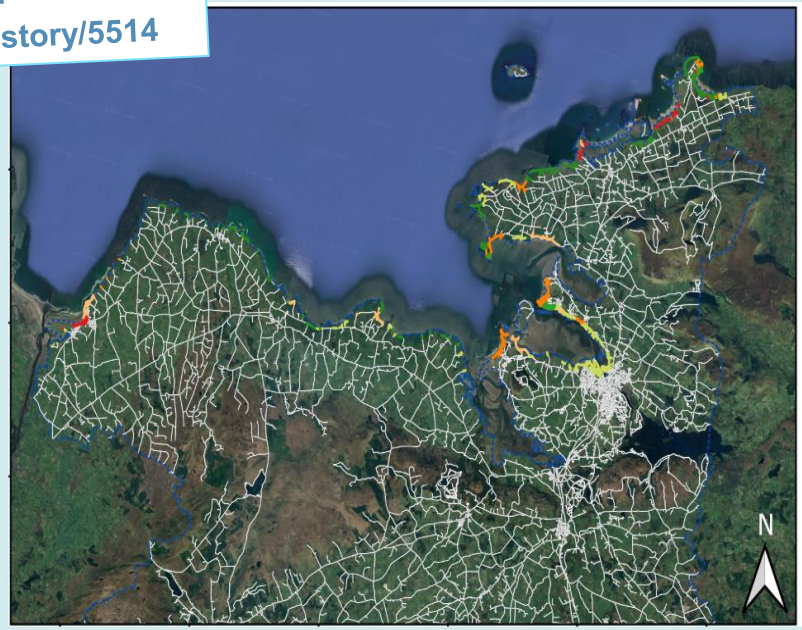
In the map on the right, you can see the key climate-related hazards in Sligo. Utilising historic data, the key hazards were identified as ***storms, coastal and land flooding, and coastal erosion.*** This work provides valuable insights and information essential to support Sligo County Council and other decision-making bodies to make informed decisions and establish effective risk mitigation strategies.

Academic Corner:

For a comprehensive overview of the methodology used to develop Sligo's high-level baseline risk map and the other 9 CCLLs, take a look at SCORE's Map and report of key climate-change hazards (D1.2) here: D1.2 Map and report of climate-change hazards.

Further, the literature review of the climate change-related extreme impacts on coastal cities can be found here: D1.1 - Literature review report.

Find more about our CCLL GeoStory at:
platform.score-eu-project.eu/catalogue/#/geostory/5514



Coastal erosion susceptibility indices for the road network in the Sligo CCLL.

This map highlights Sligo's road networks and their susceptibility to coastal erosion. The higher an area's susceptibility index (see key on the right), the higher the risk that coastal erosion can have on that area.

Susceptibility index
10
7.5
5.0
2.5
0

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Science and Engineering Expo

The Sligo CCLL team has participated in the Science and Engineering Expos annually at the Atlantic Technological University. The team was able to meet with Sligo community members of all ages: from university students to young children and their parents.

These expos are an opportunity to show how ***fun*** science can be! The Sligo CCLL team explained the different low-cost sensors and how sand dune management can be used as an ecosystem-based approach. Through hands on activities, attendees were able to learn more about the work ongoing in the Sligo CCLL.

Look up our low-cost sensor catalogue: **sensors.score-eu-project.eu**

SMARTLNB

RLS LEVEL SENSOR

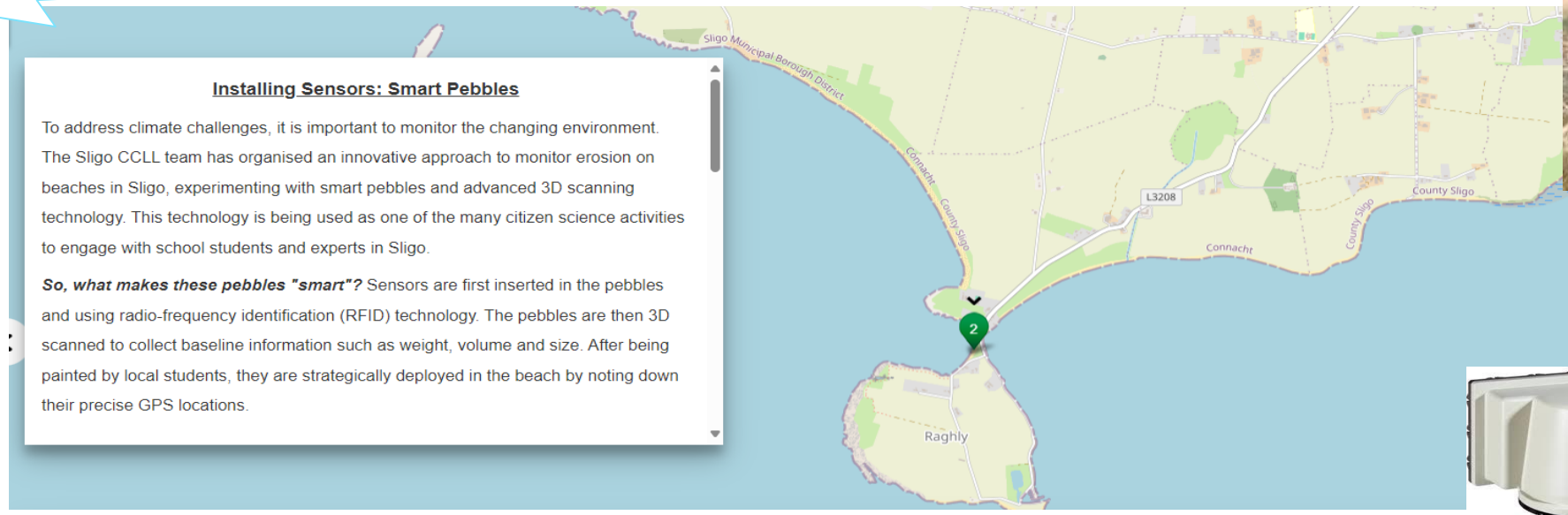
FIXED CAMERA

SMART PEBBELS

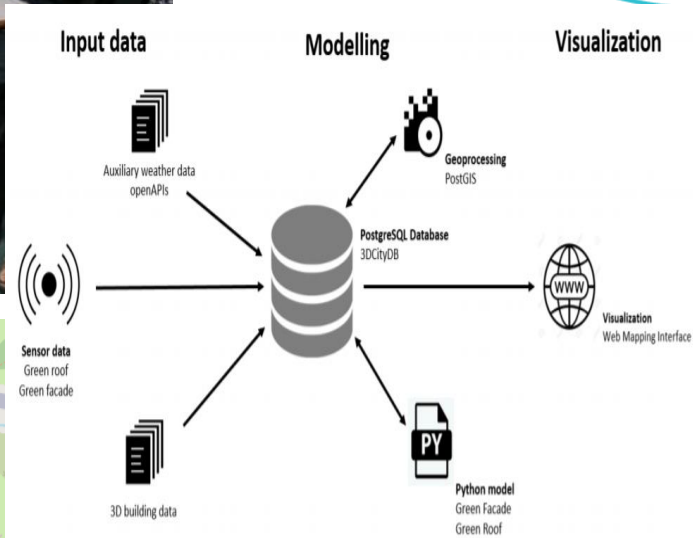
Installing Sensors: Smart Pebbles

To address climate challenges, it is important to monitor the changing environment. The Sligo CCLL team has organised an innovative approach to monitor erosion on beaches in Sligo, experimenting with smart pebbles and advanced 3D scanning technology. This technology is being used as one of the many citizen science activities to engage with school students and experts in Sligo.

So, what makes these pebbles "smart"? Sensors are first inserted in the pebbles and using radio-frequency identification (RFID) technology. The pebbles are then 3D scanned to collect baseline information such as weight, volume and size. After being painted by local students, they are strategically deployed in the beach by noting down their precise GPS locations.



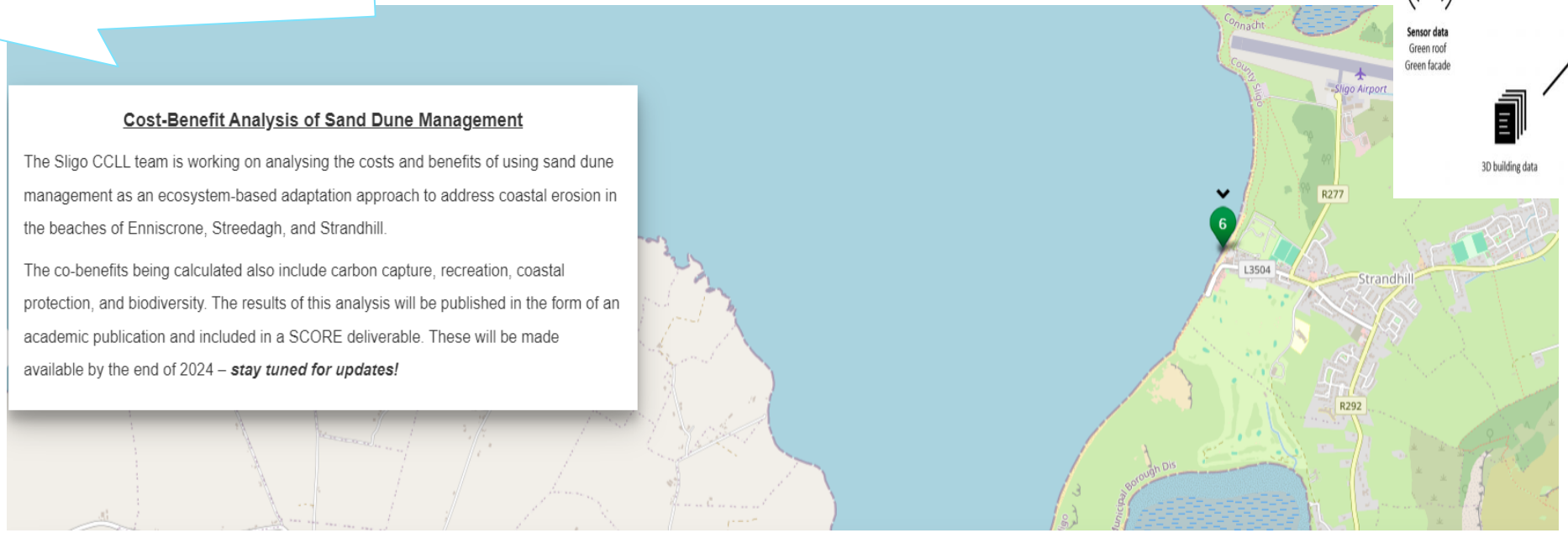
Check out our nature-based solutions catalogue:
storymaps.arcgis.com/stories/6cdbb2f6ab0744b89dffda2664dd877e



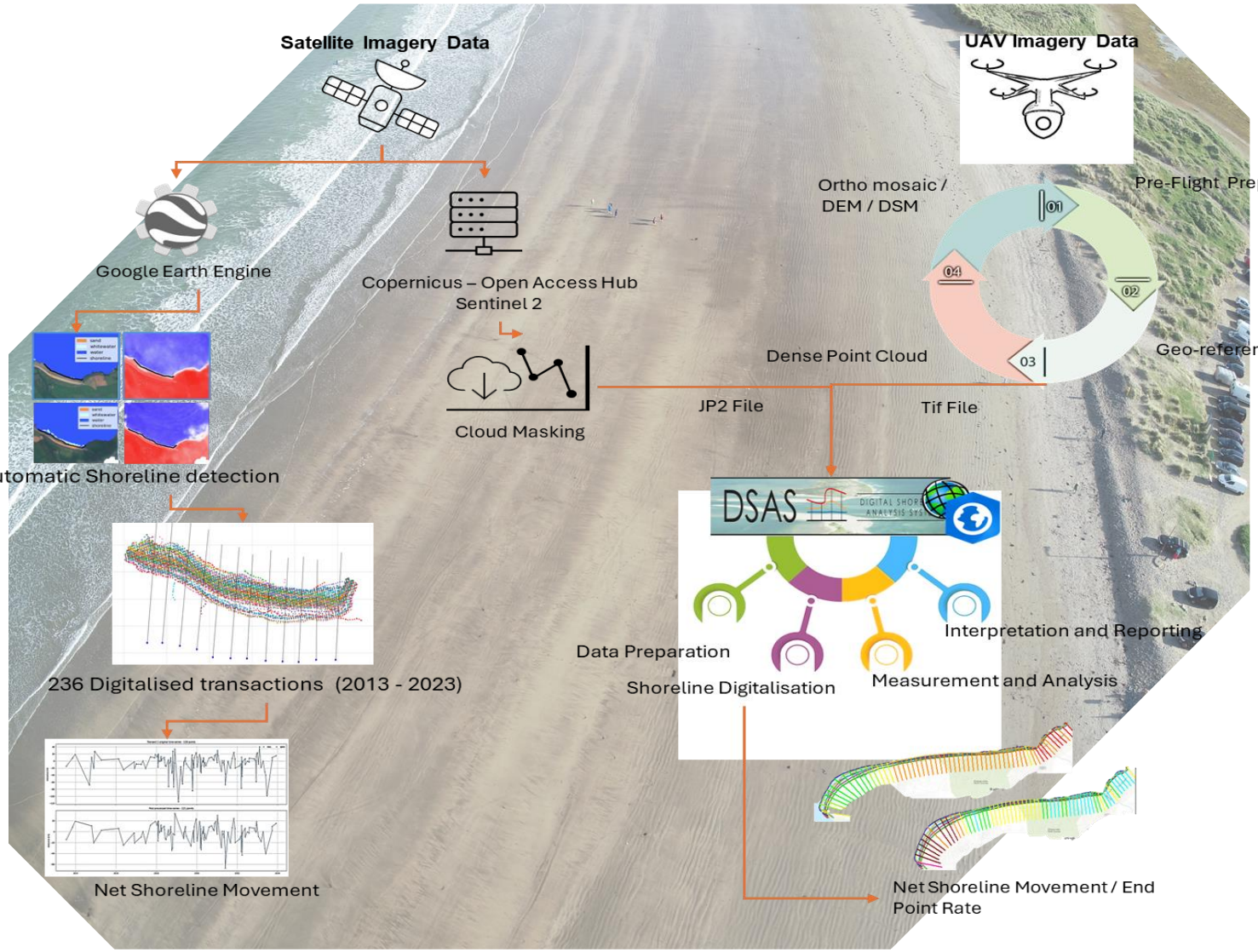
Cost-Benefit Analysis of Sand Dune Management

The Sligo CCLL team is working on analysing the costs and benefits of using sand dune management as an ecosystem-based adaptation approach to address coastal erosion in the beaches of Enniscrone, Streedagh, and Strandhill.

The co-benefits being calculated also include carbon capture, recreation, coastal protection, and biodiversity. The results of this analysis will be published in the form of an academic publication and included in a SCORE deliverable. These will be made available by the end of 2024 – ***stay tuned for updates!***



Feeding Low-Cost Real-Time Shoreline Data into Digital Twin Via Remote Sensing Technique



Remote Sensing Techniques

LiDAR Surveys
High-cost LiDAR technology provided accurate, detailed topographic data to validate the remote sensing findings.

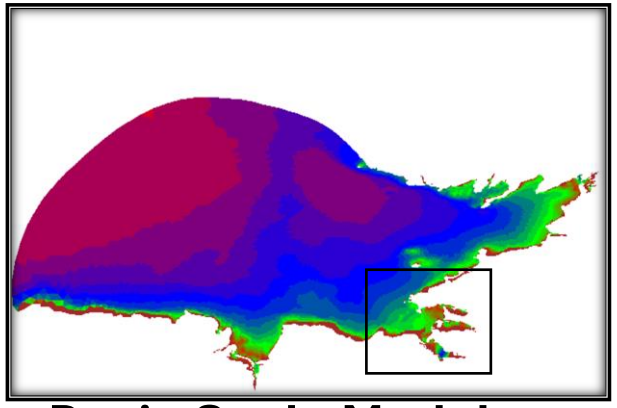
Drone Surveys
Standard camera drones were used as a low-cost alternative to capture aerial imagery and supplement the satellite data.

Integrative Approach
By combining multiple remote sensing techniques, the study was able to achieve a comprehensive assessment of the coastal environment.

As part of SCORE, we investigated shoreline changes on three beaches in the northwest of Ireland using satellite imagery, UAV drone data, and innovative data analysis tools. The aim is to develop a comprehensive understanding of shoreline dynamics

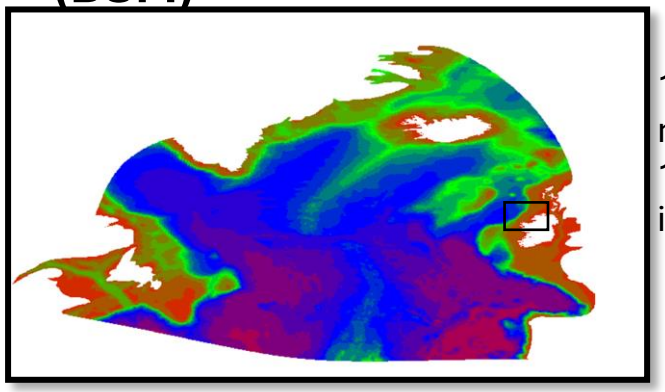
Modelling of storm surges in the Northwest of Ireland

Limited Area Model (LAM)



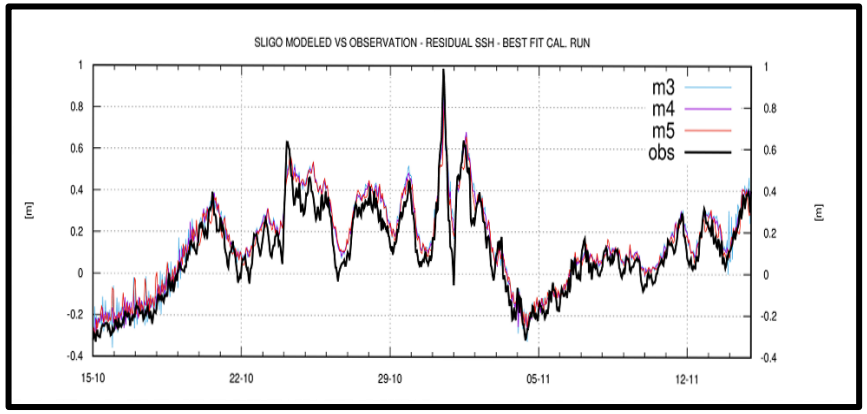
120299 triangular elements and 63016 nodes. The resolution at the coastline in the area of interest is 50 m and varies to 2 km offshore.

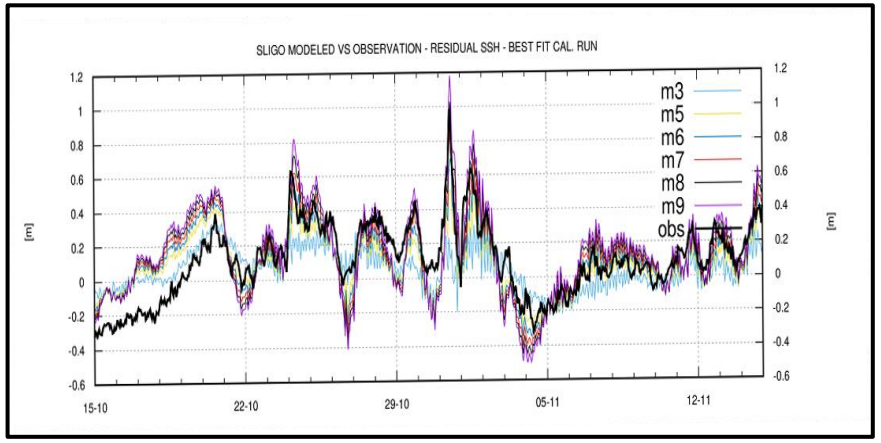
Basin Scale Model (BSM)



180158 elements and 92708 nodes The resolution varies from 100-500m in the region of interest up to 20 km off-shore.

Validation of Surge from the model with Observations

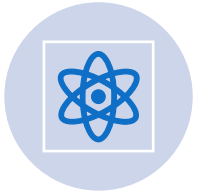




LAM will be used for storm surge forecasting and these forecasts validated with low-cost water level sensors

BSM is used for future projections of storm surges in the northwest coast , and tides, mean sea level will be added linearly for total water level projections

Conclusions on the approach for Climate Resilience



Systematic co-design and co-creation Living Lab (CCLL) infrastructure involving multiple stakeholders and supported by novel digital technologies

Accurate localised projections of climate change parameters

NbS and EBAs implementation and co-design

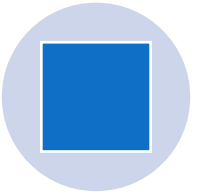
Monitoring coastal climate change and developing **early-warning systems at a local level via a network of low-cost smart sensors** deployed through citizen science activities with local coastal communities

Collecting and sharing evidence of EBA effectiveness through a high-quality **SCORE ICT Platform (SIP);**

Increasing the financial resilience of coastal cities through **financial risk assessment tools**;

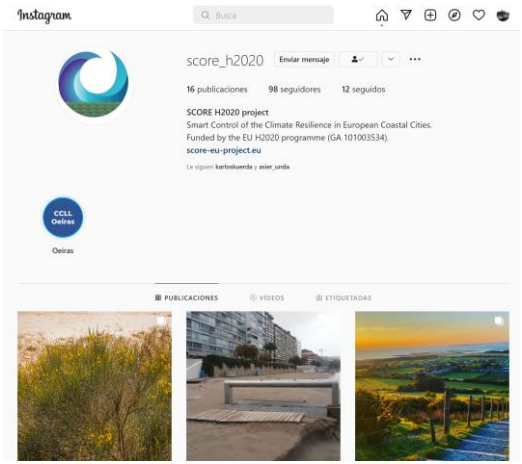
Supporting decision making in the governance of coastal cities through the development of **digital twin prototypes to analyse optimal corrective actions for sustainable**, equitable and cost-effective climate resilience.

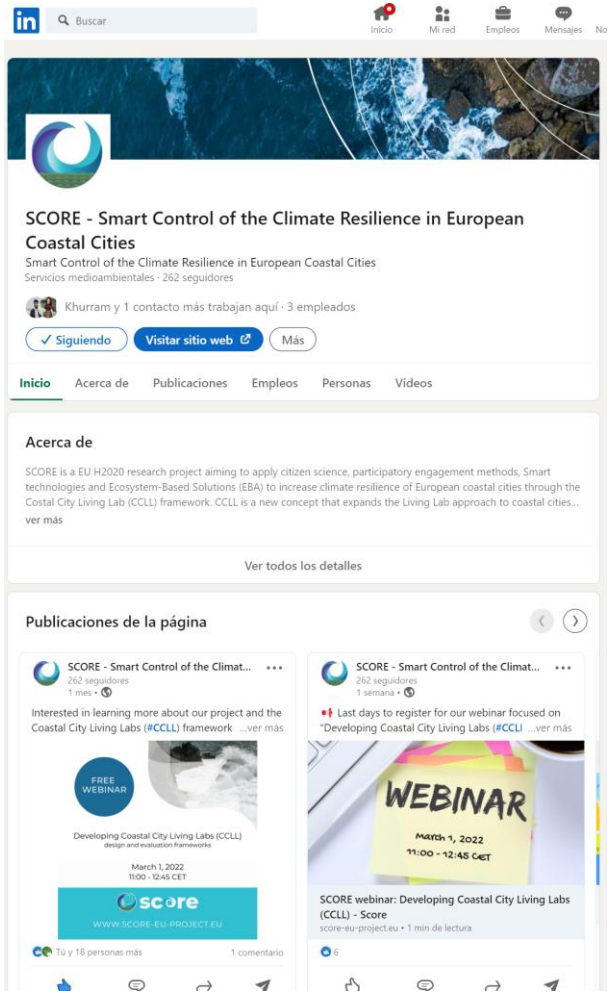
The deployment of **Systems Thinking and Social innovation** for empowering communities and co-design solutions.

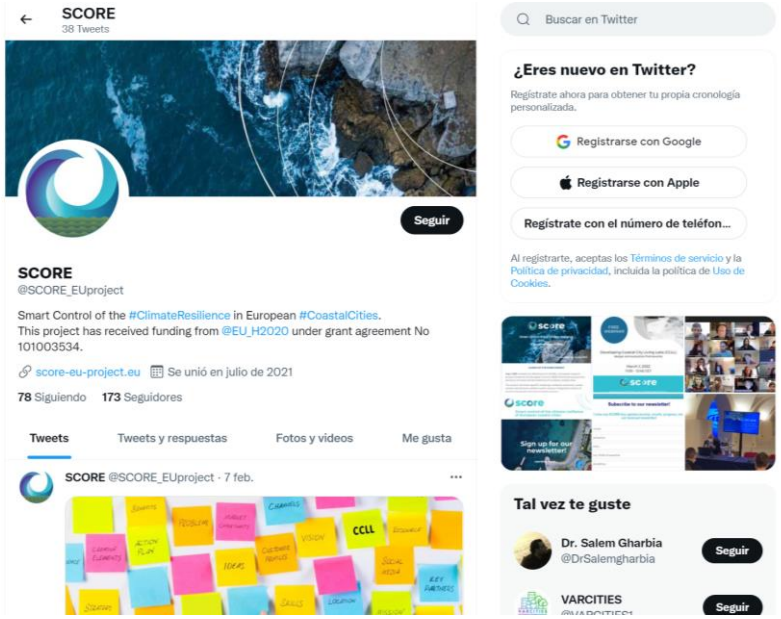


Low-cost sensors and IoT technologies implementation through **citizen science**

Do not miss a thing







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Smart Control of the Climate Resilience in European Coastal Cities

Thank you!

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