NATIONAL ASSESSMENT OF SEA LEVEL RISE VULNERABILITY OF CULTURAL HERITAGE AREAS OF TURKIYE

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The Project: Vulnerability of Coastal Cultural Heritage Areas to Sea Level Rise and Its Impacts

- 3 Year Funded Project by Scientific and Technological Research Council of Turkiye (TUBITAK)
- Multidisciplinary Team of engineers, archeologists, architects, and tourism researchers
- Objective:
  - Assess vulnerability of coastal areas with heritage sites considering sea level rise:
    - Natural and archeological sites protected by law
    - Coastal erosion, inundation, and coastal flooding due to extreme water levels
  - Prioritize the heritage sites for adaptation and planning
  - Increase climate change awareness of decision makers and experts especially teams working on-site planning, excavation schedules

Anemurium

CULTURAL HERITAGE SITES & SEA LEVEL RISE

- Impacts of Sea Level Rise on Cultural Heritage Sites
  - Inundation of the site with irreversible impact on the heritage, loss of access to the site
  - Wet-dry process becoming frequent due to coastal erosion induced by sea level rise
  - Rising of groundwater levels due to sea level rise, heritage in contact with seawater and/or salty soil
  - Unplanned unearthing of heritage due to storm surge flooding and coastal erosion induced by sea level rise
  - Erosion and subsidence failure of walls, and structures at the heritage site, damage to heritage material due to frequent interaction with seawater

Alexandria Troas

Cultural Heritage Vulnerability Assessment

Using the definitions of Day et al. (2020)

- Exposure: threats existing at the shoreline where the heritage site is located or have connection to - > Erosion, inundation, coastal flooding
  - Fuzzy Coastal Vulnerability Assessment Model (Ozyurt, 2010)
  - Physical properties & Human Intervention on the physical processes
  - Full set of IPCC SSPs
- Sensitivity: degree the system is being affected
  - Location and orientation of the cultural heritage site
  - To determine the level of interaction of the heritage site with the shoreline
- Adaptive Capacity: system capacity to withstand/recover
  - Protection Level by Law
  - External pressures other than climate change

IMPACT DECISION TABLE

	Sensitivity				
Exposure	**VL**	**L**	**M**	**H**	**VH**
VL	VL	VL	VL	L	L
L	VL	L	L	M	M
M	VL	L	M	H	H
H	L	M	M	H	VH
VH	L	M	H	VH	VH

VULNERABILITY DECISION TABLE

	Adaptive Capacity		
Impact	**High**	**Moderate**	**Low**
V. Low	VL	VL	L
Low	VL	L	M
Moderate	L	M	H
High	M	H	VH
V. High	H	VH	VH

Fuzzy Coastal Vulnerability Assessment Model (Ozyurt, 2010)

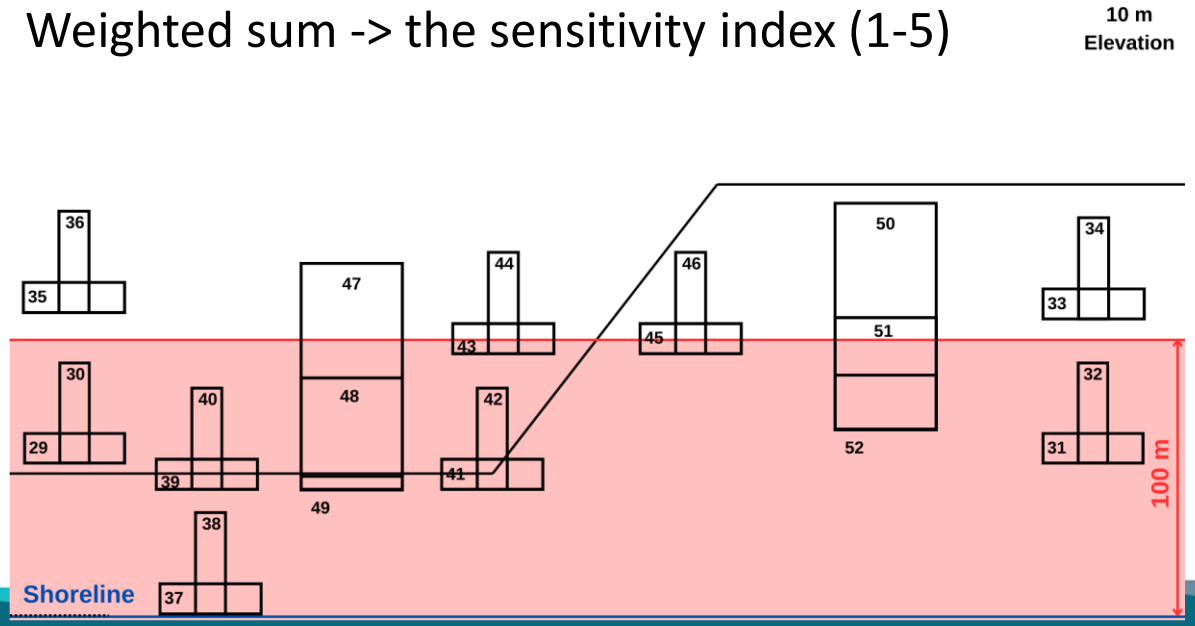
- Coastal Vulnerability Index (CVI) based tool (1-5, very low – very high)
- Impacts affected & driven by Sea Level Rise & Climate Change
  - Coastal Erosion
  - Coastal Flooding (Extreme Water Levels)
  - Inundation
  - Salinity intrusion to Rivers & Groundwater
- Global classification: micro-macro tides, global wave climate…
- Input datasets -> Whole European Coastline & Turkiye
- MATLAB & Python

Physical Parameters	Human Impact Parameters
Rate of Sea Level Rise	River Flow Regulation
Geomorphology	Engineered Frontage
Beach Slope	Natural Protection Degradation
Wave Climate	Coastal Protection Structures
Shoreline Trend	
Tides	
Extreme Water Level	

Integration of Heritage Site Characteristics

Sensitivity:

- Orientation and location of the heritage site with respect to the shoreline (Reeder-Myers 2015, Zarley et al 2016)
  - Proximity to the shoreline
  - % Area within 100 m of shoreline
  - % Area lower than 10m elevation
  - Interaction length
- Parameter weights -> AHP
- Weighted sum -> the sensitivity index (1-5)



Adaptive Capacity:

- Degree of Protection: 1st order -> higher adaptive capacity (Daire et al. 2012)
  - National and local government priority
  - Heritage management plans
  - Higher tourism value
- Urbanization: external pressure on the heritage site (Day et al. 2020)

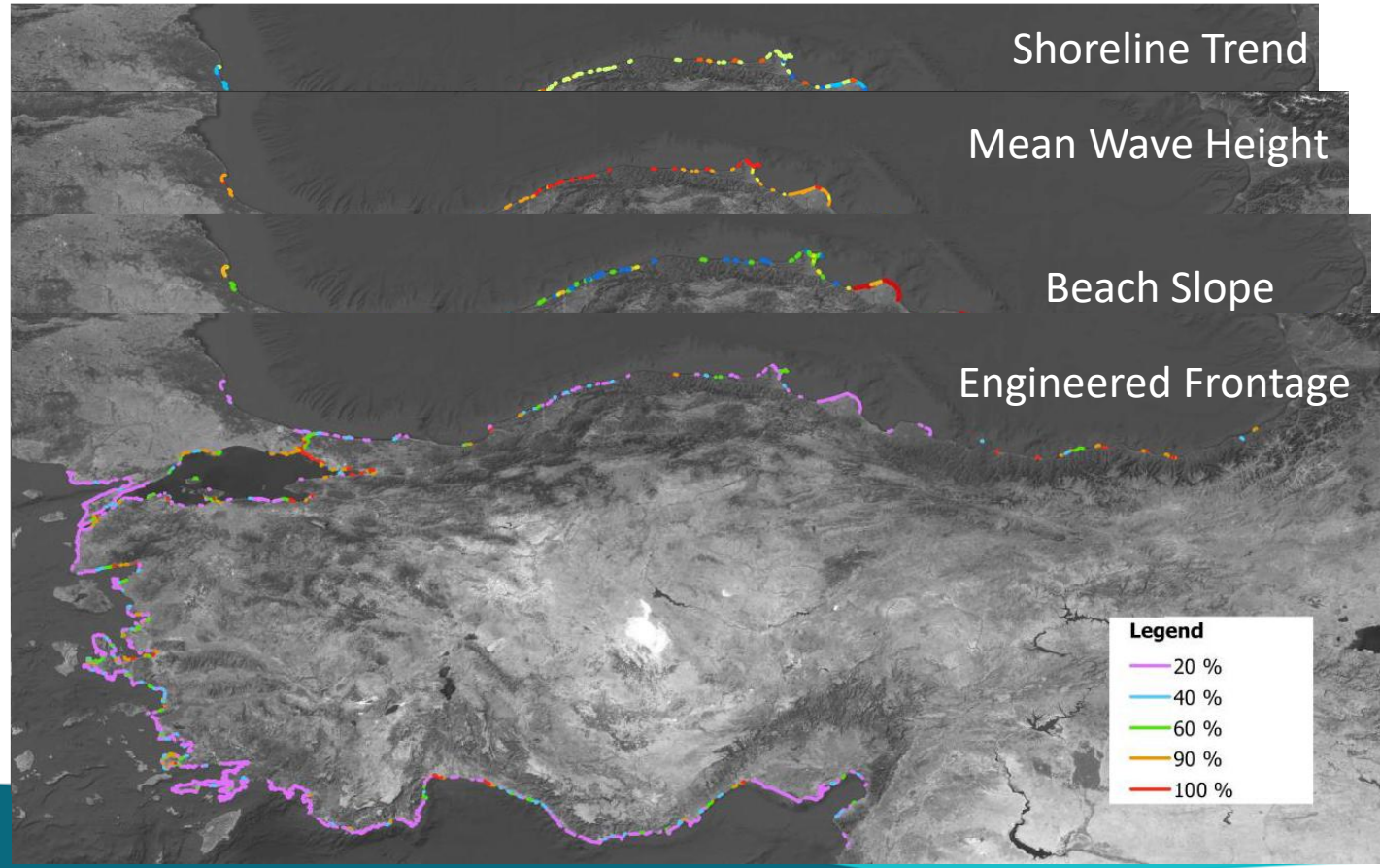
Table 1: Physical Parameters, Source and Affected Modules

Parameter Name	Affected Model Vulnerabilities	Available Sources or Database's
Rate of Sea Level Rise (RSLR)	• Inundation • Erosion • Surge	IPCC AR6 https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool IPCC AR5 https://www.spp-sealevel.de/resources/extraction-and-visualization-of-global-and-coastal-sea-level-projections-and-ocean-tides/visualization-of-global-sea-level-projections-ar5-sea-level-rise
Geomorphology	• Erosion	Global Lithology Map (Hartmann ve Moosdorf, 2012) Emodnet Coastal Type https:// emodnet.ec.europa.eu /geonetwork/srv/eng/catalog.search#/metadata/a488f13a0efb57cd5b7b3e373a55aa36fa169db5
Beach Slope	• Inundation • Erosion • Surge	Emodnet Mean DTM Dataset 2022 https://emodnet.ec.europa.eu/geoviewer/
Significant Wave Height	• Erosion	ECMWF ERA 5 Reanalysis Monthly Average Wave Heights https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview
Sediment Budget	• Erosion	Emodnet Coastal Migration https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog .search#/metadata/be6bbb6370e99abe8791eb4ee48f60bbe999964c Google Earth Images Analysis
Tidal Amplitude	• Inundation • Erosion • Surge	AVISO FES2014 database 1/16°x1/16° grid – AVISO veri bankası https://www.aviso.altimetry.fr/en/data/products/auxiliary-products/global-tide-fes.html
Extreme Water Level	• Surge	LISCOAST , Joint Research Center Dataset http://data.europa.eu/89h/a565eea4-5422-4c7d-a000-2e10ae872da7

Table 2: Human Parameters, Source and Affected Modules

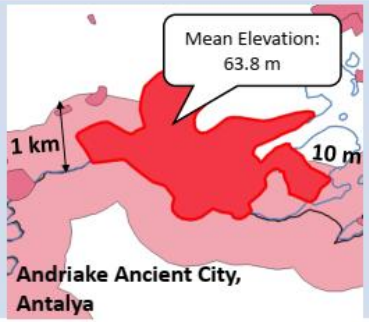
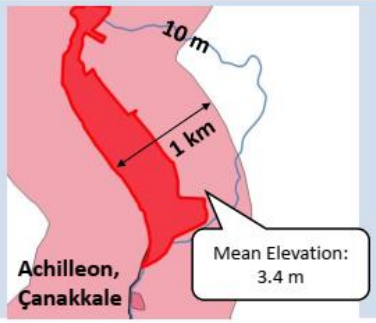
Reduction of Sediment Supply	• Erosion	Google Earth Images
River Flow Regulation	• Erosion	Turkish State Hydrological Institute (DSI) (2015) https://www.dsi.gov.tr/Sayfa/Detay/744
Engineered Frontage	• Surge • Erosion	Copernicus 2018 Coastal Land Cover https://land.copernicus.eu/local/coastal-zones/coastal-zones-2018 Google Earth Images
Natural Protection Degradation	• Inundation • Erosion • Surge	Copernicus 2012-2018 Coastal Land Cover Change https://land.copernicus.eu/local/coastal-zones/coastal-zones-change-2012-2018 Google Earth Images
Coastal Protection Structures	• Inundation • Erosion • Surge	Copernicus 2018 Coastal Land Cover https://land.copernicus.eu/local/coastal-zones/coastal-zones-2018 Google Earth Images

- Model is applied to ~ 3500 km of coastline
- Shoreline with 500 m buffer to consider the upstream/downstream influence
- Representative Data for the shoreline

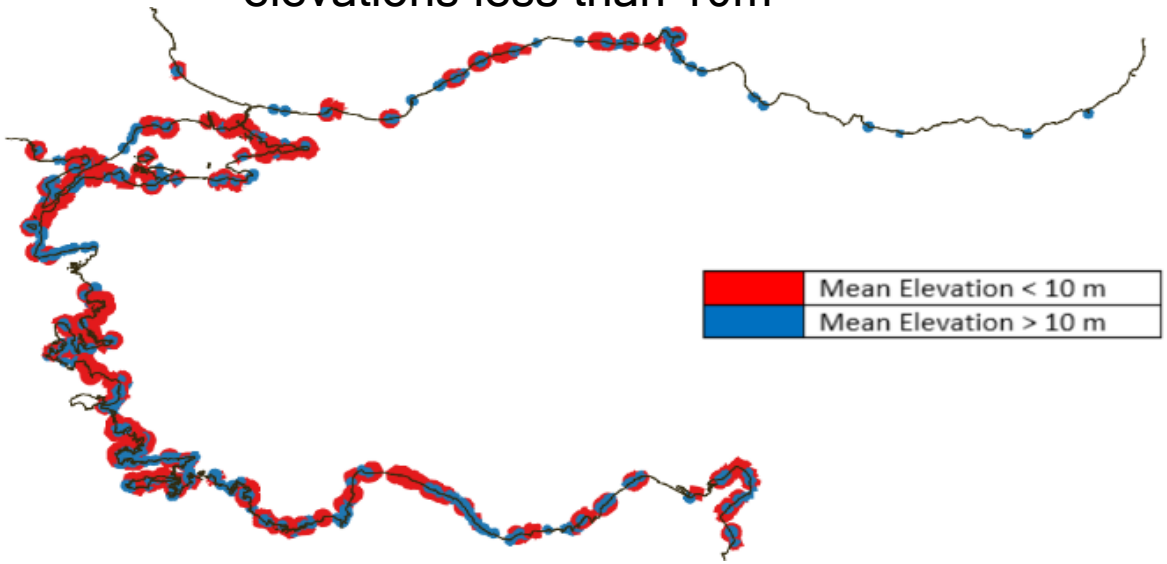


HERITAGE SITES - TURKIYE

- Law 2863 Cultural & Natural Heritage Requiring Protection: 1st Degree, 2nd Degree, 3rd Degree, National and Cultural Assets
- No single comprehensive heritage dataset -> Cross-check several public and private database
- 1250 archeological and 1936 natural heritage sites
- 22% Mediterranean, 40% in the Aegean, 32% in the Marmara, and 6% in the Black Sea Region.
- 1st degree: 33% Natural and 55% Archeological

Heritage sites below 10 - meters elevation	Heritage sites within 1-km distance to shoreline	Heritage sites within 1-km distance to shoreline and below 10-meters elevation
		

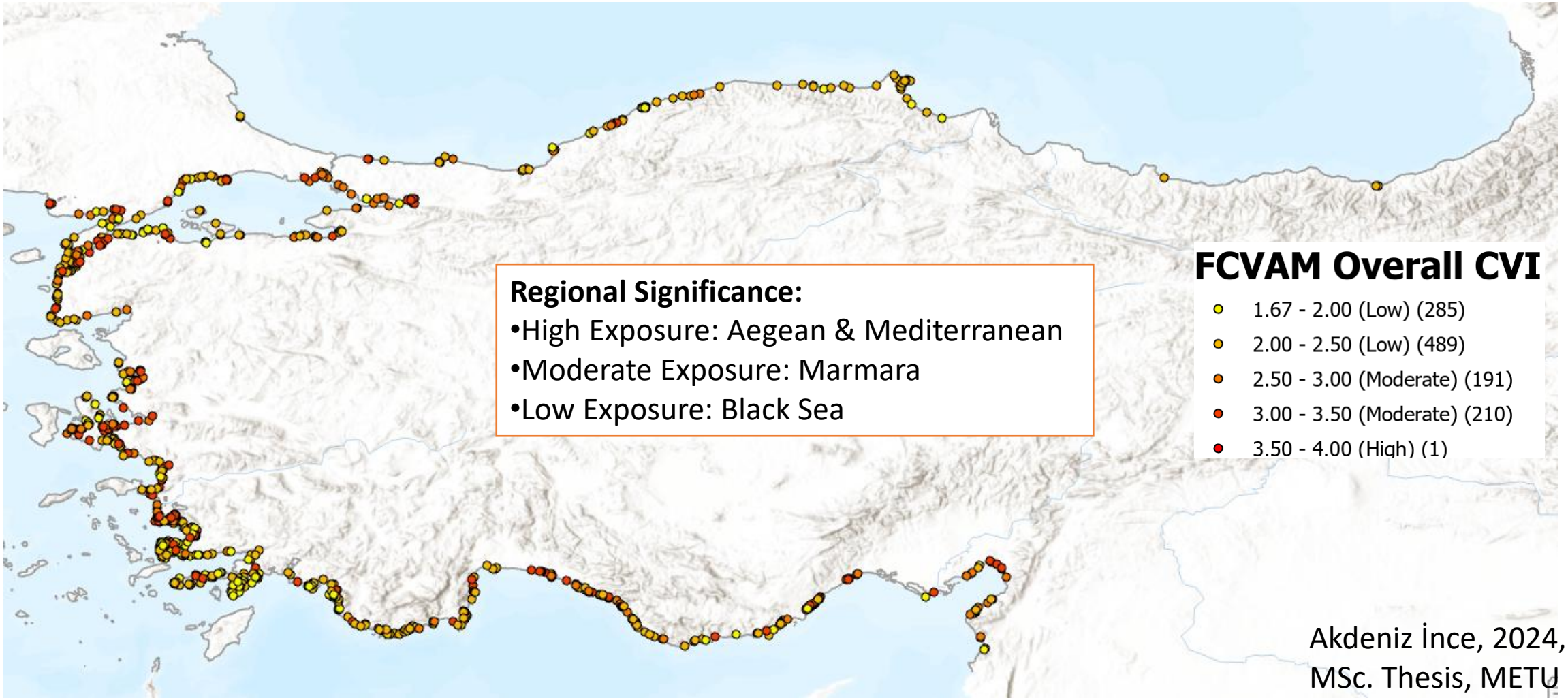
362 of the archeological sites have elevations less than 10m



Cultural Heritage Vulnerability (SSP2 – 4.5 2100)

Individual impact vulnerability is important for understanding future risks!

	Overall CVI	Erosion CVI	Inundation CVI	Flooding CVI	Sensitivity
Very Low	190	180	159	193	109
Low	357	298	355	365	252
Moderate	432	402	435	431	232
High	144	249	162	138	436
Very High	53	47	65	49	147



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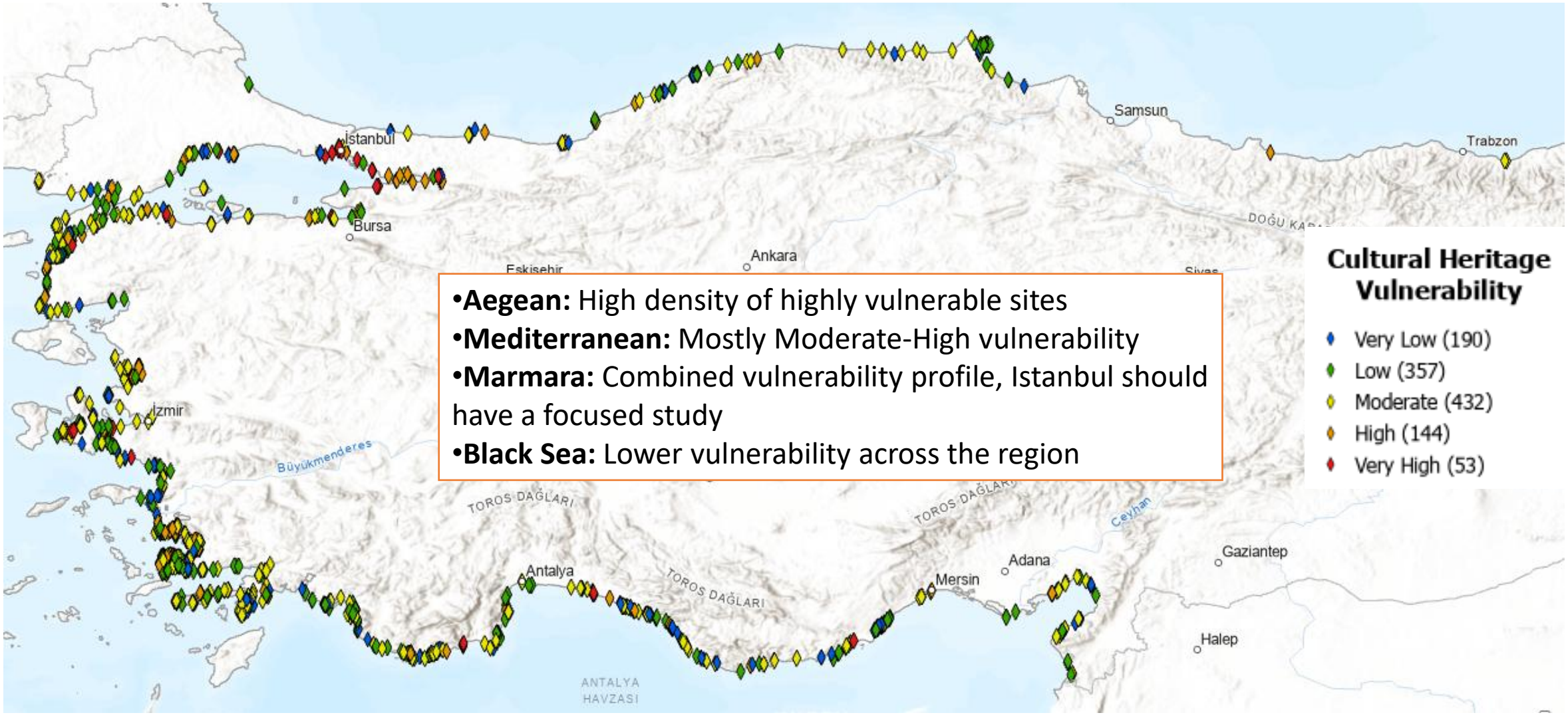
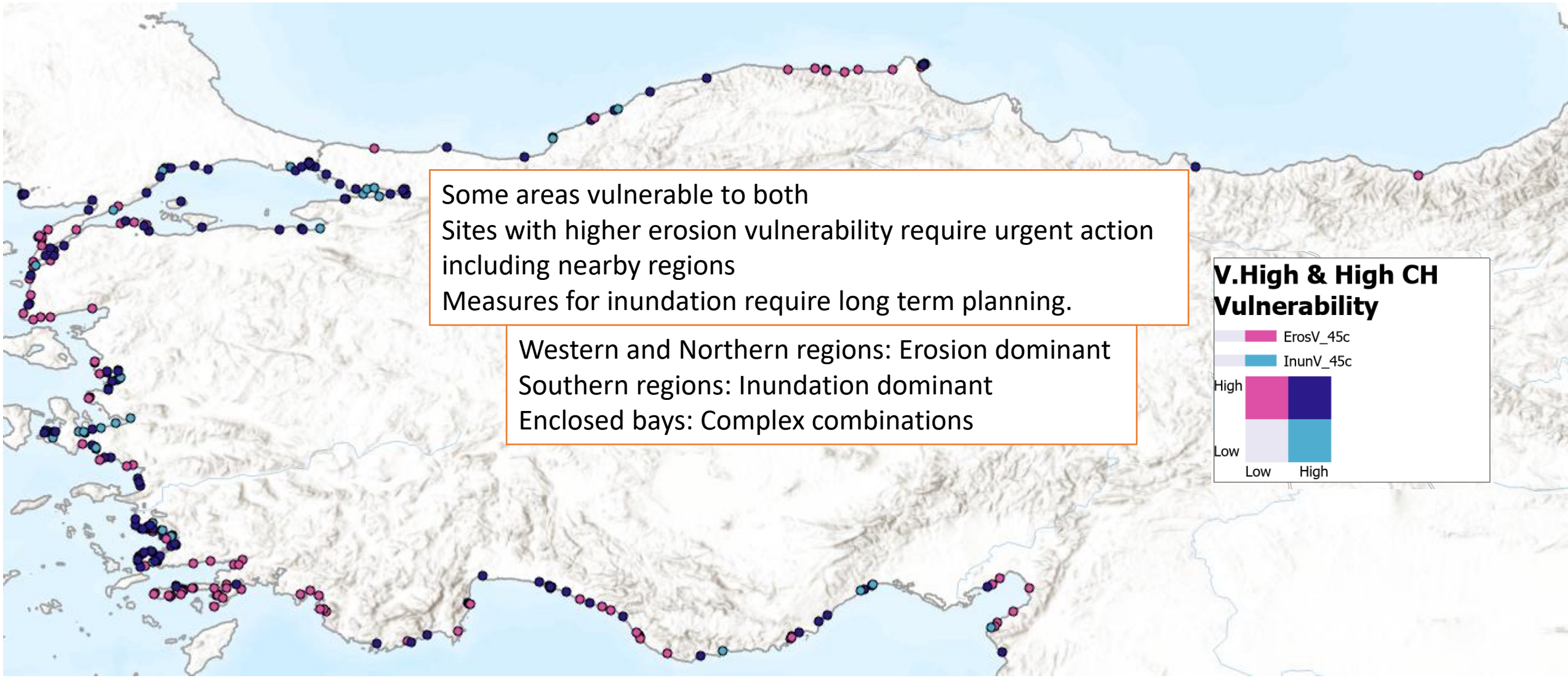
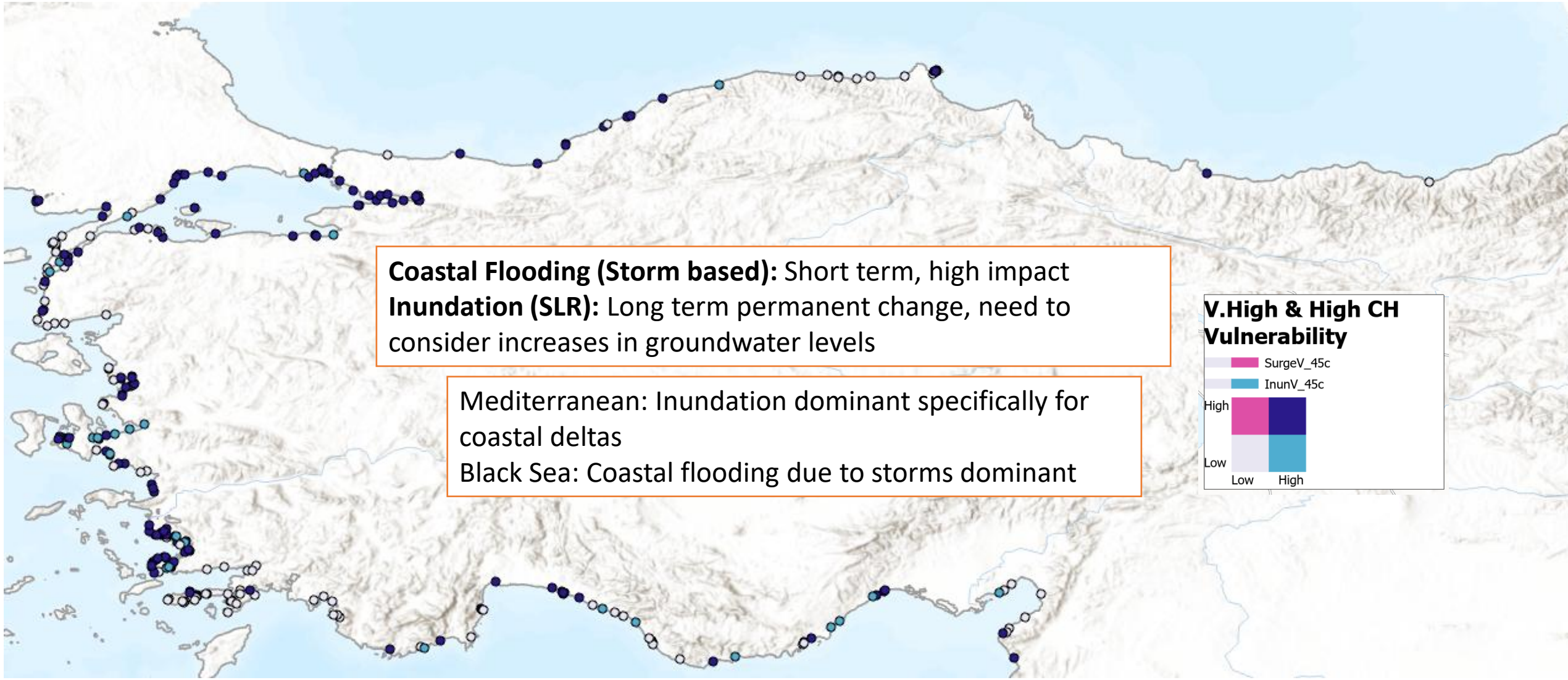
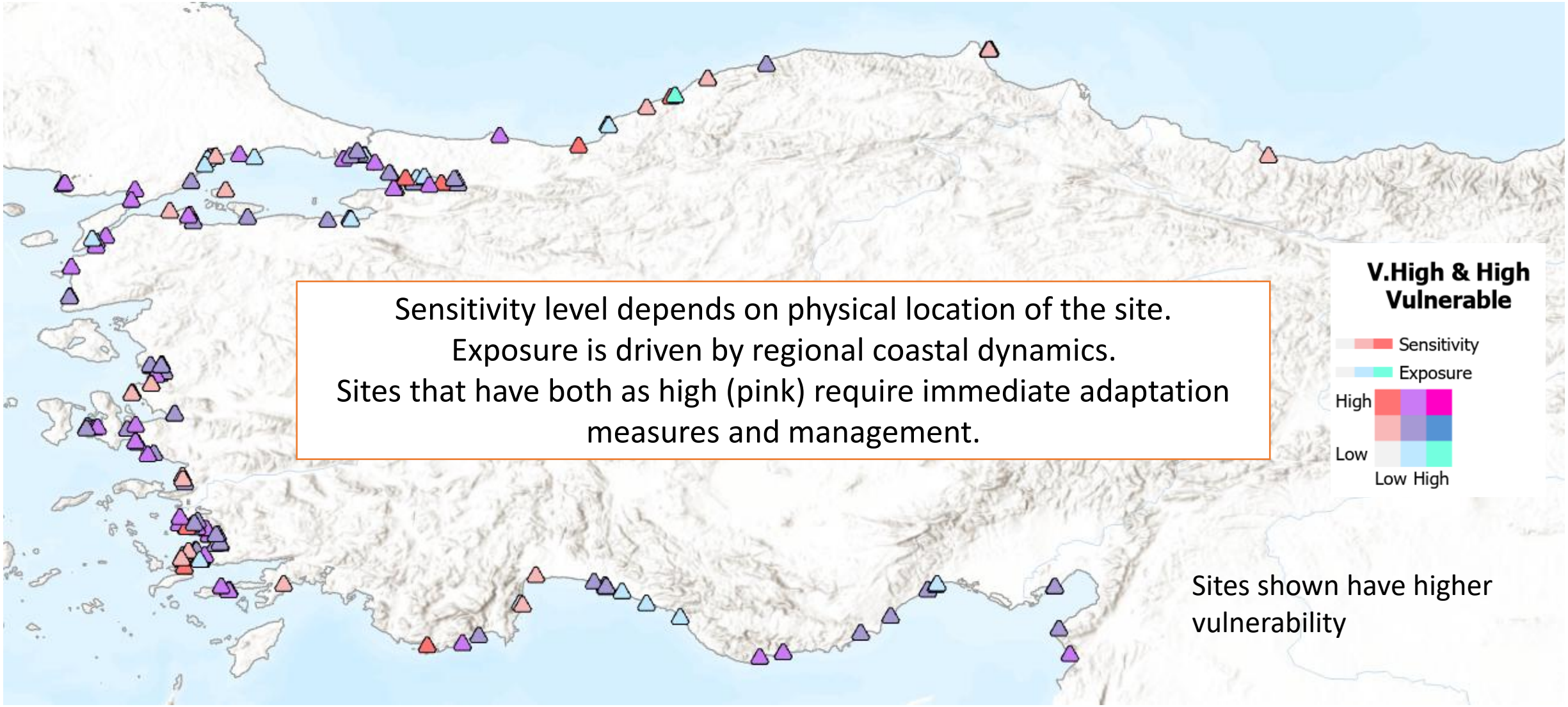


- **Aegean:** High density of highly vulnerable sites
- **Mediterranean:** Mostly Moderate-High vulnerability
- **Marmara:** Combined vulnerability profile, Istanbul should have a focused study
- **Black Sea:** Lower vulnerability across the region

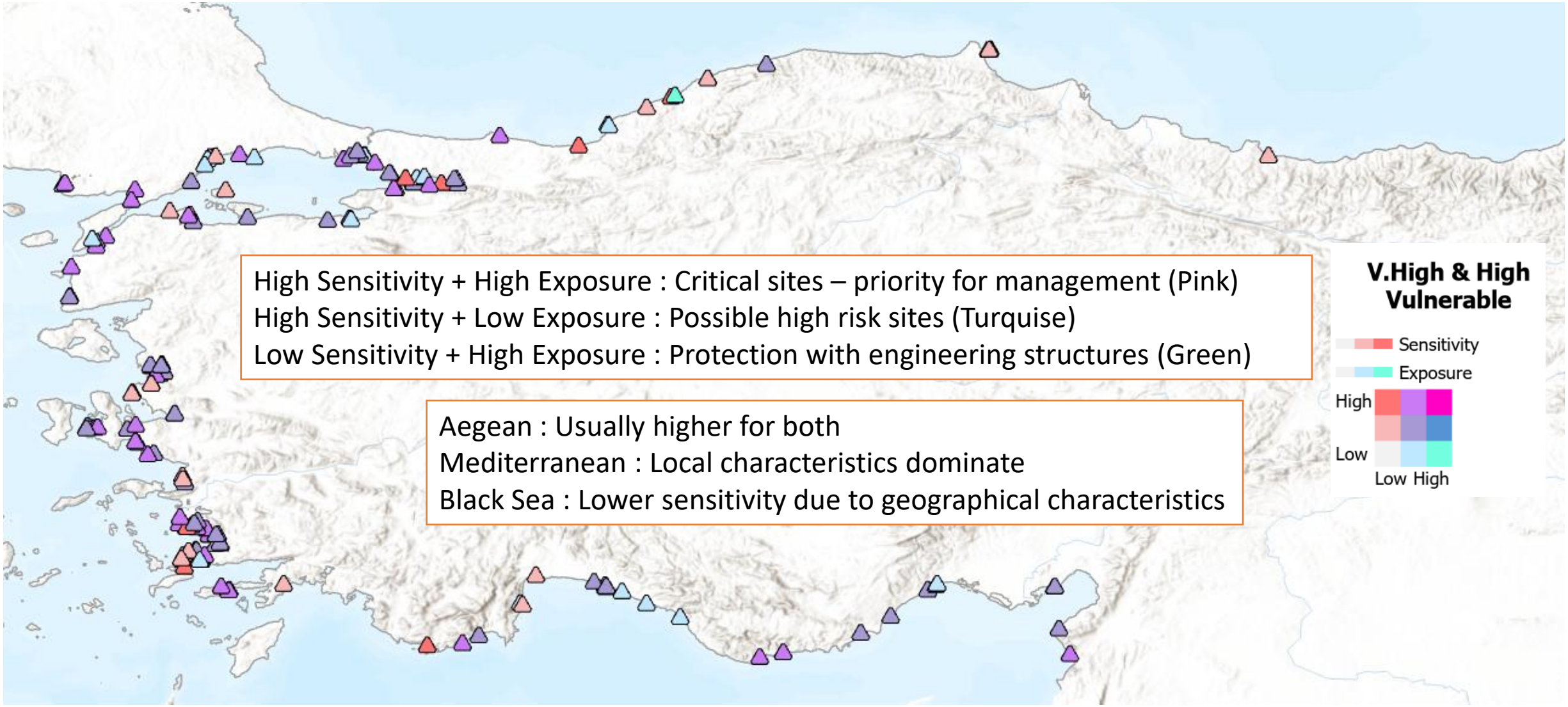

Some areas vulnerable to both
Sites with higher erosion vulnerability require urgent action including nearby regions
Measures for inundation require long term planning.
Western and Northern regions: Erosion dominant
Southern regions: Inundation dominant
Enclosed bays: Complex combinations
V.High & High CH Vulnerability
ErosV_45c
InunV_45c
High
Low
Low
High


Coastal Flooding (Storm based): Short term, high impact
Inundation (SLR): Long term permanent change, need to consider increases in groundwater levels
Mediterranean: Inundation dominant specifically for coastal deltas
Black Sea: Coastal flooding due to storms dominant
V.High & High CH Vulnerability
SurgeV_45c
InunV_45c
High
Low
Low
High



Sensitivity level depends on physical location of the site.
Exposure is driven by regional coastal dynamics.
Sites that have both as high (pink) require immediate adaptation measures and management.

Sites shown have higher vulnerability


High Sensitivity + High Exposure : Critical sites – priority for management (Pink)
High Sensitivity + Low Exposure : Possible high risk sites (Turquise)
Low Sensitivity + High Exposure : Protection with engineering structures (Green)
Aegean : Usually higher for both
Mediterranean : Local characteristics dominate
Black Sea : Lower sensitivity due to geographical characteristics
V.High & High Vulnerable
Sensitivity
Exposure
High
Low
Low High

Conclusions…

- National coastal archeological heritage assessment determined the key sites/regions for further site-specific studies using an index-based approach
- Individual impact vulnerability (erosion, inundation, extreme water levels) is important for understanding future risks!
- Sensitivity and Exposure significantly change across and within regions
- Grouping of regions of similar vulnerability characteristics can enable common adaptation measures to be developed
- Site specific maps provide asset level information but requires higher resource allocation (prioritization of sites!)
- Ongoing work of the project:
  - Assessments with full IPCC emission scenarios and comparison of 2050-2100
  - Assessment of awareness of coastal vulnerability: Ministry of Culture and selected excavation teams/heritage area managers

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A. Çağatay Uysal, 2024, MSc. Thesis, METU

THANK YOU!

VULNERABILITY OF COASTAL CULTURAL HERITAGE AREAS TO SEA LEVEL RISE AND ITS IMPACTS

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