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D.1.2.1 UNESCO vulnerability and sensitivity risk analysis

A 1.2 Mapping of priority intervention areas and related impact classes

STEP 1

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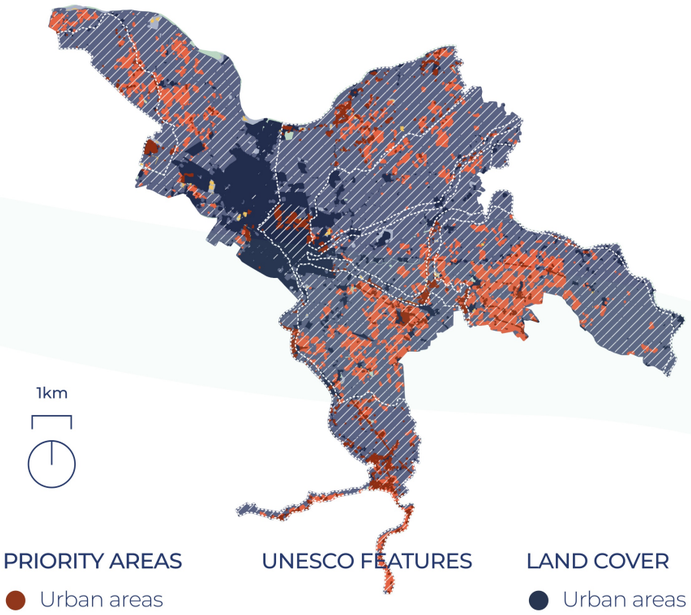
PRIORITY INTERVENTION AREAS

HEAT-RELATED IMPACT

The map highlights the areas where the historical average Land Surface Temperature (LST) has frequently been exceeded, showing two out of five impact classes. These are further subdivided into land cover units.



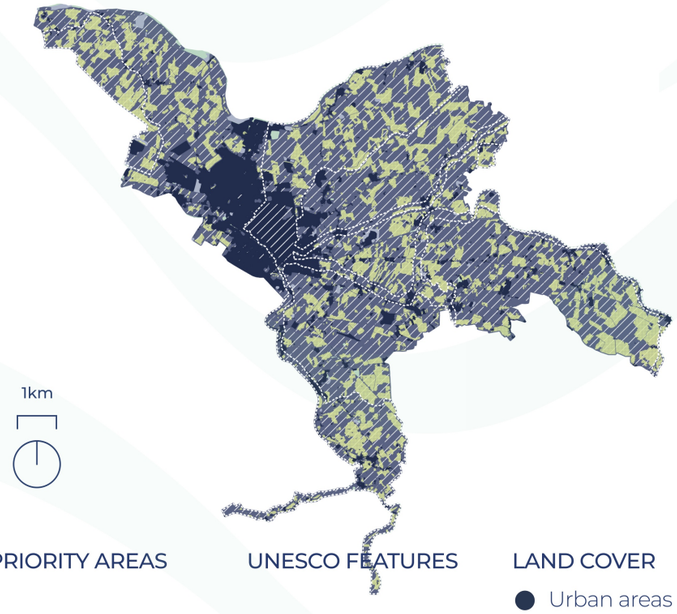
PRIORITY AREAS
- Urban areas
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas

DROUGHT-RELATED IMPACT

The map highlights the areas where the historical average Vegetation Health Index (VHI) has frequently indicated stress, showing three out of five impact classes. These are further subdivided into land cover units.



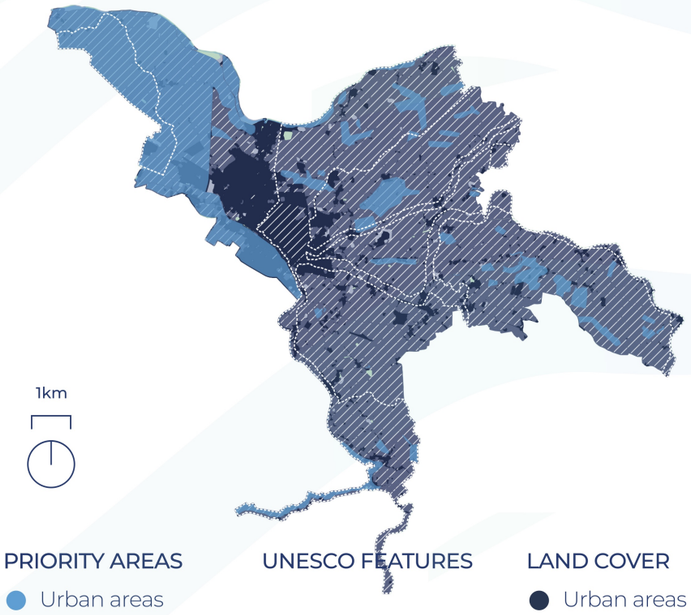
PRIORITY AREAS
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas

FLOOD-RELATED IMPACT

The map highlights areas at flood risk, identified through hazard probability scenarios based on the Flood Directive. For each site, the highest risk class has been selected, considering the regional Flood Risk Plans for each area.

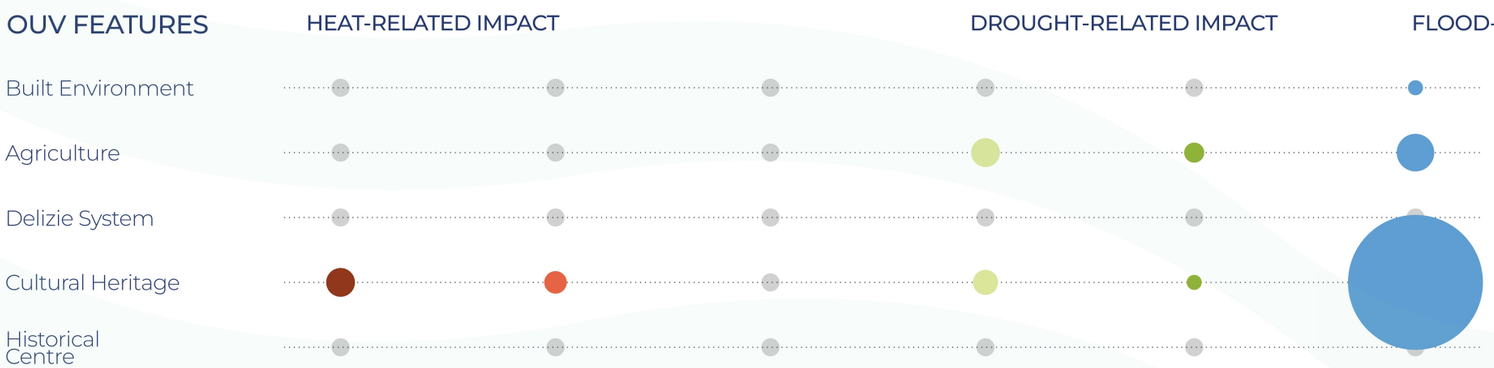


PRIORITY AREAS
- Urban areas
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas

INTERACTION BETWEEN IMPACTS AND OUTSTANDING UNIVERSAL VALUES



FERRARA

A 1.2 Mapping of priority intervention areas by morpho-typological class

STEP 2

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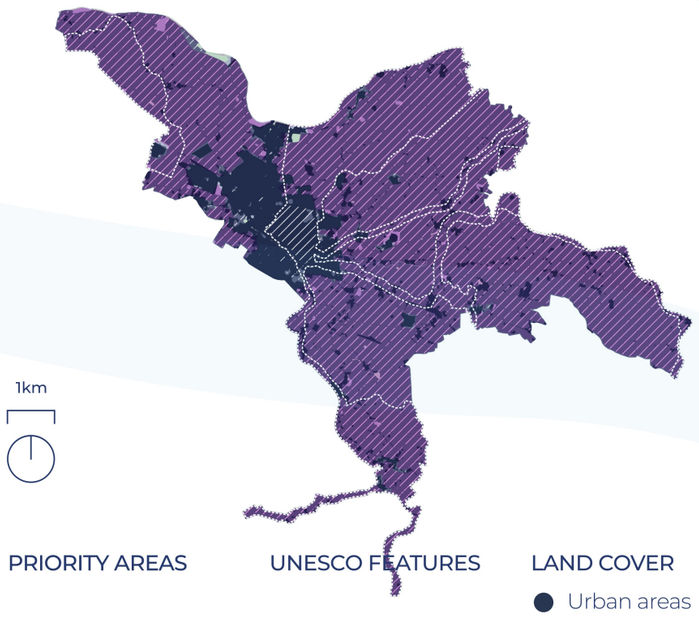
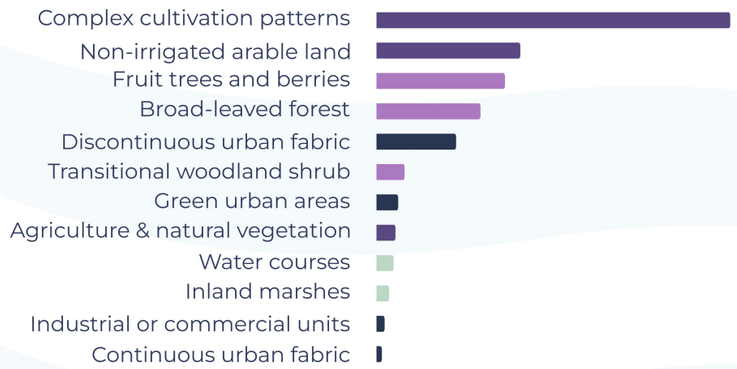
PRIORITY INTERVENTION AREAS

BY POTENTIAL VALUE OF AFFECTED **ECOSYSTEM SERVICE**

The map highlights the most sensitive areas categorized by the potential value of affected ecosystem services, based on the Burkhard matrix applied to the land cover of each site.





REGULATING SERVICES	
Global climate regulation	The agricultural landscape sequesters carbon, supporting global climate stability
Local climate regulation	The patchwork of cultivated fields and natural vegetation creates a microclimate, mitigating extreme local temperatures
Air quality regulation	The vegetation and agricultural practices help filter pollutant
Water flow regulation	The channels absorb rainfall, reducing surface runoff and soil erosion
Pollination	Diverse crops and wild plant species attract pollinators
Pest and disease control	The capacity of agroecosystems to control pests and diseases due to genetic variations of plants and animals
Regulation of waste	Farming practices and crop diversity promote natural decomposition and nutrient cycling
PROVISIONING SERVICES	
Crops	Cultivation and harvest of edible plants on agricultural fields and gardens
Biomass for energy	Cultivation and harvest of plants used for energy conversion, including organic materials to produce renewable energy.
Fodder	Cultivation and harvest of fodder for domestic animals.
Livestock (domestic)	Production and utilization of domestic animals for nutrition, including dairy, meat, and wool.
Fibre	Cultivation and harvest of natural fibers, such as silk, has historically been significant for producing textiles, fabrics, and paper.
Freshwater	Freshwater used for industrial use and irrigation.
CULTURAL SERVICES	
Recreation & tourism	Ferrara offers a unique mix of architecture, cultural heritage, and cycling routes, making it a prime destination for tourism and recreation.
Landscape aesthetics & inspiration	The agricultural landscape of Ferrara merges history with nature, featuring vast fields, canals, and Renaissance heritage that inspire reflection.
Knowledge systems	Environmental education combines local traditions and expert knowledge to promote a deeper understanding of the region's nature and heritage.
Religious & spiritual experience	Spiritual itineraries in Ferrara feature well-preserved sites that reflect the deep religious and emotional values tied to the local landscape.
Cultural heritage & cultural diversity	Ferrara's landscapes and historic architecture highlight the importance of preserving cultural landmarks and traditional land use as part of its identity.

FERRARA

03 Ferrara, city of Renaissance and its Po Delta

STEP 2 *for the Built Component Matrix*

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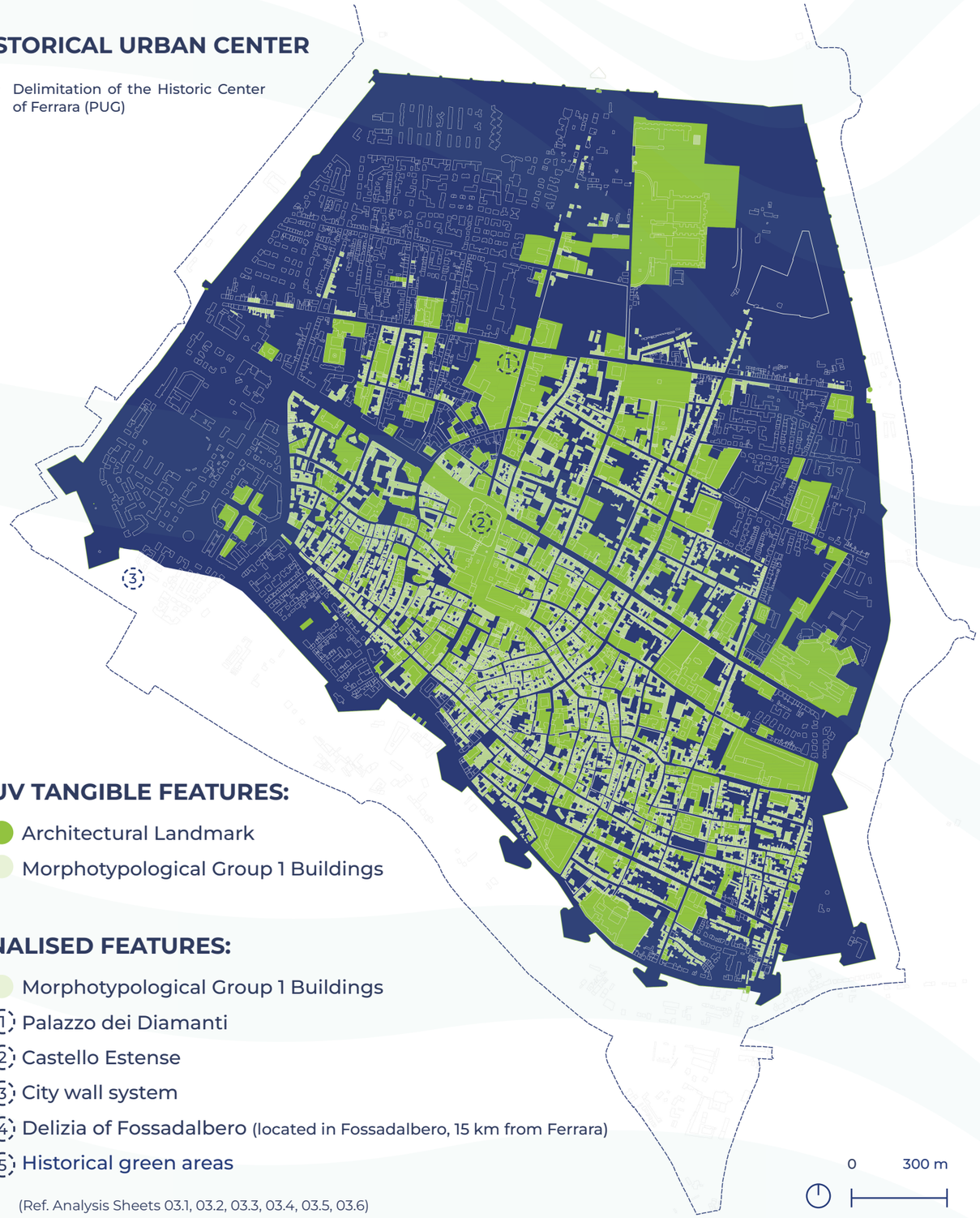
HISTORICAL URBAN CENTER

Delimitation of the Historic Center of Ferrara (PUG)



OUV TANGIBLE FEATURES:

- Architectural Landmark
- Morphotypological Group 1 Buildings

ANALISED FEATURES:

- Morphotypological Group 1 Buildings
- (1) Palazzo dei Diamanti
- (2) Castello Estense
- (3) City wall system
- (4) Delizia of Fossadalbero (located in Fossadalbero, 15 km from Ferrara)
- (5) Historical green areas

(Ref. Analysis Sheets 03.1, 03.2, 03.3, 03.4, 03.5, 03.6)

PAST EXTREME EVENTS

STRONG WINDS

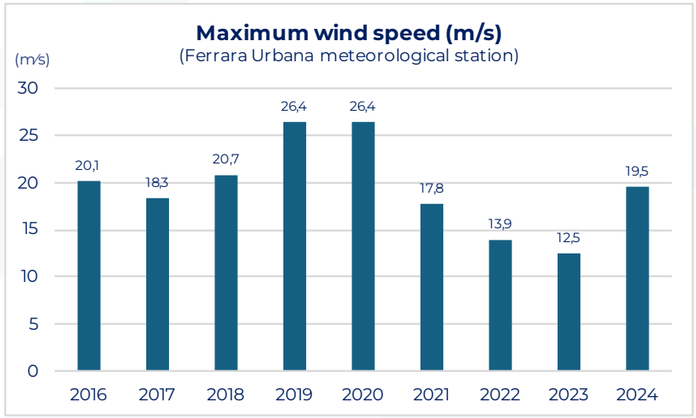
Maximum wind speed: 26,4 m/s
NW prevailing wind in Ferrara

The critical values for potential damage caused by wind are:

- Medium intensity:
  > 17.2 m/s e < 20.7 m/s
  for at least 3 consecutive hours
- High intensity:
  > 20.7 m/s e < 24.4 m/s
  for at least 3 consecutive hours
- Very high intensity:
  > 24,4 m/s

(*Ref.: "Wind risk" - Protezione Civile*)

In 2019, there were two recorded cases (on July 13 and August 2) of wind exceeding 24.5 m/s, causing significant damage.



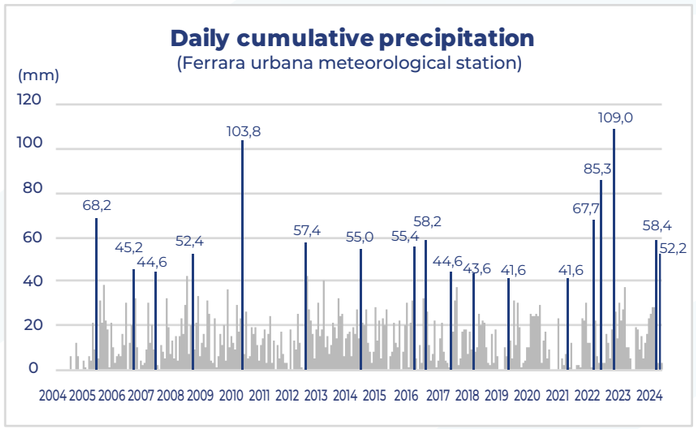
INTENSE RAINFALL

High daily accumulated rainfall values can cause **flooding** (flood risk thresholds are defined by the *Protezione Civile*).

Intense rainfall in Ferrara: the exceedance of the thresholds of 30 mm/h and 70 mm/3h may indicate intense rainfall events.

Max. cumulative precipitation over one hour (Ferrara Urbana)**:**

31/05/2005	10am-11am:	40,6 mm/h
07/09/2017	7pm-8pm:	41,0 mm/h
08/06/2018	1am-2am:	35,2 mm/h
06/09/2019	1pm-2pm:	36,0 mm/h
11/07/2020	4pm-5pm:	21,6 mm/h
20/09/2021	11pm-12pm:	28,6 mm/h
19/08/2022	6am-7am:	45,7 mm/h*
10/05/2023	9pm-10pm:	23,6 mm/h



Data source: Arpae Emilia Romagna
** year 2022: data from the meteorological station - Malborghetto*

FLOOD

Last flood events:

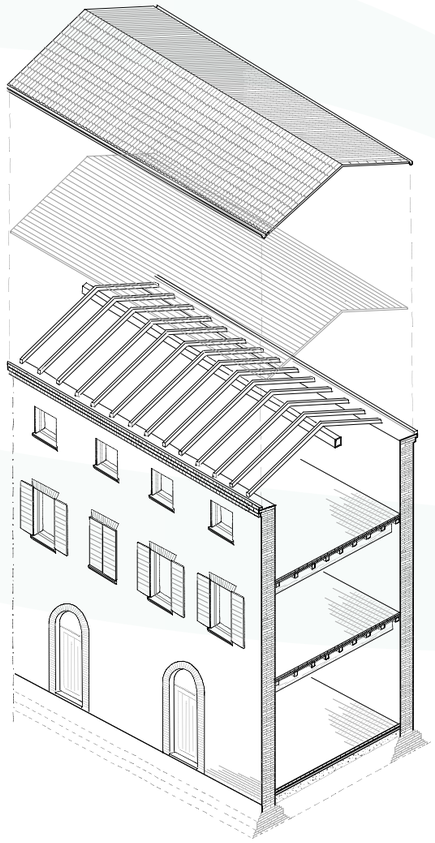
- September 2019
- August 2022



Photos: Estense.com - September 6, 2019

03.1

MORPHOTYPOLOGICAL GROUP 1



ceramic materials
wood
(stone materials)
metallic materials
(mortars and plasters)

The urban and architectural fabric of Ferrara's historic center exhibits a significant degree of uniformity. This consistency is primarily defined by the extensive use of brick masonry for all vertical structures, while horizontal partitions, including floors and roofs, are predominantly composed of wood. While structural solutions may, in certain instances, present distinctive characteristics—particularly in palaces and public buildings—the materials employed in the construction of residential architecture exhibit a notable homogeneity.
Min. height: 2 floors | Max. height: 4 floors

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

The foundation techniques are related to the nature of the soil in Ferrara, which is characterized by its "marshy" conditions and shallow groundwater levels. Typically, continuous masonry foundations are employed, varying in depth. These enlargements are achieved through one or more stepped courses of masonry (it is possible that the incorporation of piles was envisaged to compact the soil).

A.01.3 | BASEMENT

The base of masonry structures could be thickened by constructing a plinth or a basement. In some cases, a battered wall could also be implemented.

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

The vertical load-bearing structures are made of brick masonry, typically with a thickness corresponding to a double or triple wythe wall.

Mostly exposed masonry walls. Plaster finishes are scarse (in the past the irregular masonry was likely covered with plaster).

Horizontal structural elements: semicircular arch doors (brick)

Doors/windows frames are usually made of brick (only a few cases in stone) and they can also feature terracotta's decorations.

The presence of wooden shutters on the windows is common.

B01.2 | HORIZONTAL CLOSURE

Wooden floors are the most widespread horizontal partitioning system in Ferrara's traditional architecture, where they have developed with some variants (the most widespread is the coffered ceiling 'a cassettoni,' where the double wooden framing is visible and the squared pattern—'cassettone'—is achieved through wooden moldings known as 'cantinelle')

Cramp irons were used to connect the wooden structures of floors and roofs,

The flooring is usually made of square terracotta tiles (it was supported by a sand underlayer bound with a small amount of lime, which distributes the loads across the wooden horizontal structure).

B01.4 | OVERHANG ELEMENTS

A few balconies and window sills rest on stone brackets.

C01 | ROOFS

C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

The roofs of Ferrara feature short overhangs to protect the external walls. Ceramic tiles lay on wooden boarding, and it's supported by a wooden structure. (To cover larger spaces, the roof truss—'capriata palladiana'—is commonly used)

The decorative roof cornices are often made of terracotta.

Presence of metallic gutters for rainwater collection

C01.2 | SOARING ELEMENTS

Presence of high chimneys.

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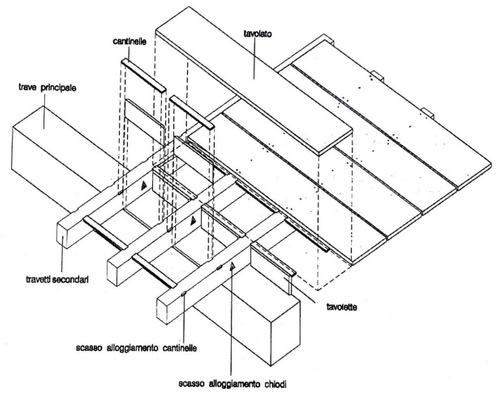
FIGURES:

a. Wooden floor with double framing and 'cantinelle' in Casa Minerbi - Del Sale. *Source: Fabbri, R. (2001)*
b. Decorated roof cornice and balcony on stone brackets.
c. Decorative elements in terracotta of two residential buildings in Via Terranova n. 7 and 9.
d. An entrance portal with semicircular arch and frame decorated in terracotta, in Via Terranova n.25.
e. Different types of roof cornices, the presence of high chimneys, and wooden window shutters.



a.



b.



c.



d.



e.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, or due to intense rainfall)

- Settlements, often differential, of the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry;
- Cracking or structural failure caused by the lateral hydrostatic pressure on basement walls and foundations exerted by floodwaters;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

(The nature of Ferrara's soil—loamy soils and shallow groundwater levels—further intensify these possible impacts)

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers)

- Localized erosion, with a long lasted action, can wash out clay mortar from masonry (action of water and eventual debris).

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials (masonry, frescoes...) due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).
- Higher humidity levels can foster the growth of mold and fungi, causing organic materials' damage (frescoes, wooden structures...)

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Thermoclastism caused by temperature fluctuations;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials;
- The erosive action of wind can facilitate the loss of material and especially decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements, especially windows (glass and shutters) and roof's components.

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate stone surfaces. The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofs may no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves;

  (The roofs of the historical urban fabric in Ferrara feature short overhangs to protect the external walls)
- Heavy rain and storm phenomena can damage roof covering and other roof elements, especially those in terracotta.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially the soaring one like chimneys.

03.2

PALAZZO DEI DIAMANTI



- ceramic materials
- wood
- stone materials (Verona limestone; white compact limestone; Breccia)
- metallic materials
- mortars and plasters
- paints

The Palazzo dei Diamanti, one of the urban residences of the Este family, was built starting in 1493 by Biagio Rossetti for Sigismondo d'Este. It is located at the Quadrivio degli Angeli and is distinguished by its iconic façade adorned with diamond-pointed stonework.
The building was reopened to the public in February 2023 after the interventions of restoration and reconfiguration of its interior and exterior spaces to accommodate exhibition purposes (Architectural project and management: LABICS). It houses the National Picture Gallery of Ferrara and temporary exhibitions by the Ferrara Art Foundation.

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

The foundation techniques are related to the nature of the soil in Ferrara, which is characterized by its "marshy" conditions and shallow groundwater levels. Typically, continuous masonry foundations are employed, varying in depth. These enlargements are achieved through one or more stepped courses of masonry (it is possible that the incorporation of piles was envisaged to compact the soil).

A.01.3 | BASEMENT

The battered wall's base is covered with diamond-shaped Verona stone blocks.

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

The vertical load-bearing structures are made of brick masonry. The principal façades are covered with diamond-shaped Verona stone blocks.

The others exterior façades are exposed masonry walls.

Horizontal structural elements: semicircular arch (brick) also feature terracotta's decorations.

Doors/windows projecting frames are made of a white compact limestone.

Windows have wooden frames (some wooden shutters) and are single-glazed.
The decorated pilasters (principal facades) are carved in Pietra d'Istria.

B01.2 | HORIZONTAL CLOSURE

Wooden floors/ceilings. There are coffered ceiling 'a cassettoni,' where the double wooden framing is visible and the squared pattern—'cassettone'—is achieved through wooden moldings known as 'cantinelle', as weel as ceiling 'a lacunari' (with a geometrical grid of recessed panels, like the one coverng the 'Salone d'onore', in the eastern wing). The presence of paint decoration on wooden elements extends to the majority of the ceilings.
Cramp irons are used to connect the wooden structures of floors and roofs.

The flooring is usually made of square terracotta tiles (it was supported by a sand underlayer bound with a small amount of lime, which distributes the loads across the wooden horizontal structure).

B01.4 | OVERHANG ELEMENTS

The projecting corner balcony rest on stone brackets.

C01 | ROOFS

C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

The roofs feature short overhangs to protect the external walls.
Ceramic tiles lay on wooden boarding, and it's supported by a wooden structure. (To cover large spaces, the roof truss—'capriata palladiana'—is used).

The decorative roof cornices on the principal facades are made of stone (Pietra di Verona), the flat band between the ashlar and the cornice at the top of the principal façades is made of terracotta, covered with a *faux stone* plaster finish.

Presence of metallic gutters for rainwater collection.

FIGURES:

a. Semicircular arches resting on stone columns in the entrance loggia, covered by a wooden ceiling.
b. The portico connecting the new loggia to the Tisi wing.
c. Comprehensive view of the Palace from the garden with the new "loggia-connection" between the Rossetti and Tisi wings.
d. Exposed collection in a room of the Rossetti wing.
e. Selection of paintings displayed in a room of the National Art Gallery characterized by a decorated wooden ceiling.

Sources (b, c, d): Labics, Palazzo dei Diamanti 1493-2023. Il progetto del nuovo spazio espositivo, Ferrara Arte, Ferrara, 2024.



a.



b.



c.



d.



e.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, or due to intense rainfall)

- Settlements, often differential, of the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry;
- Cracking or structural failure caused by the lateral hydrostatic pressure on basement walls and foundations exerted by floodwaters;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

(The nature of Ferrara's soil—loamy soils and shallow groundwater levels—further intensify these possible impacts)

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (due to intense rainfall)

- Localized erosion, with a long lasted action, can wash out clay mortar from masonry (action of water and eventual debris).

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials (masonry, frescoes...) due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).
- Higher humidity levels can foster the growth of mold and fungi, causing organic materials' damage (frescoes, wooden structures...)

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Thermoclastism caused by temperature fluctuations;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials;
- The erosive action of wind can facilitate the loss of material and especially decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements, especially windows (glass and shutters) and decorative elements.

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate stone surfaces. The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofs may no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves;

  (The roofs of the Palazzo dei Diamanti features short overhangs to protect the external walls)
- Heavy rain and storm phenomena can damage roof covering and other roof elements, especially those in terracotta.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components (especially tiles).

MOVABLE HERITAGE: COLLECTIONS

Increased Temperature:

- Increased need for environmental controls;
- Increased insect pest problems.

Increased Precipitation and
Increased Water Vapour Content in the Air (leading to changes in relative humidity):

- Damage to paintings;
- Warping, cracking of wood;
- Damage to archival, paper, book, and photo collections;
- Increased risk of mould, especially organic collections;
- Increased salt damage to ceramics with humidity fluctuations;
- Increase in pest populations and infestation.

03.3

CASTELLO ESTENSE



ceramic materials

wood

stone materials

metallic materials

paints and frescoes

The construction of the Castello Estense began in 1385 at the behest of Nicolò II d'Este. As political and cultural symbol of Ferrara, and becoming the residence of the Este family, a series of transformations over the centuries has shaped its architecture into a structure composed of four imposing corner towers, which enclose equally large two-story wings, surrounding a vast quadrangular inner courtyard. The perimeter of the castle is protected by a large flooded moat, with three ravelins, each equipped with a drawbridge. Today, the Castle Museum offers a narrative journey through its spaces, from the prisons to the Este residences. In the coming years, the castle will undergo restoration work, necessary especially due to the damage caused by the earthquakes that hit the Emilia region in 2012.

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

It is on the massive masonry structure of the basements, built with low barrel vault ceilings that linked the underground rooms of the towers, that the large mass of the castle building rests.

A.01.3 | BASEMENT

A high, tapered basement reaches up to the ground floor's spandrel, marked by a stone ledge.

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

The vertical load-bearing structures are made of brick masonry.

Doors/windows have non-projecting brick frames and stone windowsills.

Windows feature wooden frames (no shutters) and are single or double-glazed.

Presence of elements in Pietra d'Istria (columns, balaustrades, decorative elements such as the "Leoni e Wor.bas" relief.

Decorations: Frescoed rooms and, in the case of the Ducal Chapel, coverings in polychrome marbles. In the exterior, in the courtyard, there's a fragment of a monochrome-painted niche on a wall, and others exposed painted portions.

B01.2 | HORIZONTAL CLOSURE

Cross vault ceilings are located on the ground floor and the first floor.

Wooden floors/ceilings: coffered ceiling 'a cassettoni,' ceiling 'a lacunari' among other simplier wooden structures. The vaulted or suspended ceilings were often made with reed mats coated in lime on wooden centering.

The flooring is mainly made of terracotta tiles in the ground floor, while in the upper floors rooms it's mainly in stone tiles. Very few floors from the Este period have been preserved in the Castle: they have been largely replaced, primarily with more recent marble floors, as well as terracotta floors and marble terrazzo.

B01.4 | OVERHANG ELEMENTS

The projecting wooden 'balcony' (north side) rest on stone brackets. It is enclosed by a glass system and features a metal roof.

C01 | ROOFS

C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

The roofs feature short overhangs.

Ceramic tiles lay on wooden boarding, and it's supported by a wooden structure.

The roof cornices are made mainly in stone, but also in wood (eg. in the courtyard)

Presence of metallic gutters for rainwater collection.

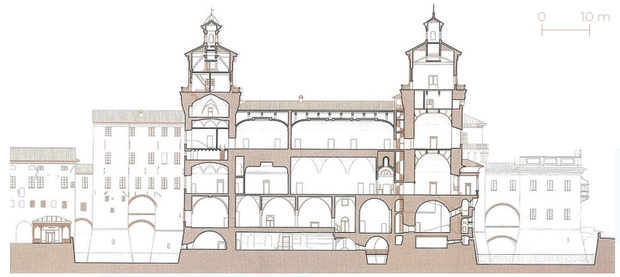
C01.2 | SOARING ELEMENTS

The towers feature lantern turrets with a metallic decorative element at the top.

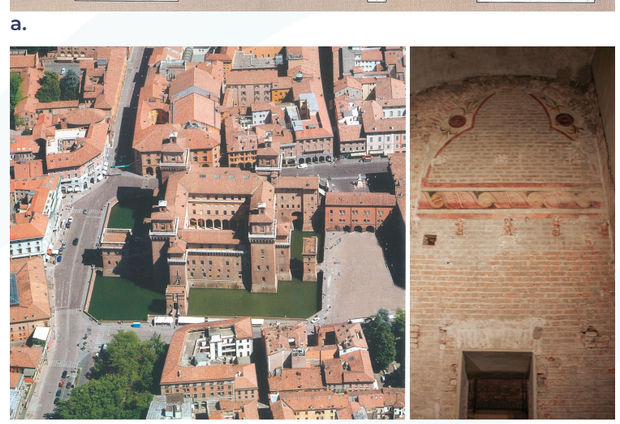
FIGURES:

a. Section including Torre Marchesana and Torre dei Leoni.
b. Aerial view of the west side of the castle.
c. A ground-floor room in the north wing of the Castle features frescoed decorations that originally adorned the exterior walls of the Rocca dei Leoni, when in the 15th century was still separate from the Castle.
d. Detail of the est side of the Castle with a stone balustrade.
e. View of the colonnade in the courtyard.

Images (a, b): Bentini, J., Di Francesco, C. (2002). Il Castello Estense. J. Bentini, M. Borella (Eds.), BetaGamma, Viterbo.



a.



b.

c.



d.



e.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, or due to intense rainfall)

- Settlements, often differential, of the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry;
- Cracking or structural failure caused by the lateral hydrostatic pressure on basement walls and foundations exerted by floodwaters;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

(The Castel is surrounded by a large flooded moat.
The risk of the moat overflowing is low because it is controlled, but the constant contact of the structure's base with water creates conditions that facilitate the progression and intensification of many deterioration phenomena.)

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers)

- Localized erosion, with a long lasted action, can wash out clay mortar from masonry (action of water and eventual debris).

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials (masonry, frescoes...) due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).
- Higher humidity levels can foster the growth of mold and fungi, causing organic materials' damage (frescoes, wooden structures...)

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Thermoclastism caused by temperature fluctuations;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials;
- The erosive action of wind can facilitate the loss of material and especially decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements, especially windows (glass and shutters) and roof's components.

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate stone surfaces. The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofs may no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves;

(roof gutters and rain leaders present several damaged portions)

- Heavy rain and storm phenomena can damage roof covering and other roof elements.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially the soaring one like the lantern turrets and the decorative elements at the top.

03.4

CITY WALL SYSTEM

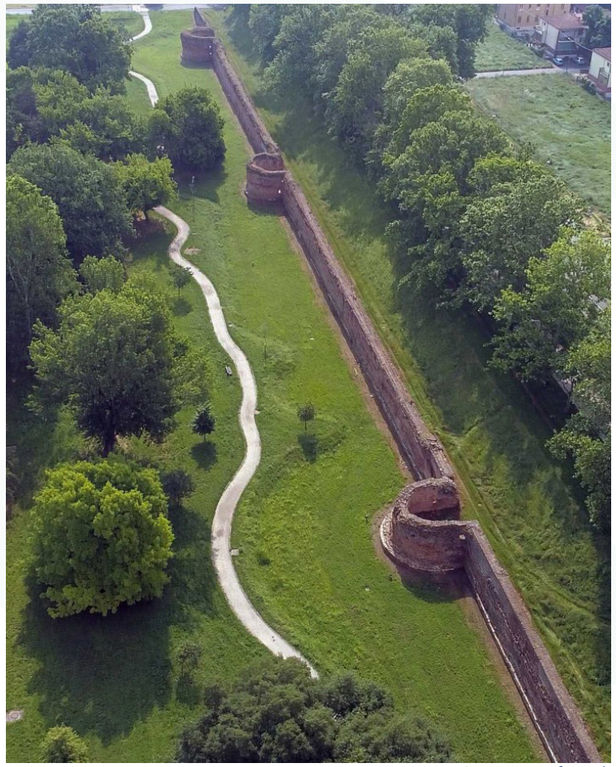


Image: museoferrara.it

ceramic materials

wood

stone materials

The Ferrara's fortification system exhibits a strategic alternation of curtain walls, bastions, towers, and gates (eg. Porta degli Angeli, Porta Paola, Baluardo di San Pietro, Torrione di San Giovanni, Torrione del Barco), many of which remain well preserved today. The north and northeast sides reveal the first three defense systems' types: embankment, moat, and wall.
The expansion of the city (*Addizioni*) was further completed with the construction of a new, modern defensive system to adapt the city's defenses to new siege techniques. This system, integrating features from all significant periods of military architecture and elements of various construction types, is considered the unique complete and well preserved version of the "Italian Bastioned System". The 9 kilometers of defensive walls that still delineate the historic city of Ferrara today serve as expansive gardens, providing a recreational space for both locals and visitors.

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

The foundation techniques are related to the nature of the soil in Ferrara, which is characterized by its "marshy" conditions and shallow groundwater levels. Continuous masonry foundations are employed in the city walls, varying in depth and supported by a series of sloped buttresses.

The masonry basement is in direct contact with the ground.

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

The vertical structures of the curtain walls, bastiones and gates are made of brick masonry. In some cases, wall's quoins or other architectural elements made of stone material are present (eg. Porta Paola principal facade feature stone facing)

Doors and windows are present in some of the buildings comprising the city walls system, such as Porta degli Angeli and Porta Paola, both recently restored.

B01.2 | HORIZONTAL CLOSURE

Horizontal structural elements: some components of the fortified system presents horizontal structural systems (eg. Torrione del Barco feature a masonry barrel vault, Porta degli Angeli preserved its semicircular masonry arch).

Where present, the floors of the buildings have a wooden structure.

C01 | ROOFS

C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

Some components of the fortified system, like the Baluardo di San Pietro or Porta Paola and Porta degli Angeli, are covered with a roof featuring short overhangs. Ceramic tiles lay on wooden boarding, and it's supported by a wooden structure. Some of this military architectures were completed with merlons (eg. Baluardo di San Pietro), which are no longer preserved today.
Presence of metallic gutters for rainwater collection.

FIGURES:
a. Detail of the brick masonry of the walls (southern stretch).
b. Torrione del Barco (NW corner of the city walls), it is part of the fortifications constructed between 1493 and 1506 to protect the "Addizione Erculea". (*Image: Ducatoestense.com*)
c. The Baluardo of Santa Maria is a testament to the pentagonal star-shaped fortress constructed between 1608 and 1618 by order of the Pope.
d. View of the northeast stretch of the walls.

Images (c-d): www.museoferrara.it.



a.



b.



c.



d.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, or due to intense rainfall)

- Settlements, often differential, of the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry;
- Cracking or structural failure caused by the lateral hydrostatic pressure on basement walls and foundations exerted by floodwaters;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

(The nature of Ferrara's soil—loamy soils and shallow groundwater levels—further intensify these possible impacts)

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers)

- Localized erosion, with a long lasted action, can wash out clay mortar from masonry (action of water and eventual debris).

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials (masonry) due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).
- Higher humidity levels can foster the growth of mold and fungi, causing organic materials' damage (wooden structures...)

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Thermoclastism caused by temperature fluctuations;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials;
- The erosive action of wind can facilitate the loss of material;
- Winds, gusts and changes in direction can affect the stability of a facade's elements, especially windows (glass and shutters) and roof's components. (Only present in some of the buildings composing the fortified system)

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate stone surfaces. The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofs may no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves; In most of the cases, the recent restoration works already managed this problem.

  (The roofs of the historical urban fabric in Ferrara feature short overhangs to protect the external walls)
- Heavy rain and storm phenomena can damage roof covering and other roof elements, especially those in terracotta.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially tiles.

03.5

DELIZIA OF FOSSADALBERO



Image: DucatoEstense.com

ceramic materials

wood

stone materials

metallic materials

mortars and plasters

paints and frescoes

The Delizia of Fossadalbero is one of the Este residences which represented the result of the territorial transformation implemented by the Este family. The newly acquired agricultural lands were firstly managed through technically efficient farms (castalderie), but were then equipped with palaces which also suited to courtly life. The system of Delizie thus constituted a unified anthropized landscape that extended from the urban center towards the sea. The Delizia of Fossadalbero, located near the Po Grande, was the center of a vast agricultural estate, covering 283 hectares of arable land in 1451. The existing "castalderia" di Fossadalbero (documented in 1415) was later added with a palace likely constructed during the first half of the 15th century. The building, surrounded by a large park, preserves part of its fortified appearance, featuring Guelph-style battlements. The interior features numerous rooms, including a private chapel. The building is privately owned property.

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

The foundation techniques are probably continuous masonry foundations are employed, with enlargements achieved through one or more stepped courses of masonry.
(implement the information regarding the characterization of the soil type and stratigraphy, as weel as the foundation system)

A.01.3 | BASEMENT

Presence of a stone basement in many sides of the building.

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

The vertical load-bearing structures are made of brick masonry. The principal façades exposed masonry walls, the wing's one are covered with plaster.

Doors/windows projecting frames are made of a white compact limestone.

Windows have wooden frames (some wooden shutters) and are single or double-glazed.
The decorated pilasters (principal facades) are carved in Pietra d'Istria.

B01.2 | HORIZONTAL CLOSURE

Wooden floors/ceilings. There are coffered ceiling 'a cassettoni,' where the double wooden framing is visible and the squared pattern—'cassettone'—is achieved through wooden moldings known as 'cantinelle'.

The presence of paint walls decoration and on wooden elements .

Cramp irons are probably used to connect the wooden structures of floors and roofs. (No information about the latest restoration interventions)

The flooring is mainly made of square or hexagonal terracotta tiles (it was supported by a sand underlayer bound with a small amount of lime, which distributes the loads across the wooden horizontal structure).

C01 | ROOFS

C01.1 | HORIZONTAL CLOSURE
(roof's structure, water drainage system)

The 'fortified' part of the building is crowned by Guelph-style battlements, while the other buildings' roof feature short overhangs to protect the external walls. Ceramic tiles lay on wooden boarding, and it's supported by a wooden structure. (No information about the latest restoration interventions)

The decorative roof cornices on the principal facades are made of stone (Pietra di Verona), the flat band between the ashlar and the cornice at the top of the principal façades is made of terracotta, covered with a *faux stone* plaster finish.

Presence of metallic gutters for rainwater collection.

C01.2 | SOARING ELEMENTS

Presence of both battlements and two high chimneys.

FIGURES:

a. Aerial view of the principal façade of the Delizia, surrounded by a large park and cultivated lands..
b. View of the east side of the building.
c, d: View of interior spaces of the Delizia. Currently it is the location of a restaurant.
d. The Delizia's tower and the entrance portico with semicircular arches supported by stone columns.

Images (a-d): DucatoEstense.com



a.



b.



c.



d.



e.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, or due to intense rainfall)

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- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

(Implement the information regarding both the characterization of the soil type and stratigraphy and the foundation system.)

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers)

- Localized erosion, with a long lasted action, can wash out clay mortar from masonry (action of water and eventual debris).

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials (masonry, frescoes...) due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).
- Higher humidity levels can foster the growth of mold and fungi, causing organic materials' damage (wooden structures, frescoes,...)

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Thermoclastism caused by temperature fluctuations;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials;
- The erosive action of wind can facilitate the loss of material and especially decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements, especially windows (glass and shutters) and roof's components.

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate stone surfaces. The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofs may no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves;

Heavy rain and storm phenomena can damage roof covering and other roof elements, especially clay tiles.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially tiles and the soaring elements like the battlements and the chimneys.

03.6

HISTORICAL URBAN CENTER'S GREEN AREAS



POTENTIAL IMPACTS
on the vegetation

Drought:
Reduced water availability can cause dehydration, leaf loss, and increased susceptibility to pests and diseases.

Heat:
Heatstress, both chronic and abrupt, affects plant growth and development. Heat waves can damage leaves and root systems.

Flood:
Excess water can lead to root asphyxiation, rot, and also reduce tree stability.

Wind:
Strong winds can uproot or break large trees, while prolonged wind stress can compromise tree stability.

GREEN AREAS:

- Public (including historical parks and gardens)
- Private (including historical parks and gardens)

0 300 m

ANALISED HISTORICAL GREEN AREAS

To identify distinctive features exposed to the different impacts considered for green/natural areas: Drought, heat, flood, wind.

(a) Parco Massari

named after the adjacent palace built in the late 16th century, is the largest public garden within the city walls, covering an area of approximately four hectares. Designed in 1780 by the Ferrarese architect Luigi Bertelli for Marquis Camillo Bevilacqua (1745–1821), this garden was renowned for its numerous sculptures and the great variety of citrus trees and flowering plants that filled its magnificent pathways with fragrance.
In the mid-19th century, the Massari family acquired the palace and transformed the entire complex into an English garden. The layout of the flowerbeds retains its 19th-century design, and many trees are centuries old. Notable species include the two Lebanese cedars at the entrance, several yews, an imposing ginkgo, and the giant oak near the Corso Ercole I d'Este entrance.
Since 1936, the park has been owned by the Municipality of Ferrara and has been designated as a public park.

(b) Piazza Ariostea

The construction of the square is attributed to Duke Ercole I (1431–1505), who established it as a representative space of great political, urban, and ideological significance. In addition to hosting the city market, the square became the stage for the *spectacula* of ducal magnificence and housed one of the most imposing equestrian monuments of the Italian Renaissance, erected in honor of the duke himself, the promoter of the grand urban expansion of the city (Addizione Erculea). While in the 19th century, it became a symbol of the city's identity, in 1833, the statue of Ludovico Ariosto marked its transformation into a cultural and social space. Today, the square retains its historical significance and is renowned for the Palio of Ferrara, which revives ancient Renaissance traditions.

(c) Giardino di Palazzo Costabili

The Neorenaissance garden of Palazzo Costabili (National Archaeological Museum) is an imaginary reconstruction of a Renaissance garden carried out in the 1930s. Prior to this, the garden was simply cultivated as a vegetable plot. The garden is divided into sections with boxwood hedges, outlining the flowerbeds and preserving the alignments of the existing pathways. After the 1950s, a labyrinth, a rose gallery, and various tree species were added, including Cupressus arizonica, yews, Thuja species, Robinia trees, and firs. The successive 20th-century interventions thus erased the original formal layout of the Renaissance garden, which had been designed for horticultural purposes. The current appearance of the garden is the result of restoration work completed in 2010 (under the direction of the Ministry of Cultural Heritage and Activities), which respected the geometric pathways and the backdrop formed by the monumental Cedrus libani.

Interreg
Co-funded by the European Union
Italy – Croatia
CAMPUS

a



b







c









A 1.2 Mapping of priority intervention areas and related impact classes

STEP 1

Interreg

Co-funded by the European Union

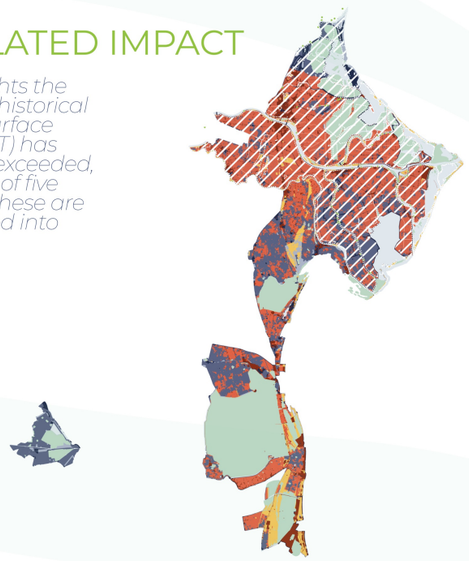
Italy – Croatia

CAMPUS

PRIORITY INTERVENTION AREAS

HEAT-RELATED IMPACT

The map highlights the areas where the historical average Land Surface Temperature (LST) has frequently been exceeded, showing two out of five impact classes. These are further subdivided into land cover units.



6 km

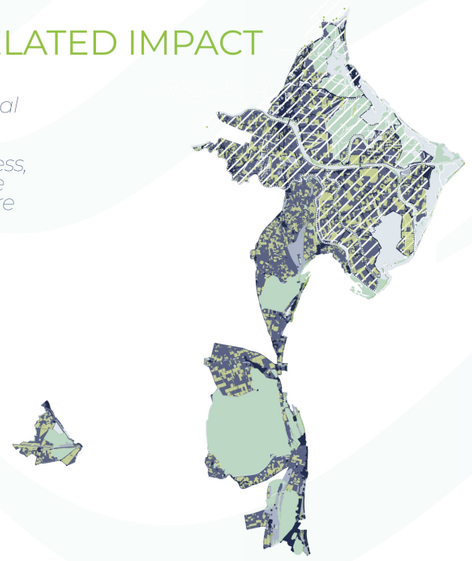
PRIORITY AREAS
- Urban areas
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas
- Wet areas

DROUGHT-RELATED IMPACT

The map highlights the areas where the historical average Vegetation Health Index (VHI) has frequently indicated stress, showing three out of five impact classes. These are further subdivided into land cover units.



6 km

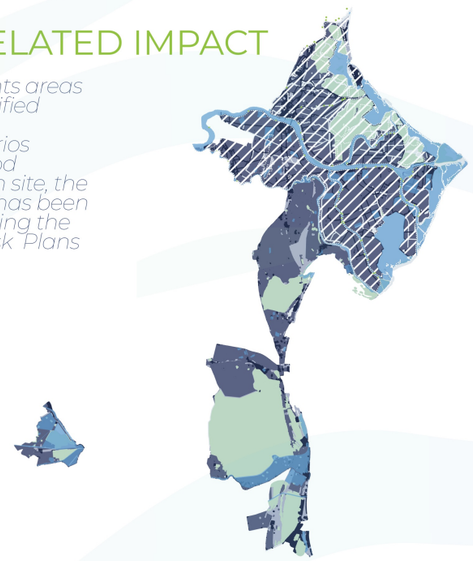
PRIORITY AREAS
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas
- Wet areas

FLOOD-RELATED IMPACT

The map highlights areas at flood risk, identified through hazard probability scenarios based on the Flood Directive. For each site, the highest risk class has been selected, considering the regional Flood Risk Plans for each area.



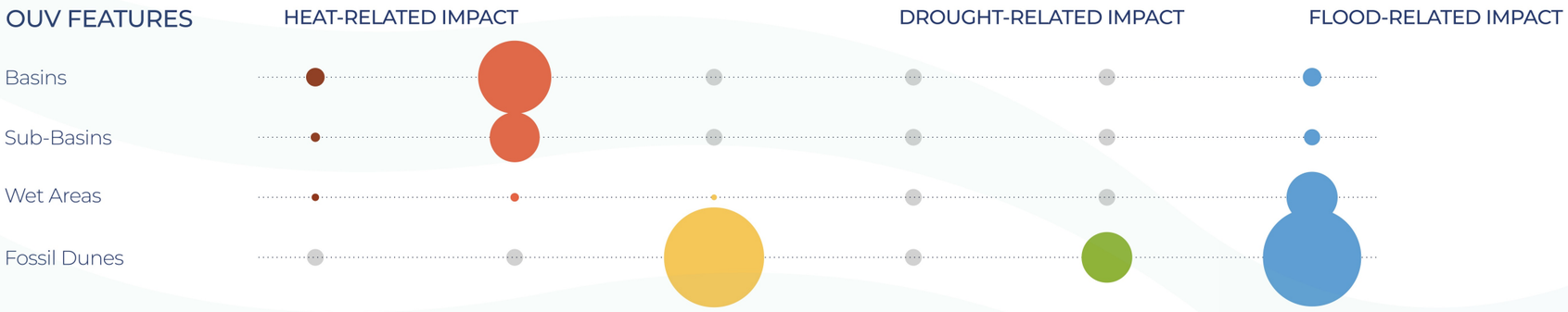
6 km

PRIORITY AREAS
- Urban areas
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas
- Wet areas

INTERACTION BETWEEN IMPACTS AND OUTSTANDING UNIVERSAL VALUES



PO DELTA

A 1.2 Mapping of priority intervention areas by morpho-typological class

STEP 2

Interreg

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CAMPUS

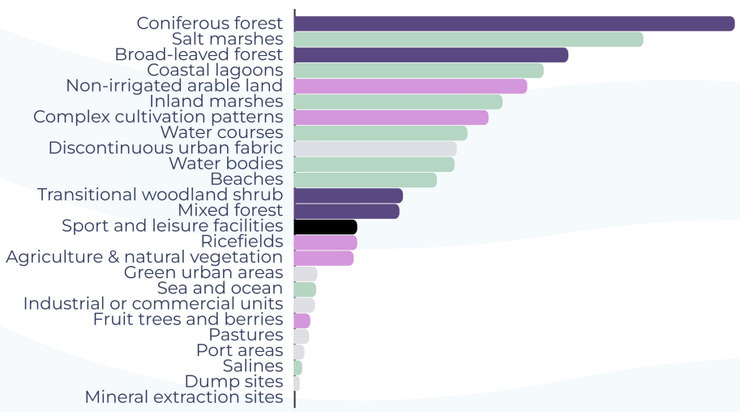
PRIORITY INTERVENTION AREAS

BY POTENTIAL VALUE OF AFFECTED **ECOSYSTEM SERVICE**

The map highlights the most sensitive areas categorized by the potential value of affected ecosystem services, based on the Burkhard matrix applied to the land cover of each site.



POTENTIAL PROVISION VALUE BY LAND COVER CLASS



REGULATING SERVICES	
Global climate regulation	Wetlands and reed beds store carbon, contributing to global climate regulation
Local climate regulation	The water and marshland areas regulate local temperatures, with a cooling effect in hot seasons
Air quality regulation	Wetlands and vegetation act as filters for particulate matter and pollutants, improving air quality
Water flow regulation	Floodplains: The floodplains of the delta act as natural water regulators, reducing the risk of floods by absorbing excess water
Water purification	Barene; River Branches: Riparian vegetation and wetlands naturally filter water, improving its quality by absorbing nutrients and pollutants
Nutrient regulation	Barene; River Branches: These elements act as buffers for nutrient loads, helping to prevent eutrophication in water bodies
Erosion regulation	Fossil Dunes; Sandbars; Forests: These features protect the coastline from erosion, while stabilizing the soil in the interior regions
Natural hazard regulation	Sandbars: They serve as natural barriers against storms and rising sea levels, protecting the coastal areas of the delta
Pollination	Sandbars; Forests: These habitats host several pollinator species
Pest and disease control	The diverse wetland ecosystem supports species that naturally control pests and diseases
Regulation of waste	Wetlands and river systems break down and absorb waste, purifying the water and promoting nutrient cycling
PROVISIONING SERVICES	
Crops	Land reclamation system: It has made it possible to cultivate the land in the delta area, and which annually generates agricultural products and supports the local economy
Fodder	Land reclamation system: Reclaimed land also supports fodder production, sustaining livestock farming
Livestock (domestic)	Land reclamation system: The agricultural systems of the delta support livestock production, an important resource for local economy
Aquaculture	Lagoons; Fishing Valleys: They are vital ecosystems for the local fishing industry, providing a rich source of fish contributing significantly to the local economy
Fish, seafood & edible algae	Fishing Valleys: The fishing valleys of the Po Delta are specifically managed for aquaculture
Wild foods & resources	Lagoons: The lagoons provide wild foods such as fish, shellfish, and natural resources harvested by the local fishermen and population
CULTURAL SERVICES	
Recreation & tourism	The delta landscape attracts visitors due to its biodiversity, scenic beauty, and recreational opportunities, contributing to the regional economy
Landscape aesthetics & inspiration	The landscape is a source of aesthetic and cultural inspiration, having influenced art, architecture, and literature
Knowledge systems	The agricultural, fisheries, and handicraft sectors of the Po Delta are essential for the local economy, biodiversity conservation, and cultural heritage promotion
Natural heritage & natural diversity	The biodiversity and natural heritage of the delta represent a universal value beyond direct economic benefit, contributing to the conservation of biological diversity

PO DELTA

A 1.2 Mapping of priority intervention areas and related impact classes

STEP 1

Interreg

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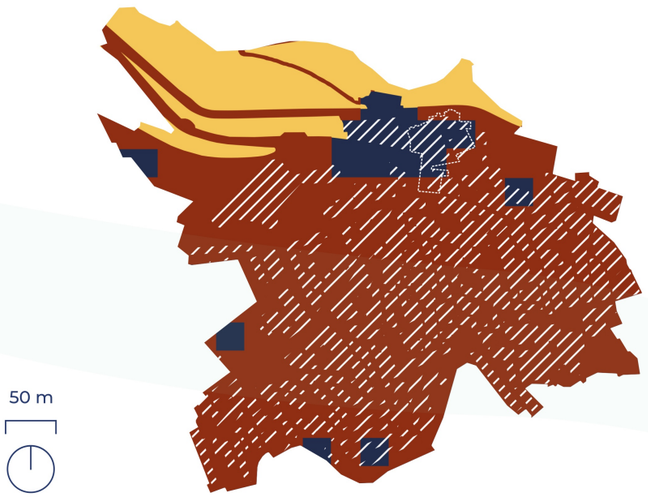
PRIORITY INTERVENTION AREAS

HEAT-RELATED IMPACT

The map highlights the areas where the historical average Land Surface Temperature (LST) has frequently been exceeded, showing two out of five impact classes. These are further subdivided into land cover units.



PRIORITY AREAS
- Urban areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Forests and seminatural areas

DROUGHT-RELATED IMPACT

The map highlights the areas where the historical average Vegetation Health Index (VHI) has frequently indicated stress, showing three out of five impact classes. These are further subdivided into land cover units.

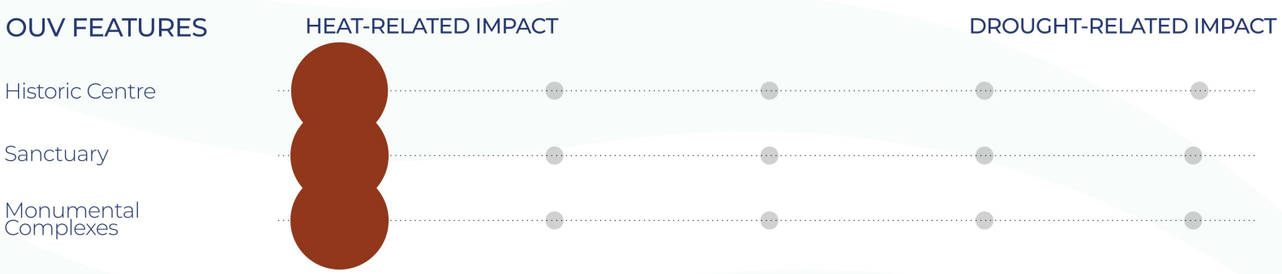


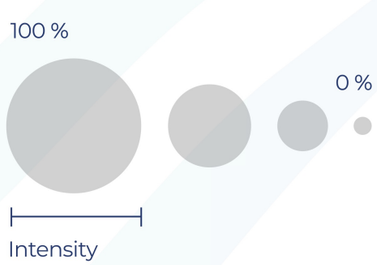
PRIORITY AREAS
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas

INTERACTION BETWEEN IMPACTS AND OUTSTANDING UNIVERSAL VALUES





THE SANCTUARY OF SAN MICHELE

02 The Sanctuary of St. Michael the Archangel

STEP 2 *for the Built Component Matrix*



Core and Buffer zone of the Site

MONTE SANT'ANGELO

0 75 m

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OUV TANGIBLE FEATURES:

- The Sanctuary and heritage system

Heritage system in the buffer-zone:

- Architectural landmarks
  - 2 Norman-Swabian and Aragonese Castle
  - 3 Monumental complex of S. Pietro (Baptistery of St. John in Tumba, Church of S. Maria Maggiore, Church of St. Peter's remains)
  - 4 Monastery and Church of San Nicolò
  - 5 Monastery and Church of Santissima Trinità
  - 6 Monastery and Church of San Francesco d'Assisi
  - 7 Church of S.Salvatore
  - 8 Cassa Palace
- Historical urban center's buildings

ANALISED FEATURES:

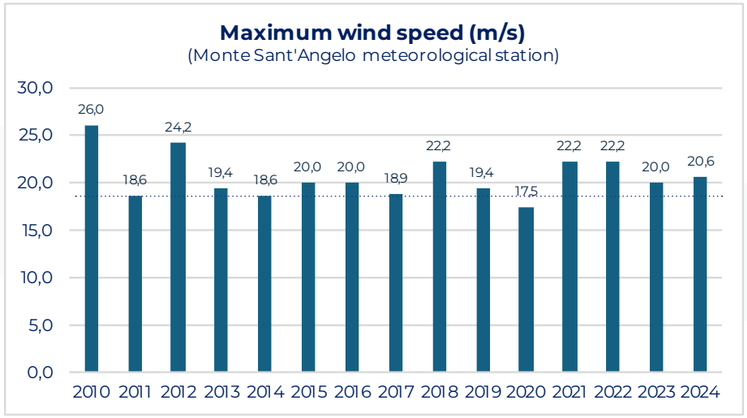
- (1) The Sanctuary
  (Ref. Analysis Sheets 02.1)

OTHER URBAN ELEMENTS:

- Forest and seminatural areas
- Other buildings

PAST EXTREME EVENTS

STRONG WINDS

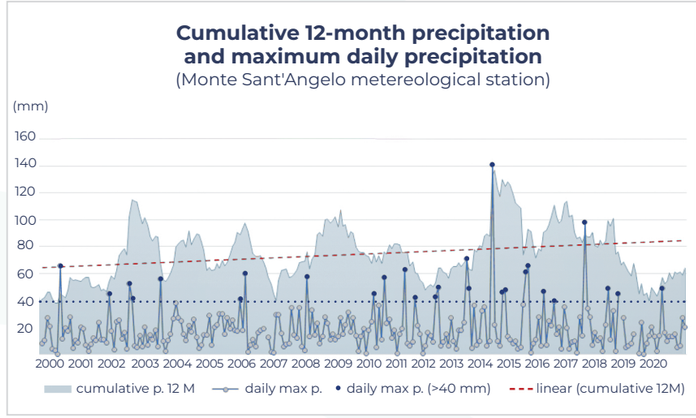


Maximum wind speed registered in 2010: 26 m/s

NE and E prevailing wind in Monte Sant'Angelo

Moderate-intensity winds (>20 m/s) have been recorded almost every year over the past 15 years.

INTENSE RAINFALL

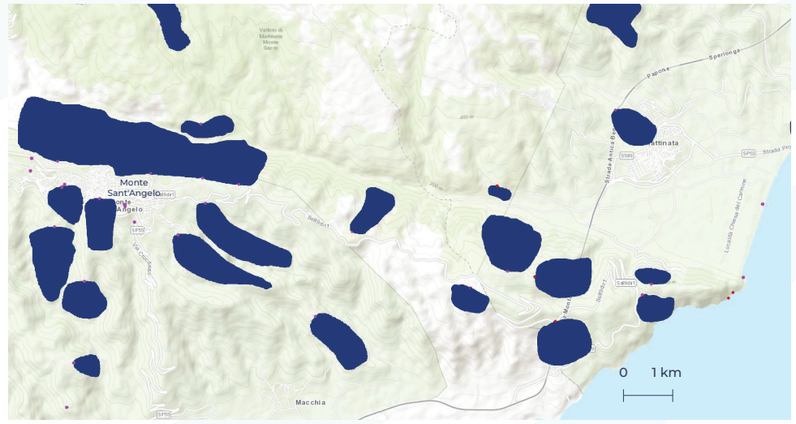


Maximum daily precipitation registered in 2014: 141 mm

An increase in maximum daily rainfall and annual cumulative precipitation is observed.

Source: Regione Puglia, "Contesto climatico - Indirizzi per la stesura della Strategia Regionale di adattamento ai cambiamenti climatici (SRACC)", 2023.

LANDSLIDE



- Areas interested by Collapse/Toppling
- Landslide Phenomenon Identification Point (PIFF)

Source: Carta Inventario dei Fenomeni Franosi (IFFI Inventory), Ispra.

02.1

THE SANCTUARY COMPLEX



Image: Management Plan 2.0 (2022-2027) - The Longobards in Italy. Places of the Power (568-774 A.D.), november 2021.

- stone materials (limestone)
- ceramic materials
- mortars and plasters
- frescoes and paints
- wood
- metallic materials (copper)
- metallic materials (bronze)

The Sanctuary of Saint Michael the Archangel, in Monte Sant'Angelo, consists of a series of buildings that develop around the natural cave carved into the limestone. The different components of the Sanctuary reveal its phases of transformation. Between the 7th and 8th centuries, both the staircase leading to the altar of the cave and a small two-nave building were constructed, along with a series of crypts for pilgrims. Later, in the 13th century, during the Angevin period, the majestic central cross-vaulted nave was built above the cave's entrance, and the Angevin staircase was added, connecting the cave directly to the current upper atrium. This exterior space is dominated by the Sanctuary's facade and the octagonal bell tower, built in the second half of the 1200s.

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES

The foundations utilize the natural limestone soil. The Sanctuary is carved into the rock, with crypts and underground spaces forming part of the foundational system. The local limestone (Gargano calcarenite) is generally more porous than compact limestone, making it more susceptible to weathering and deterioration due to water action and humidity.

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

Masonry is characterized by regular shaped stone blocks (local limestone)
Most of the complex's buildings feature exterior exposed stone walls (except for the facade of the Madonna della Libera, which has a plastered wall).
Horizontal structural elements: vaults and arches (limestone)

Doors/windows local limestone frames.

The copper-based door, manufactured in Constantinople in 1076 AD and located at the Basilica's entrance,ed is enrich by numerous engravings, polychrome decorations, inlays and *niello*.

Presence of decorative elements:
The facade of the Basilica is adorned with stone sculptures (including the S.Michael statue), a richly carved stone decoration on the frame and other decorative elements (bronze cross).
The three crypts are filled with numerous artifacts, fragments, frescoes, and significant wall writings and graffiti (rich epigraphic corpus, consisting of approximately 200 pilgrims' inscriptions carved in the interior limestone walls). The Sanctuary's museums showcase various sculptures found during the excavations, as well as artifacts and donations from various pilgrims.
(The surfaces inside the Church of the Madonna della Libera are completely plastered, with both faux marble - on the entablatures and on the bodies of the lesenes and columns - and stucco decorations).

B01.3 | VERTICAL CONNECTIONS

The interior Angevin staircase, built in local limestone, connect the cave directly to the upper atrium.

C01 | ROOFS

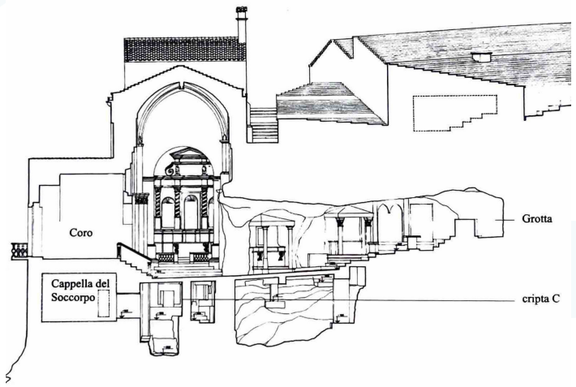
C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

The roofs covering is made of ceramic tiles
(It is necessary to analyze the rainwater drainage system)

C01.2 | SOARING ELEMENTS

Presence of decorative elements on the top of the facades.

FIGURES:
a. Perspective section N-S of the Sanctuary, following 1950s excavations (author: N.Tomaiuoli).
b. Pilgrims' names engraved on limestone by a local lapicides. *Source: UNESCO WHL-nomination file 1318 (2011).*
c. Lombard spaces known as "Crypt B" and "Crypt C". *Source: Caliandro, L.P., Angelucci, F. (2016).*
d. The Cave with the Altar of Saint Michael the Archangel.



a.



b.



c.



d.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01 | ATMOSPHERIC MOISTURE CHANGE

01.1 | FLOODS

Localized flooding in this site is not common, but can occur due to the limited capacity of infrastructure (drainage systems) to manage large volumes of rain water. As a consequence, the following may occur:

- Settlements—often differential—can occur in the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability (some areas of the municipal territory, localized on top of a hill, are classified as moderate to high risk (PG1-PG2) in the PAI plans.[1] Landslides are often associated with soil instability following heavy rainfall)

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

1. *Piani di Assetto Idrogeologico (PAI) of Puglia Region.*

B01 | ELEVATED STRUCTURES

01 | ATMOSPHERIC MOISTURE CHANGE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (masonry, frescoes...) due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).
- Higher humidity levels can foster the growth of mold and fungi, causing organic materials' damage (frescoes, wooden structures...)

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves, snow)

- Thermoclastism caused by temperature fluctuations can cause expansion and contractions of materials, resulting in cracking, weakening and damage to the stonework;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials (especially limestone);
- Wind-driven atmospheric particulate and sand can cause corrasion and facilitate the loss of decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements.
- Flying debris carried by the wind can damage and break the building's envelope components (mainly the glass windows).

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate surfaces (limestone). The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01 | ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofs may no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves;
- Heavy rain and storm phenomena can damage roof covering and other roof elements.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves, snow)

- Prolonged exposure to high temperatures can lead to surface cracking.
- Snow load exceeding the building's capacity can lead to structural damage.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially the soaring one like, in this case, the decorative elements on the top of the facades.

A 1.2 Mapping of priority intervention areas and related impact classes

STEP 1

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PRIORITY INTERVENTION AREAS

HEAT-RELATED IMPACT

The map highlights the areas where the historical average Land Surface Temperature (LST) has frequently been exceeded, showing two out of five impact classes. These are further subdivided into land cover units.



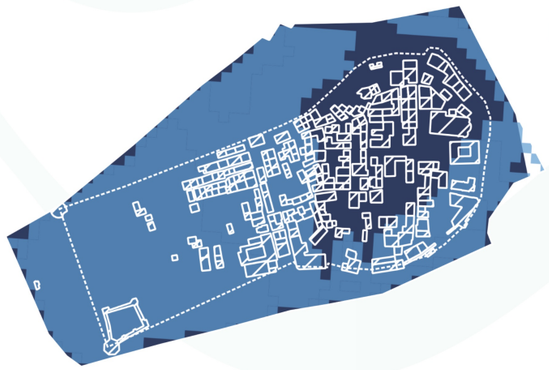
PRIORITY AREAS
- Urban areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Forests and seminatural areas

FLOOD-RELATED IMPACT

The map highlights the areas where the historical average Vegetation Health Index (VHI) has frequently indicated stress, showing three out of five impact classes. These are further subdivided into land cover units.

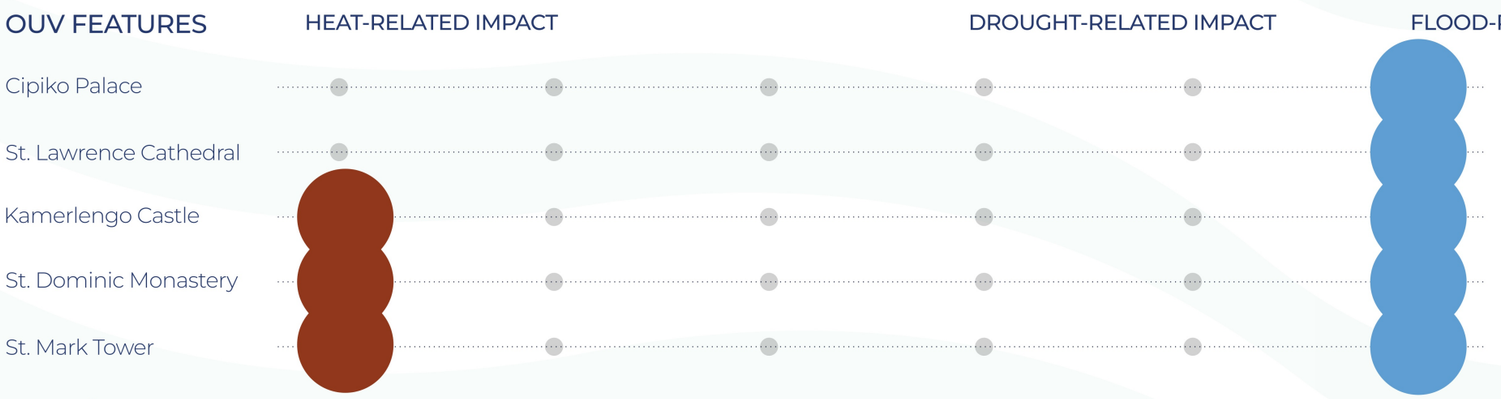


PRIORITY AREAS
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas

INTERACTION BETWEEN IMPACTS AND OUTSTANDING UNIVERSAL VALUES



HISTORIC CITY OF TROGIR

01 Historic city of Trogir

STEP 2 *for the Built Component Matrix*

Interreg

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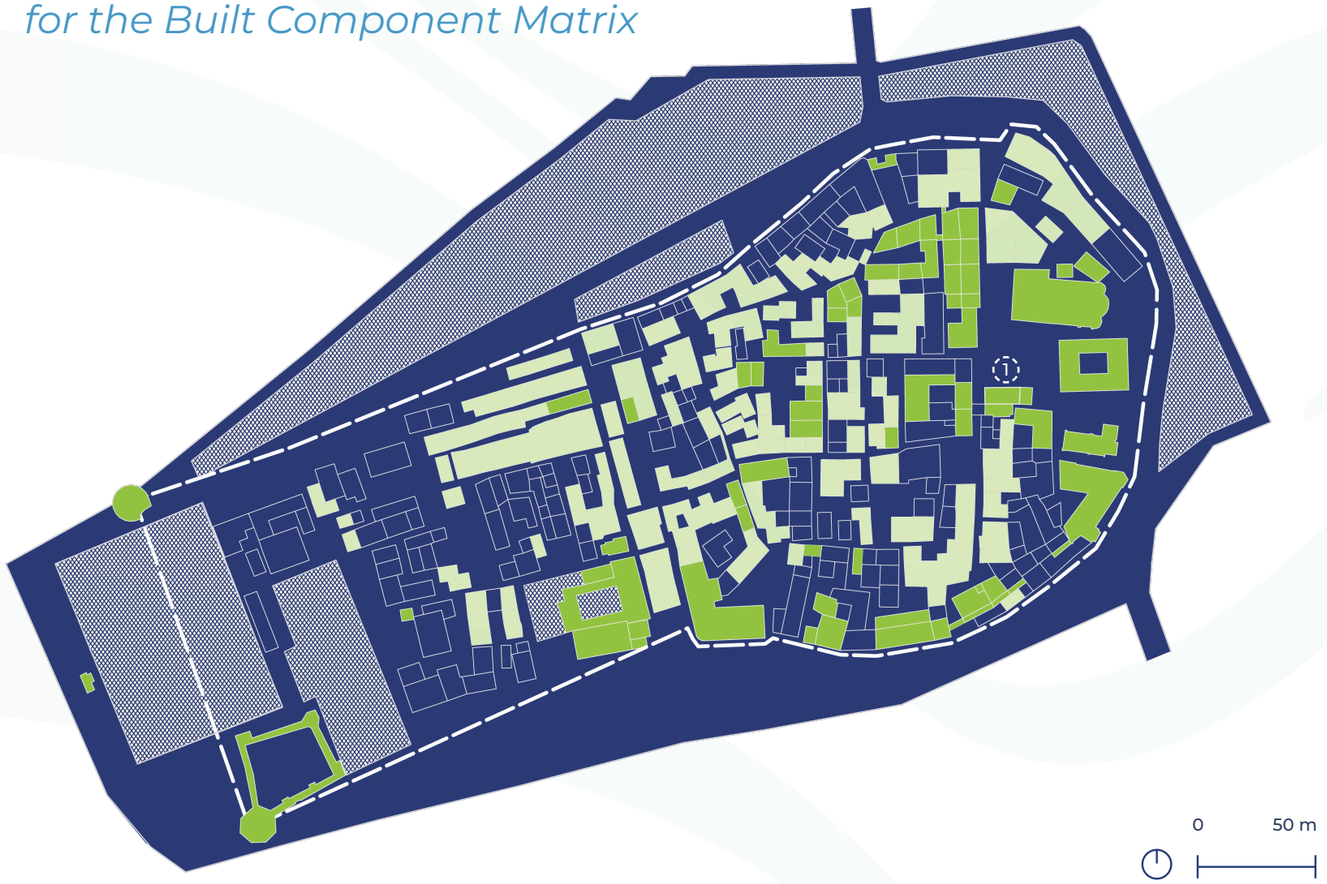


OUV TANGIBLE FEATURES:

- Architectural Landmark
- Morphotypological Group 1 Buildings

ANALISED FEATURES:

- Morphotypological Group 1 Buildings
- 1 Town Lodge

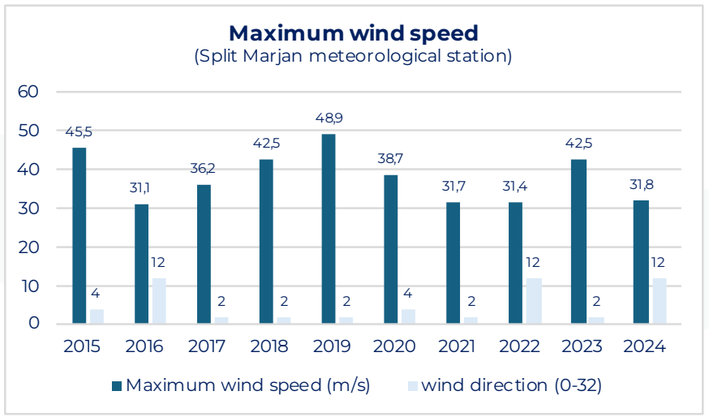
(Ref. Analysis Sheets 01.1, 01.2)

OTHER URBAN ELEMENTS:

- Public and Private Green Areas
- Other buildings

PAST EXTREME EVENTS

STRONG WINDS



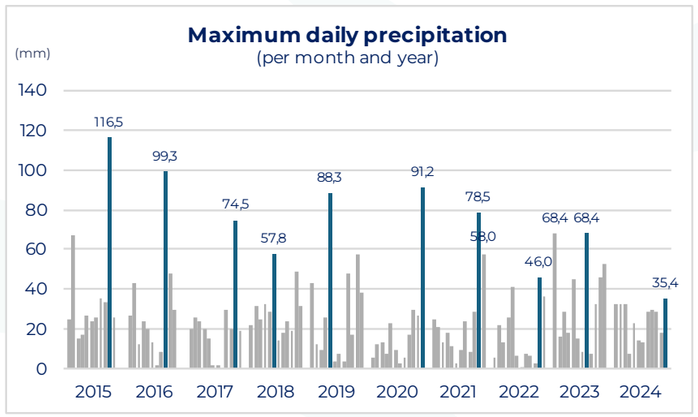
At least one occurrence of strong winds is registered annually.

Maximum wind speed: 48,9 m/s - Wind direction: 2 (or 22,5°)*

SW prevailing wind in Trogir (source: StruSoft Climate data)

**0-32: coding system based on the wind rose, divided into 32 sectors, with each sector representing an 11.25-degree interval (0= North 8=East, 16=South, 24=West)*

INTENSE RAINFALL



Maximum daily precipitation: October 2015: 116,5 mm

FLOOD due to intense rainfall



Photos: Marin Buble, Antonio Miše

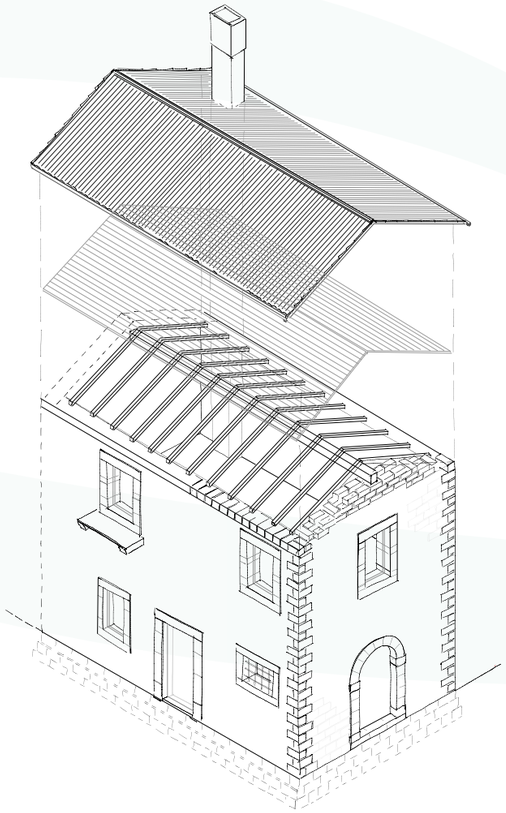
Last flood events:

January 2019

November 2019

01.1

MORPHOTYPOLOGICAL GROUP 1



- ceramic materials
- wood
- stone materials
- metallic materials
- mortars and plasters

Residential buildings'blocks in the eastern tip of the islet, where the Ancient Tragurion grid is still recognizable, has also retained evidence of the early mediaeval period's layout. An external staircase along the façade allows for the separation of the economic and residential functions of these buildings. The distinctive features of Romanesque houses (mostly preserved in the external façades - narrow and relatively tall), are also recognizable in the predominant use of the local limestone as building material, and in the shapes of the door and window frames. A few decoration are carved into limestone elements.

Min. height: 2 floors | Max. height: 4 floors

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATIONS

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

The foundation techniques are related to the characteristics of the soil (predominantly alluvial) and the use of local limestone. The buildings are probably constructed on the foundations of earlier structures also built in stone, as evidenced by the results of some archaeological excavations in the eastern tip of the islet.

The local Seget stone (low porosity limestone) is used to build the majority of Trogir's buildings. This provides good water resistance and, consequently, high durability, reducing the level of impacts due to water action and humidity (especially in the parts of the building in contact with the ground).

B01 | ELEVATED STRUCTURES

B01.1 | VERTICAL CLOSURE

Masonry is characterized by regular shaped stone blocks (In the case of palaces, public buildings) or irregular blocks with mortar. In any case, large regular shaped blocks form the corners of the buildings.

Mostly exposed stone walls. Plaster finishes are scarse (in the past the irregular stone masonry was likely covered with plaster).

The Seget stone (usually from Sutilije) due to the degradation of the material, gradually acquires a characteristic warm yellow-light brown color).

Horizontal structural elements: semicircular arch doors (stone)

Doors/windows stone frames (usually non-projecting frames that give the façade a completely plain surface).

Presence of decorative elements: scarse in the common residential buildings (the ones that exist help identify the Romanesque style).

B01.3 | VERTICAL CONNECTIONS

Stone stairs are located on the exterior of historic buildings (feature of the urban layout)

B01.4 | OVERHANG ELEMENTS

Presence of a few balconies and window sills (likely dating back to the 13th century) that rest on wooden or stone brackets.

C01 | ROOFS

C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

Ceramic tiles (the stone slate roof of historical houses have been lost) lay on wooden boarding, and it's supported by a wooden structure.

Only a few metallic gutters (No stone gutter for rainwater collection have been preserved, perhaps the roofs were not equipped with them).

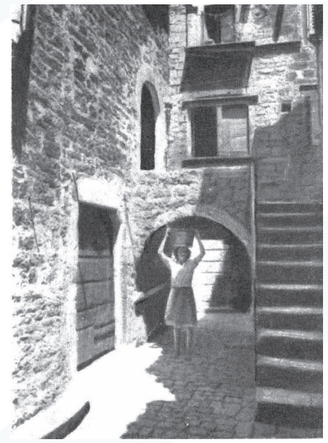
C01.2 | SOARING ELEMENTS

Presence of high chimneys.

FIGURES:

a. Romanesque house with an external staircase.
b. Window sill supported on wooden brackets.
c. The Garagnin-Fanfogna Palace. Section of the "Old Houses" (left) and the "New Houses"(right). *State Archives in Split.*
d. Decorated frame of a "double-lancet window".
e. The common type of a stone Romanesque window.

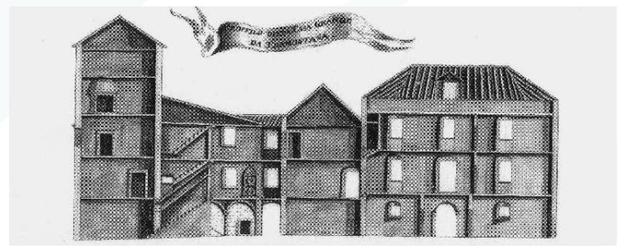
Sources: Fisković, C. (1952), Babić, I. (2016)



a.



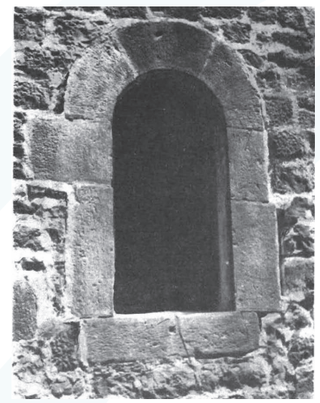
b.



c.



d.



e.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, sea, or due to intense rainfall)

- Settlements, often differential, of the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry;
- Cracking or structural failure caused by the lateral hydrostatic pressure on basement walls and foundations exerted by floodwaters;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, seas)

- Localized erosion, with a long lasted action, can wash out clay mortar from masonry (action of water and eventual debris).

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Thermoclastism caused by temperature fluctuations;
- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts;
- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

03 | WIND

- Wind-driven rain lead to moisture's penetration into porous materials (especially limestone);
- Wind-transported salt can cause alveolization ;
- Wind-driven atmospheric particulate and sand can cause corrasion and facilitate the loss of decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements, especially windows (glass and shutters) and roof's components.

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate surfaces (limestone). The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

C01 | ROOFS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES

- Cracks, fractures, detachments and loss of materials (clay tiles) due to moisture absorption.

01.3 | INCREASE IN RAINFALL AND INTENSE RAINFALL

- The rainwater disposal systems in roofsmay no longer be adequate due to changes in rainfall patterns and the intensification of extreme precipitation events. Consequently, necessary modifications may affect the preservation of the characteristic appearance of historic buildings, as well as the historic systems themselves;
- Heavy rain and storm phenomena can damage roof covering and other roof elements.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially the soaring one like chimneys.

01.2

THE LOGGIA



Image: Photograph Collection of the Department of Art History of the Universität Wien.

- **stone material 1:** limestone
- **stone material 2:** Marble (cipollino)
- **stone material 3:** Granite
- **ceramic materials**
- **mortars and plasters**
- **paints**
- **wood**

The municipal Loggia was first constructed at the end of the 13th century. It is located in the central square of the city, as the political and economic centre and the intersection of the main streets, was a site of extraordinary public significance. After its renovation in 1471, the Loggia features a well proportioned open portico with a wooden roof supported by spolia columns (except one). It undergoes several transformations over the centuries, until the 1892 restoration, when the roof was rebuilt.

CONSTRUCTIVE FEATURES AND MATERIALS

A01 | FOUNDATION

A01.1 | SOIL, FOUNDATION'S STRUCTURES, SITE DRAINAGE

The structure stands on a basement made of regular shaped blocks of Seget stone (low porosity limestone) and precise joints, without visible mortar.

B01 | ELEVATED STRUCTURE

B01.1 | VERTICAL STRUCTURE

Vertical structural elements: The vertical supporting structure consists of six columns with capitals - ancient Corinthian and Gothic, arranged on the open sides facing the square. The columns (except one) are ancient spolia. One of them is made of three pieces of different stone materials, the largest one is made of granite. Two of the columns are carved from cipollino: the third, to the right of the entrance, and the fifth, at the corner, on which the coat of arms with the heraldic features of the Loredan family is carved.

The side adjacent to the Clock Tower is made of stone masonry, with the same characteristics of the basement. The longer side wall is plastered.

Presence of decorative elements: several decorations and inscriptions carved into many stone elements, in addition to the bas-relief depicting the Lion of Saint Mark, surrounded by various other sculpted figures. The stone balaustrade present a carved inscription.

B01.3 | VERTICAL CONNECTION

Semicircular stone stairs lead to the loggia from the lower level of the square.

C01 | ROOF

C01.1 | HORIZONTAL CLOSURE (roof's structure, water drainage system)

Horizontal structural elements: The roof structure is made of wooden beams, on which rests a painted wooden boarding. The double-pitched roof is covered with ceramic tiles

There's no stone gutter for rainwater collection

FIGURES:

a. State of the the loggia without a roof (photograph taken before the 1890 restoration). Source: *Photograph Collection of the Department of Art History of the Universität Wien.*

b. Corner pillar with a Gothic capital and with a coat of arms featuring the heraldic traits of the Venetian Loredan family.

c. Interior of the Loggia. Reliefs above the judge's table with the lion of St. Mark (archival photograph from the early 20th century). *Source: Babić, I. (2016)*



a.



b.



c.

POTENTIAL IMPACTS ON EXPOSED ASSETS
Climate indicator | Climate change effects | Impacts

A01 | FOUNDATIONS

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.1 | FLOODS (rivers, seas, or due to intense rainfall)

- Settlements, often differential, of the foundations, caused by the loss of soil bearing capacity or stabilization;
- Long lasted action can even wash out clay mortar from masonry (*The stone masonry of the loggia features very thin joints, so its vulnerability to this impact is significantly reduced*);
- Cracking or structural failure caused by the lateral hydrostatic pressure on basement walls and foundations exerted by floodwaters;
- Structural settlements due to localized erosion of subsoil and/or foundations.

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence - on surfaces and/or subflorescence - beneath surfaces) | wet-dry process.

01.3 | INTENSE RAINFALL

- Heavy rainfall can lead to ground instability.

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

B01 | ELEVATED STRUCTURES

01|ATMOSPHERIC MOISTURE CHANGE, SEA LEVEL RISE

01.2 | CHANGES IN HUMIDITY CYCLES AND SEA-SALT CHLORIDES

- Cracks, fractures, detachments and loss of materials due to moisture absorption and crystallization of soluble salts within them (efflorescence and/or subflorescence).

01.3 | INTENSE RAINFALL

- The mechanical action of wind driven rain can lead to erosion;
- The constant presence of humidity can increase biological growth on surfaces;
- Surface recession can occur in areas exposed to rain washout. (chemical attacks from clean rain - karst effect, acid rain - sulfuric and nitric acids, and dry deposition of gaseous pollutants - particularly SO_2 and NOx).

01.4 | INCREASE IN TIME OF WETNESS

- Actions and damage related to volumetric changes, chemical action, loss of strenght, caused by the saturation of materials with water.

02 | TEMPERATURE CHANGE

02.1 | DIURNAL, SEASONAL, EXTREME EVENTS (heat waves)

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- Wind-driven atmospheric particulate and sand can cause corrasion and facilitate the loss of decorative reliefs;
- Winds, gusts and changes in direction can affect the stability of a facade's elements *(the Loggia doesn't present overhanging element, so its susceptibility to this its reduced)*.

04 | CLIMATE AND POLLUTION ACTING TOGETHER

- Acid rain can leads to the formation of black crusts on carbonate surfaces (limestone). The black crust, having a higher thermal capacity than the stone substrate, can expands more than it does and fracture.

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- Prolonged exposure to high temperatures can lead to surface cracking.

03 | WIND

- Winds, gusts and changes in direction can affect the stability of roof's components, especially the tiles.

A 1.2 Mapping of priority intervention areas and related impact classes

STEP 1

Interreg — Co-funded by the European Union

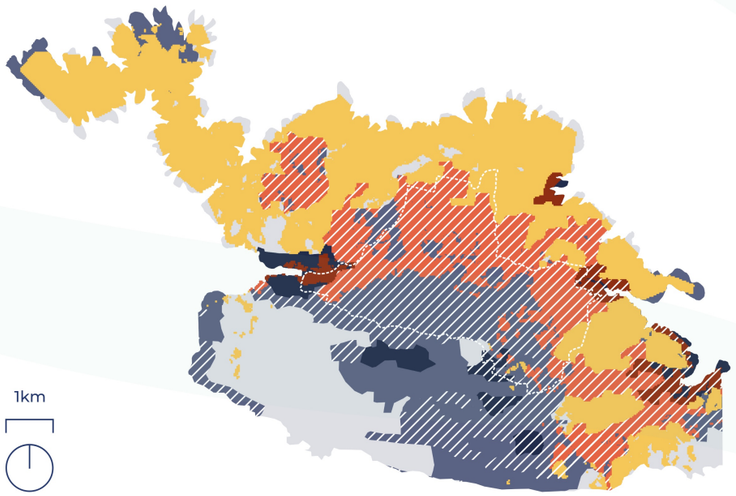
Italy – Croatia

CAMPUS

PRIORITY INTERVENTION AREAS

HEAT-RELATED IMPACT

The map highlights the areas where the historical average Land Surface Temperature (LST) has frequently been exceeded, showing two out of five impact classes. These are further subdivided into land cover units.



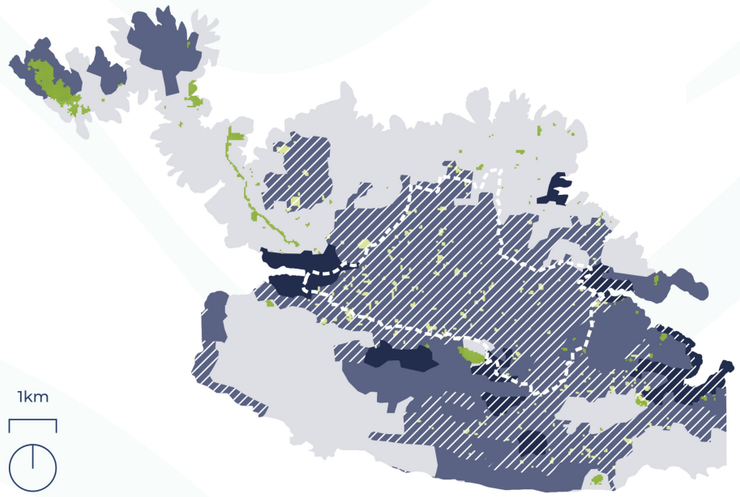
PRIORITY AREAS
- Urban areas
- Agricultural areas
- Forests and seminatural areas

UNESCO FEATURES
- Unesco Core Area
- Outstanding Universal Values

LAND COVER
- Urban areas
- Agricultural areas
- Forests and seminatural areas

DROUGHT-RELATED IMPACT

The map highlights the areas where the historical average Vegetation Health Index (VHI) has frequently indicated stress, showing three out of five impact classes. These are further subdivided into land cover units.



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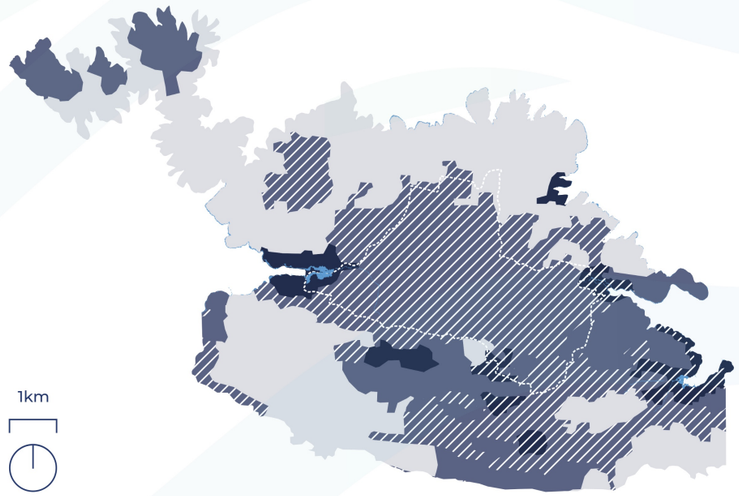
The map highlights areas at flood risk, identified through hazard probability scenarios based on the Flood Directive. For each site, the highest risk class has been selected, considering the regional Flood Risk Plans for each area.



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INTERACTION BETWEEN IMPACTS AND OUTSTANDING UNIVERSAL VALUES



STARI GRAD PLAIN

A 1.2 Mapping of priority intervention areas by morpho-typological class

STEP 2

Interreg

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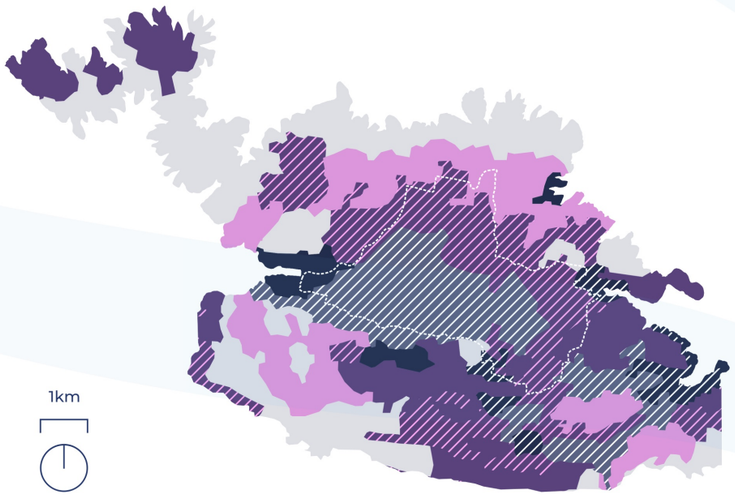
PRIORITY INTERVENTION AREAS

BY POTENTIAL VALUE OF AFFECTED **ECOSYSTEM SERVICE**

The map highlights the most sensitive areas categorized by the potential value of affected ecosystem services, based on the Burkhard matrix applied to the land cover of each site.



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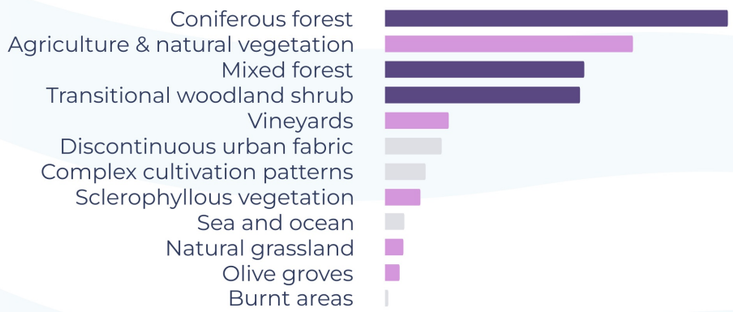
POTENTIAL PROVISION VALUE BY LAND COVER CLASS



REGULATING SERVICES	
Global climate regulation	The agricultural landscape, particularly the traditional dry-stone walls, sequesters carbon, supporting global climate stability
Local climate regulation	The patchwork of cultivated fields and natural vegetation creates a microclimate, mitigating extreme local temperatures
Air quality regulation	The vegetation and agricultural practices help filter pollutants, improving air quality
Water flow regulation	The structured landscape channels and absorbs rainfall, reducing surface runoff and soil erosion
Natural hazard regulation	The stone walls and terraces provide resilience against soil erosion and flooding risks
Pollination	Diverse crops and wild plant species attract pollinators, sustaining agricultural productivity
Regulation of waste	Farming practices and crop diversity promote natural decomposition and nutrient cycling
PROVISIONING SERVICES	
Crops	Mediterranean diet: Through the traditional cultivation of fruits, vegetables, and grains, which are essential components of the Mediterranean Diet, forming a key part of the traditional agricultural system of Stari Grad Plain; Stari Grad Plain; Suhozidi:The agricultural layout protects the cultivation of crops, supporting local food production and biodiversity
Fibre	Hvar lace: Traditionally to produce the lace has been used agave plant fiber produced into the Benedictine Convent
CULTURAL SERVICES	
Knowledge systems	Stari Grad Plain; Suhozidi: The traditional knowledge of managing the agricultural landscape, especially the cultivation and maintenance of the suhozidi (dry-stone walls), represents specialized expertise developed
Religious & spiritual experience	Cross Procession: It is a religious ritual deeply connecting the local community to the surrounding landscape, celebrating their spiritual bond with the territory
Cultural heritage & cultural diversity	Klapa singing: As a form of musical expression that strengthens local cultural identity and represents a vital example of cultural diversity and intangible heritage

STARI GRAD PLAIN

A 1.2 Mapping of priority intervention areas and related impact classes

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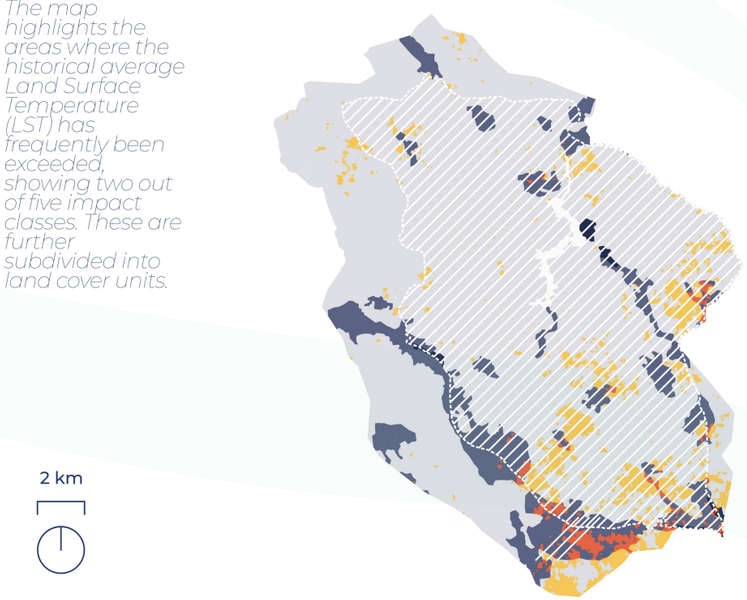

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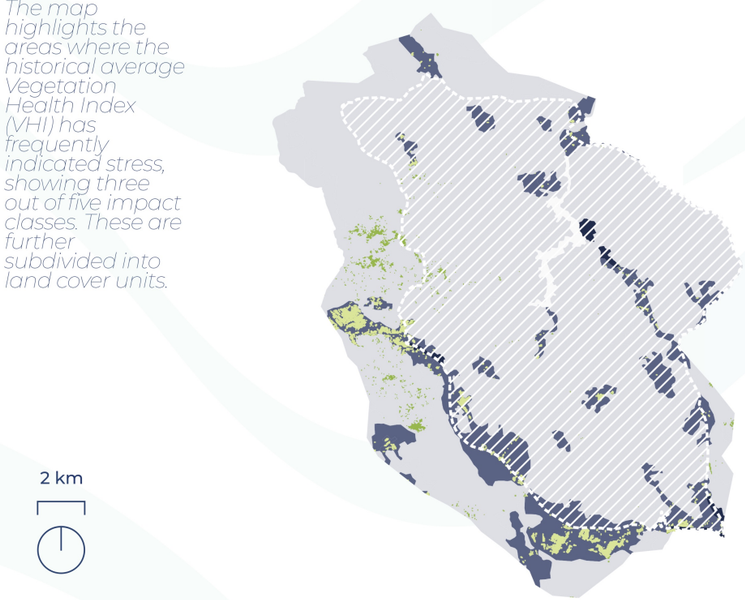

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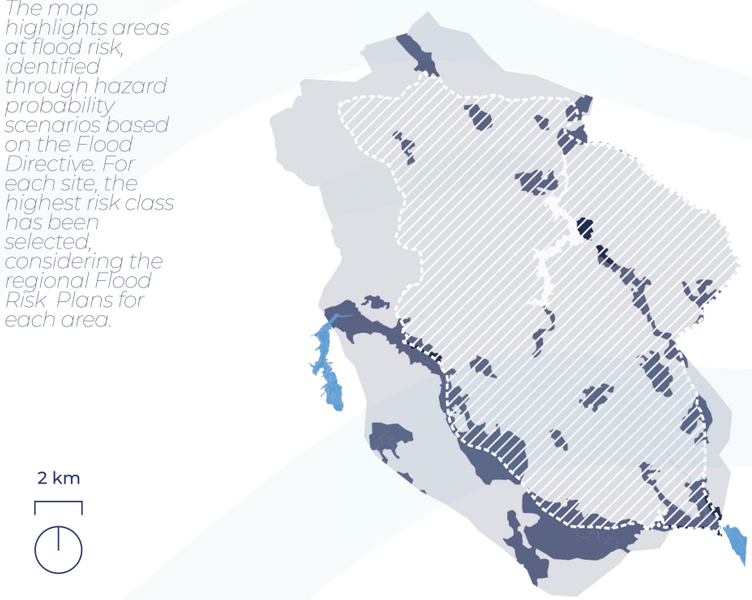

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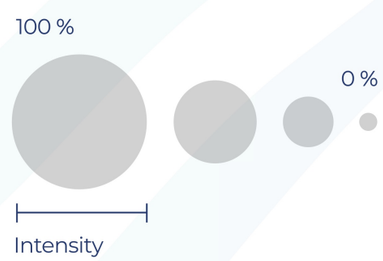
INTERACTION BETWEEN IMPACTS AND OUTSTANDING UNIVERSAL VALUES





PLITVICE LAKES

A 1.2 Mapping of priority intervention areas by morpho-typological class

STEP 2

Interreg

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PRIORITY INTERVENTION AREAS

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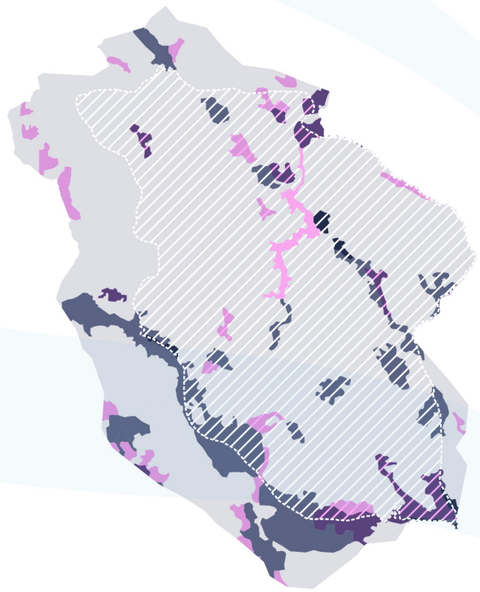

2 km

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POTENTIAL PROVISION VALUE BY LAND COVER CLASS



REGULATING SERVICES

Global climate regulation

The extensive vegetation cover acts as a significant carbon sink

Local climate regulation

The large water bodies and forests create a cooling effect, buffering temperatures

Air quality regulation

Forests and water systems filter air pollutants, maintaining high air quality

Water flow regulation

The lakes and cascading waterfalls naturally regulate water flow, reducing floods

Water purification

Karst Forms: The karst formations in Plitvice naturally filter the lakes' water by absorbing and trapping pollutants, providing a fundamental purification function

Nutrient regulation

Forests: These forests regulate nutrient cycles by recycling organic matter and maintaining the ecological balance of the system

Erosion regulation

Forests: The forests, especially the roots help stabilize the soil and prevent erosion along the lakeshores and mountainous areas

Natural hazard regulation

The karst landscape and forested catchment areas provide natural flood and erosion protection

Pollination

The rich biodiversity supports a wide range of pollinators essential for surrounding ecosystems

Pest and disease control

The diverse ecosystem hosts natural predators, regulating pests and diseases

Regulation of waste

Wetlands and forests act as natural filters, breaking down organic matter and maintaining water purity

PROVISIONING SERVICES

Freshwater

Lakes; Watercourses: Plitvice Lakes provide freshwater resources essential for local fauna and human use

CULTURAL SERVICES

Recreation & tourism

The lakes attract numerous visitors, supporting the region's tourism and recreational development

Landscape aesthetics & inspiration

The outstanding scenic beauty of the lakes and forests inspires artists and visitors alike, enhancing the aesthetic value of the site

Natural heritage & natural diversity

Biodiversity and natural heritage of Plitvice Lakes lie in the conservation of endemic species and unique habitats, providing non-material value beyond economic gain

PLITVICE LAKES