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WP3 DEFINITION AND MONITORING OF CLIMATE ADAPTATION PLANS
Activity 3.1 CLIMATE VULNERABILTY AND RISK ANALYSIS

Methodology process; 5 climate data sheets

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PP1 - MUNICIPALITY OF PESARO
PP3 - MUNICIPALITY OF MISANO ADRIATICO
PP4 - CITY OF DUBROVNIK DEVELOPMENT AGENCY DURA
PP5 - REGIONAL NATURAL PARK “COASTAL DUNES FROM TORRE CANNE TO TORRE SAN LEONARDO”

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1. Introduction

The climate vulnerability and risk analysis carried out in activity 3.1 is a first step to raise awareness and improve knowledge about climate change impacts in the pilot areas. The kind of information provided through the vulnerability and risk analysis is a fundamental component for the design of the climate adaptation plans.

The differences between the pilot areas in terms of interests expressed by local experts/decision-makers and quality/quantity of data availability have made it necessary to adopt a flexible working methodology. The methodology is based on the same main principles and step-by-step process in all the pilot areas, but it is then adapted according to the specific situations and challenges to be tackled in each case.

The methodology for the development of the climate vulnerability and risk analysis is based on a three-steps process(Fig.1):

1. the definition of the most relevant hazards and climate change impacts;
2. the selection and collection of a dataset for each pilot area;
3. the development of the vulnerability assessment.

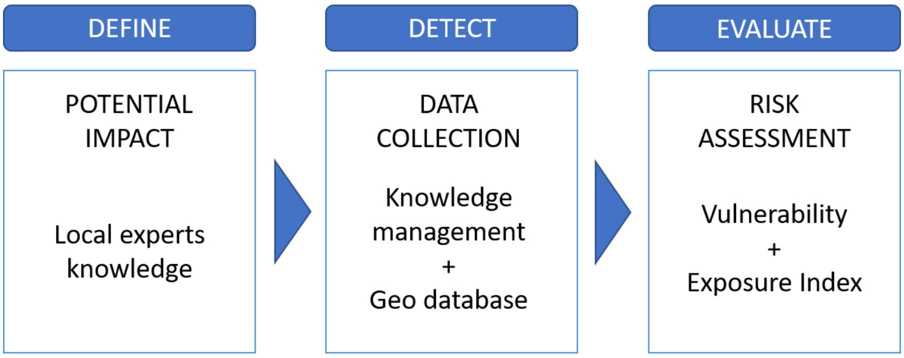


Figure 1 Action 3.1 work flow in 3 steps.

2. The definition of the most relevant hazards and climate change impacts

In order to develop an appropriate analysis for each different location, it was decided, in agreement with all partners, to focus on 4 main climate change impacts (and related hazards) identified as the most relevant for the pilot areas. In this project, "hazards" and "impacts" are defined, according to IPCC 5th report (IPCC, 2014), as follow.

<u>Hazards</u>: the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

<u>Impacts</u>: effects on natural and human systems. In this report, the term impact is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

The detection of the hazards and the potential impacts is based on two phases:

- identification of a broader group of hazards and climate change impacts;
- the selection of a narrower set of hazards and impacts that are considered to be more relevant for the pilot areas based on local expert's knowledge.

Hazards that contribute to climate change impacts that have been considered in this project are: increasing temperature; decreasing temperature; increasing extreme atmospheric events; increasing windstorms; increasing precipitations; decreasing precipitations; sea level rise. Each of these hazards, singularly or jointly, are considered to insist in different ways and with different intensity on certain macro-areas or sectors. Macro-areas that can be affected by climate change and that have been considered in this project are: agriculture; ecosystem & environment; energy; coastal areas; hydrology & water resources; socio-economic. For each sector, a set of impacts considered more relevant for the Adriatic Region have been identified (Table 1). The larger list of sectors and impacts listed in Table 1 was largely drawn from the United States Environment Protection Agency guidelines (EPA, 2018).

Sector	Impacts
Agriculture	Variation in crop yield
	Variation in livestock production
	Increased irrigation demand
Hydrology and water resources	Increase of drought
	Increase of flooding
	Increased competition for water
	Increase of urban flooding
Coasts	Increased erosion
	Coastal flooding
	Damage to costal human infrastructures
	Damage to costal natural environments
Energy	Impacts on energy infrastructures (energy plants, etc)
	Increased energy demand for cooling
Socio-economic	Increased Urban Heat Island effect
	Impacts on weakest group of people
	Impacts on commercial activities
	Impacts on public services
	Impacts on industrial activities
	Impacts on transportation network
	Impacts on tourism sector
Ecosystems and environment	Loss of species
	Loss of habitat
	Increased forest fires
	Increase of invasive species and parasites
Other	Other

Table 1 First list of climate change impacts from which the PPs are asked to choose.

Hazards, macro-areas and specific impacts have been organized in an excel sheet in the format of a questionnaire. The questionnaire has been than submitted (ANNEX I) to local experts for each pilot areas. The local experts have been asked to complete the questionnaire indicating which hazard and (no more than 4) impacts are more relevant for their territories, also linking each selected impact to the most relevant hazards. First results of the survey for each project partner can be found in ANNEXES II. The results have been then discussed with each partner.

3. The selection and collection of a dataset for each pilot area

Based on the results from the first round of climate change impacts identification, data selection and collection activities were initiated. All Project Partners (PPs) were asked to provide data and information that were considered necessary in order to proceed with the development of the risk and vulnerability assessment. Data and information requested were specific for each pilot areas and they were a consequence of the impacts previously identified. Data requested to each partner, which can be found in ANNEX III, vary from climate data (e.g. historical series of precipitation and temperature), to cartographic data to be used in GIS environment (e.g. shape files of buildings, transport networks, land use, hydrology, etc…).

The vulnerability and risk assessment is meant to be based on a GIS environment in which vulnerability and risk are geographically spatialized and visible in a set of maps. However, this is not possible for those impacts that are not possible to link to specific geographic areas.

The bulk of data and information that were initially considered useful for the analysis and that were therefore requested to the PPs were:

- DSM (Digital Surface Model) and/or
- DTM (Digital Terrain Model) (raster)
- Land Cover (.SHP)
- Land Use (.SHP)
- Protected Areas, ZPS, SIC (.SHP)
- Soil Type and geological map (.SHP)
- Administrative unit boundaries (.SHP)

- Population census data (.SHP, DATA)
- Buildings and infrastructures (street
  and railway, etc.) (.SHP)
- Slow mobility network
- Hydrology map (.SHP)
- Beach Nourishment Plan (.SHP,
  DATA)
- Cadastral data (commercial tourism activities, residential etc.) (.SHP)
- Cultural and Natural Heritage
- Tourist numbers data
- Tourist infrastructures and buildings (.SHP)
- Water consumption by sector (as detailed as possible)
- Energy Performance Certificate for Building
- Agriculture typology map
- Daily Precipitation and temperature
  data 1990 – 2017

Slight differences about the data requested can be found between partners, see ANNEX III for more details.

After this phase of data selection and collection some first challenges emerged particularly in the case of the Croatian pilot areas. In some cases, data required were not available in GIS file format or they were not available at all. The impacts that would be possible to analyze were then reconsidered and discussed with PPs. The ultimate impacts selected for each pilot area are summarized in table 2.

Pilot area	**Impacts**
Misano Adriatico	Increased coastal erosion
	Increased energy demand for cooling
	Impacts on transportation network

	Impacts on tourism sector
Pesaro	Increased competition for water
	Increased coastal erosion in natural areas
	Increased energy demand for cooling
	Impacts on tourism sector
Parco delle Dune Costiere	Variation in crop yield
	Increase of drought
	Increased coastal erosion
	Loss of habitat
Dubrovnik	Urban heat Island
	Urban flooding
	Sea level rise
Rovinj, Vrsar, Poreč	Urban heat Island
	Urban flooding
	Sea level rise

Table 2 - Ultimate list of impacts for each pilot area

4. Impacts analysis

The final phase of action 3.1 is specifically oriented to vulnerability and risk assessment related to the impacts identified in the first phase. The results of the analysis might differ from case to case according on data availability and quality. For this reason, typology and quality of the outputs are expected to be different from case to case.

In this section, the methodology applied for the development of the risk and vulnerability assessment for each climate change impacts selected by the PPs is presented. The methodology developed is largely based on the IPCC principles and methodology that can be found in the 5th Assessment Report from the IPCC (IPCC, 2014). In this report we consider Vulnerability as the Sensitivity minus the Adaptive Capacity. Therefore, Risk is equivalent to Exposure plus Vulnerability. According to IPPC' glossary:

Sensitivity: *The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct or indirect.*

Adaptive Capacity: *The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.*

Vulnerability: *The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. See also Contextual vulnerability and Outcome vulnerability.*

Exposure: *The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.*

Risk: *The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.*

The first section is dedicated to the development of two general indicators, namely "Land Surface Temperature - LST" and "Vegetated Surfaces - VS", that are used in all pilot areas to build more specific indicators according to the impact to be assessed. Both LST and VS contribute to define vulnerability (as sensitivity or adaptive capacity) for impacts such as "energy demand for cooling", "urban heat island", "impacts on tourism sector", etc. The sections that follow are specific for each pilot area and impact, except for the Croatian pilot areas that have the same impacts and share the same methodology.

4.1 Land Surface Temperature (LST)

The parameter Land Surface Temperature (LST) represents "the radiative skin temperature of the land surface". LST is measured by using satellite images obtained with remote sensing technology and its estimation depends on the albedo, the vegetation cover and the soil moisture (Liu & Zhang, 2011; Benali et al., 2012). LST is a parameter that supports the identification of spatial and temporal variation in temperature at the ground level (spatial resolution 30 meters). LST is particularly useful in urban contexts to identify those areas that might suffer the most from heat waves and their consequences. The definition of the LST indicator is developed starting from open source data and it is thus possible for all the pilot areas. First step is to download Landsat 8 satellite images[1] that cover the pilot area and that provide a clear visibility (no atmospheric interference e.g. clouds). The procedure to convert the thermal infrared band was then carried out in GIS environment. The LST mean value was then calculated for each geographical unit that was used in the analysis (e.g. census geometry, hexagon or transept) and normalized.

4.2 Vegetated surfaces

The identification of vegetated surfaces is considered useful for the purposes of this project particularly as regards the assessment of potential impacts such as:

[1] https://landsat.usgs.gov/landsat-data-access

i)“increase energy demand for cooling”, ii) “loss of habitat” and “variation in crop yield”, iii) “urban flooding”.

In the first case, we assume that the presence of vegetated surfaces in urban areas can locally mitigate the increase in temperature and, accordingly, reduce the need for artificial cooling systems. Second, the evaluation of the presence or absence of vegetated surfaces in different times and in the same location is assumed to be an indicator for detecting certain habitat loss trend or change in agricultural practices. Third, the presence of vegetation is assumed to correspond to less impermeable surfaces and to reduce run-off, thus reducing the potential for urban flooding events.

Vegetation surfaces can be identified starting from open source data, downloading Sentinel 2 satellite images. The identification and quantification of green vegetation areas in the pilot areas in this project occurred as follow. Using Sentinel 2 images as a base, through visual image interpretation, around 500 samples of vegetated areas were identified and classified as “green”, furthermore, around 500 samples of non-vegetated areas were identified and classified as “no_green”. Maximum Likelihood Classification tool was then used to reclassify the entire satellite image (raster) in two classes (“green areas”; “no-green areas”). The reclassified raster was then converted into vector format in order to calculate the area of the green surfaces. The process was repeated for each pilot area.

4.3 Misano Adriatico

The analysis for Misano Adriatico was carried out to assess risk and vulnerability to climate change impacts such as: “impacts on transportation network”, “coastal erosion”, “impacts on tourism sector”, “energy demand for cooling”. The geographical unit of analysis is the census geometry downloaded by ISTAT website.

4.3.1 Impacts on transportation network

The analysis aims to identify those streets and railroad sections that are more vulnerable to river flooding and flooding from coastal storm. Streets and railroad sections were overlapped to the areas identified by the PAI (see table 2). According to the PAI area in which streets and railroad sections are located, they have different value corresponding to the probability of the event to occur. In this case, the transportation network provides the exposure, while the PAI classification represents different levels of sensitivity. No adaptive capacity was here considered; therefore, vulnerability corresponds to sensitivity in this case. The sections identified are visible in Maps 1-2.

Typology of event	Probability[2]	CODE
River flooding	High-frequency	RF_h
	Medium-frequency	RF_m
	Low-frequency	RF_l
Flooding from coastal storm	High-frequency	FC_h
	Low-frequency	FC_l

Table 3 - Definition of the areas according to PAI.

[2] Considering that the high-frequency areas overlap with medium and low-frequency areas, an equal value of 1 was assigned to all categories. Doing so, because overlapping values shall add up, RF_h=3, RF_m=2, RF_l=1, FC_h=2, FC_l=1.

Figure 1 – Transportation network risk map 1.

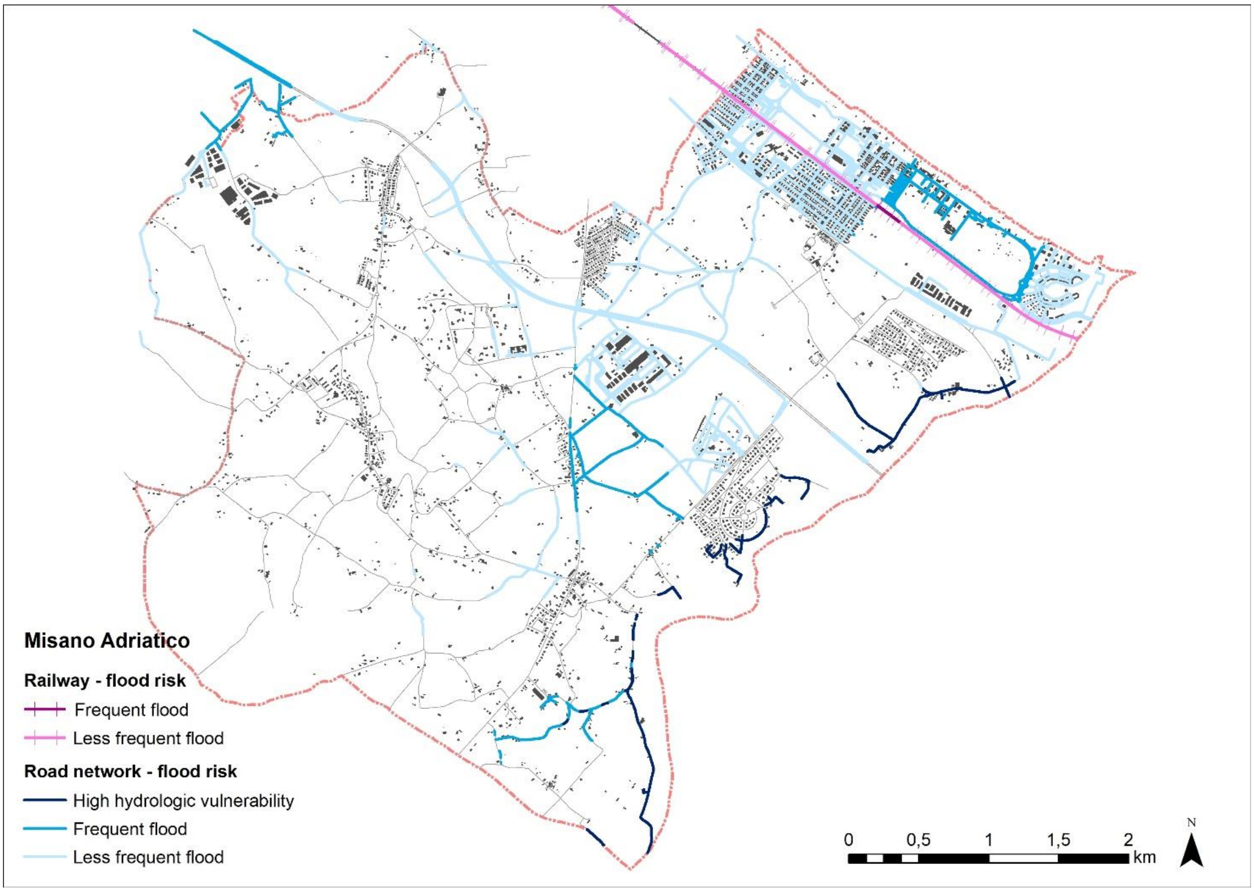
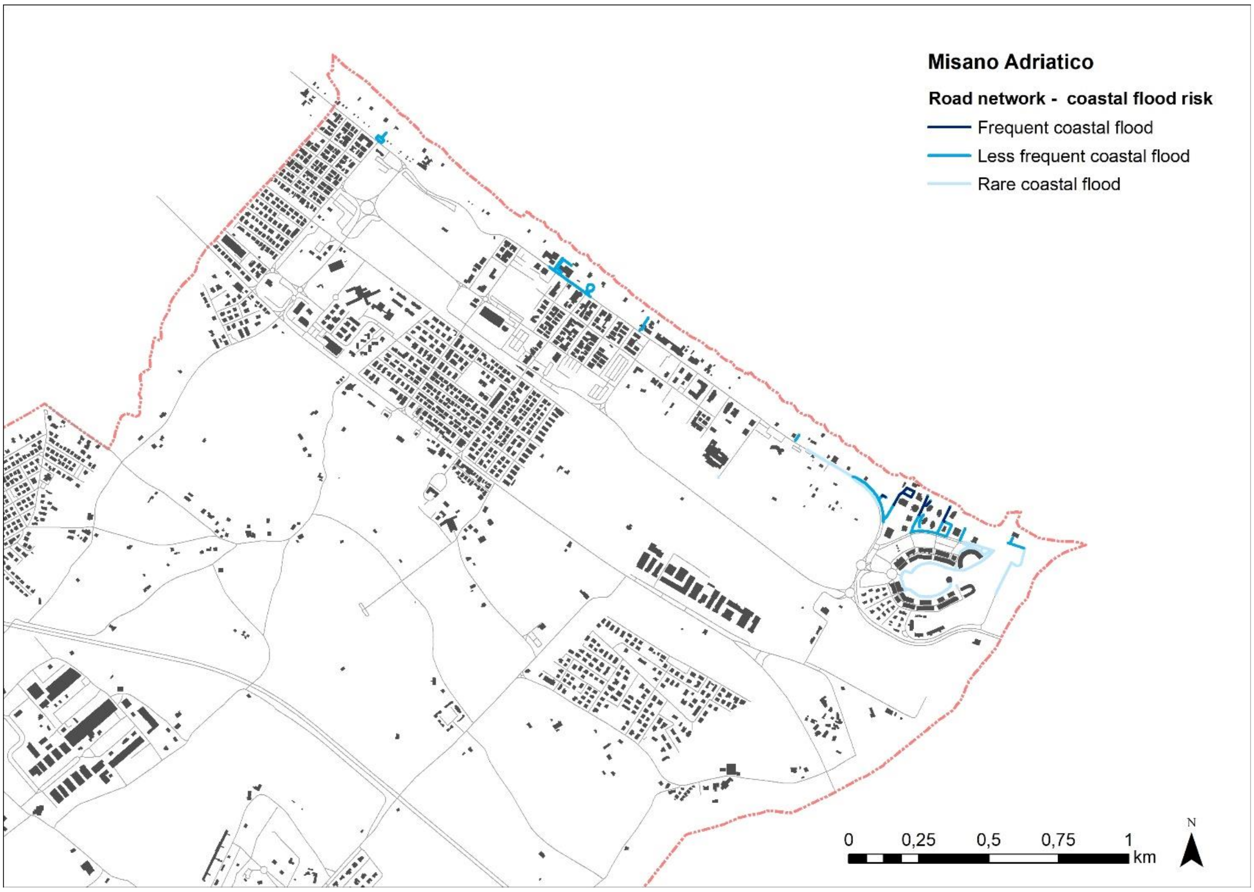


Figure 2 - Transportation network risk map 2.



4.3.2 Coastal erosion

"Coastal erosion" is here understood adopting a broad interpretation that includes several factors. The geographical unit of analysis correspond to 250m x 500m transepts (250 m along the shore line and 500m from the shoreline). Transept Area (TA)= 125.000 m^2. All the values have been normalized to be aggregated.

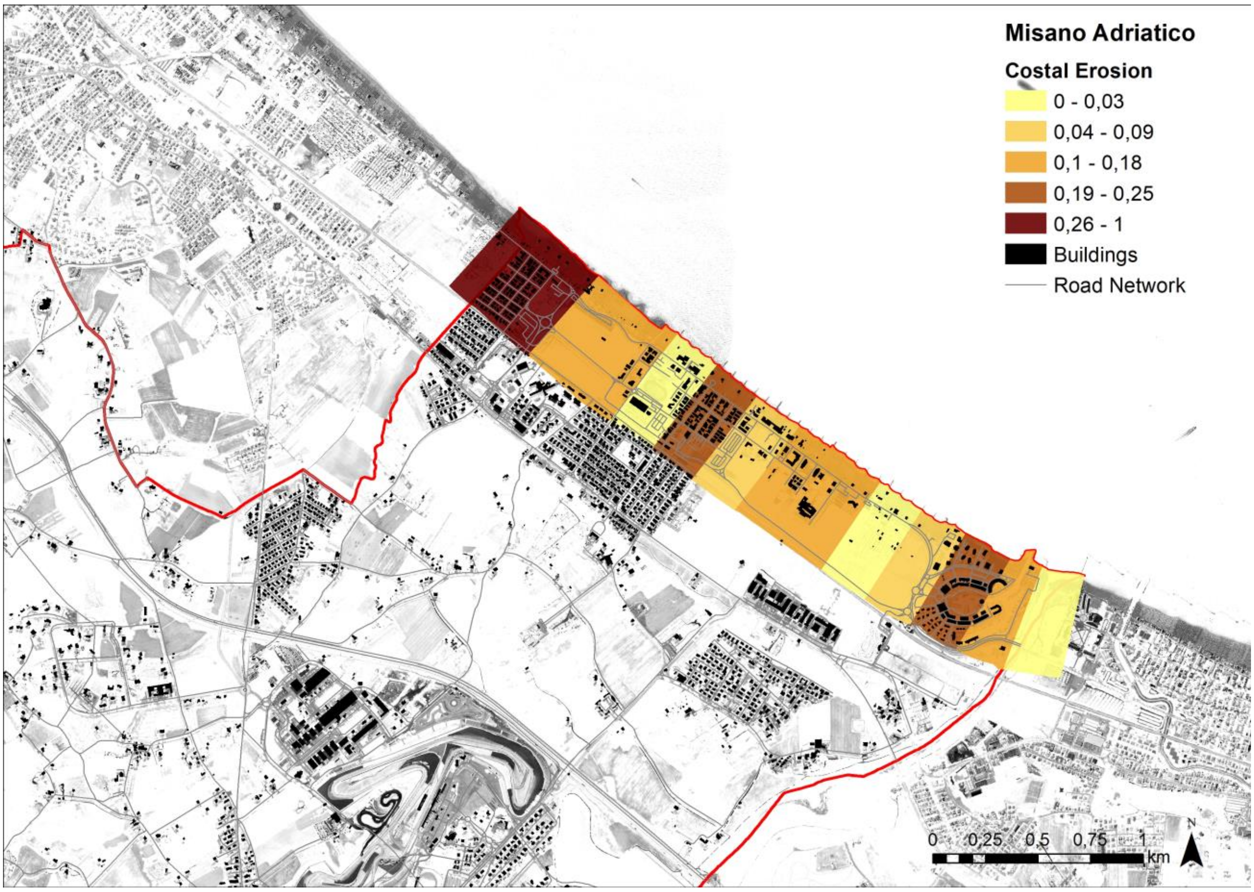
The level of sensitivity is provided by the indictor ASE and the % of land <1m elevation within each transept. ASE indicator (Accumulation, Stable, Erosion) describes the state of the coast after the defense operations carried out and it also takes into account the trend of the shore line, volumes of sand lost and accumulated (Aguzzi et al., 2012). The % of surfaces <1m has instead been drawn from a DTM analysis. The combination of these two indicators provides the sensitivity value normalized.

The level of exposure is here represented by the sum of the built-up area (percentage of the transept area) and the population density.

The adaptive capacity is here embedded in the ASE indicator, as it already considers adaptation measures.

Figure 3 shows those areas with higher risk value regarded the "coastal erosion impact".

Figure 3 - Coastal Erosion Risk map.



4.3.3 Impacts on tourism sector

The methodology is here developed to assess the risk and vulnerability of touristic assets and activities to increasing temperature, river flooding and flooding by coastal storms. Potential sea-level rise (>1m) was not included as, after a preliminary analysis, the vulnerable areas to sea-level rise overlapped with areas flooded by coastal storms giving redundant results. The focus of the analysis was on urban areas.

Touristic assets here considered are “reception facilities” and “restaurants”. The list of touristic assets (.csv format) was downloaded by the Emilia Romagna region database. The .csv file (including coordinates) was imported in GIS environment and converted into shape file.

The points representing touristic assets were overlapped to the areas identified by the PAI as in Table 3.

According to the PAI area in which the asset is located, a corresponding value is assigned to every asset. At this point, these values are transferred to the geographical unit of analysis building one indicator as follows:

$$\text{Ind}_A = \left[\frac{\left(\frac{NRF\_h + NRF\_m + NRF\_l}{Ntot} \right)}{CA} + \frac{\left(\frac{NFC\_h + NFC\_l}{Ntot} \right)}{CA} \right]$$

Where:

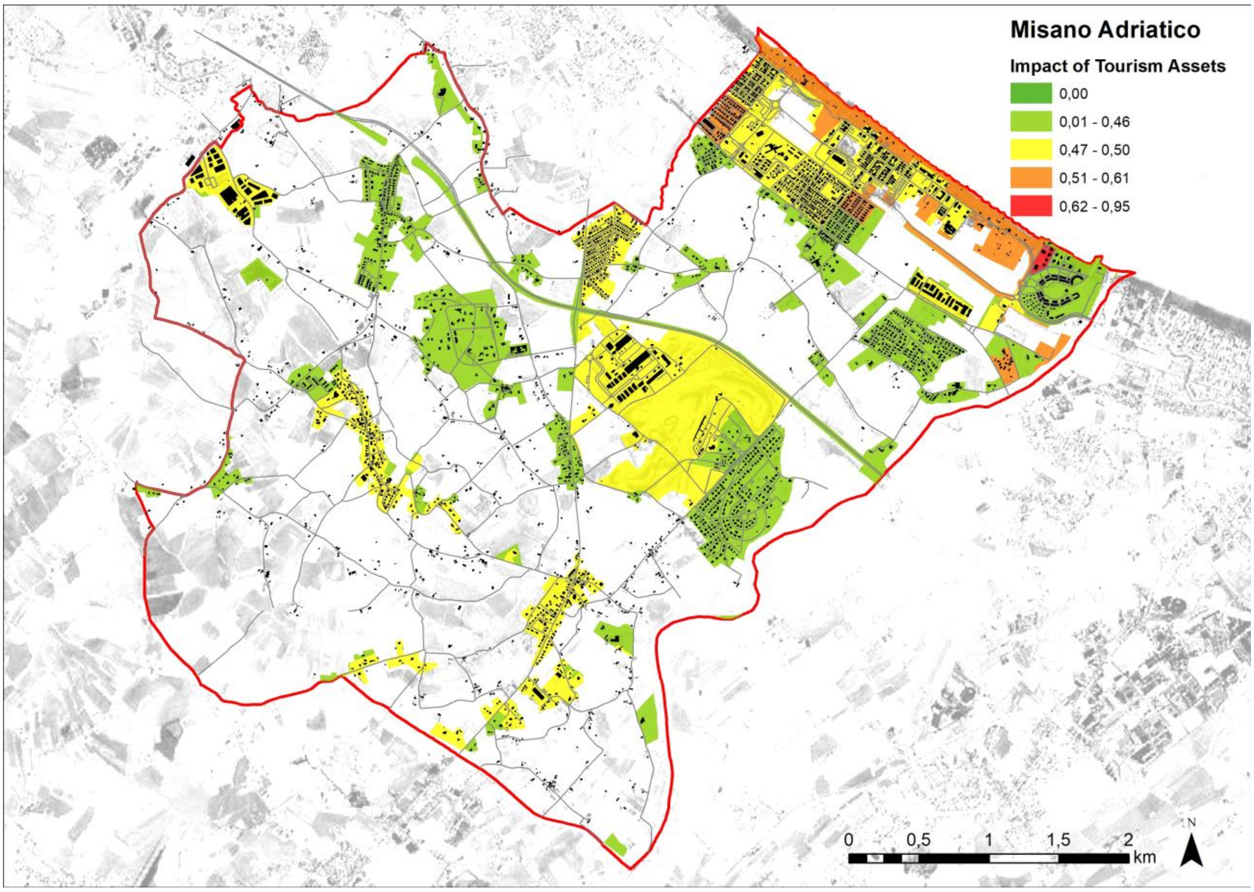
NRF_h: number of touristic assets located in RF_h areas within the census
NRF_m: number of touristic assets located in RF_m areas within the census
NRF_l: number of touristic assets located in RF_l areas within the census
NFC_h: number of touristic assets located in FC_h areas within the census
NFC_l: number of touristic assets located in FC_l areas within the census
Ntot: total number of activities located in the census
CA: Census Area

Sensitivity and Exposure elements are here considered together in an early stage of the process. In this case, elements for adaptive capacity were not considered due to lack of data. Therefore, vulnerability value for the tourist sector correspond to the sensitivity.

$$V = \frac{\mathrm{IndA} + LST}{2}$$

LST = mean Land Surface Temperature for each unit

Figure 4 - Impacts on tourism sector, Risk Map.



4.3.4 Energy demand for cooling

Objective of this analysis is to identify those areas in which is more likely that an increase in energy demand for cooling might occur. The focus of the analysis was on urban areas. Factors here considered are impermeable surfaces (such buildings, streets and other paved surfaces), Land Surface Temperature, number of buildings, presence of vegetated surfaces. The value of each indicator has been normalized. Exposure is represented by the summation of number of flats while LST and “Impermeable Surfaces” represents Sensitivity. The presence of Vegetated surfaces can be considered as an “Adaptive Capacity” factor. The analysis was carried out for each census (considered as geographical unit of analysis).

$$S = \frac{(Is + LST + Nf)}{3}$$

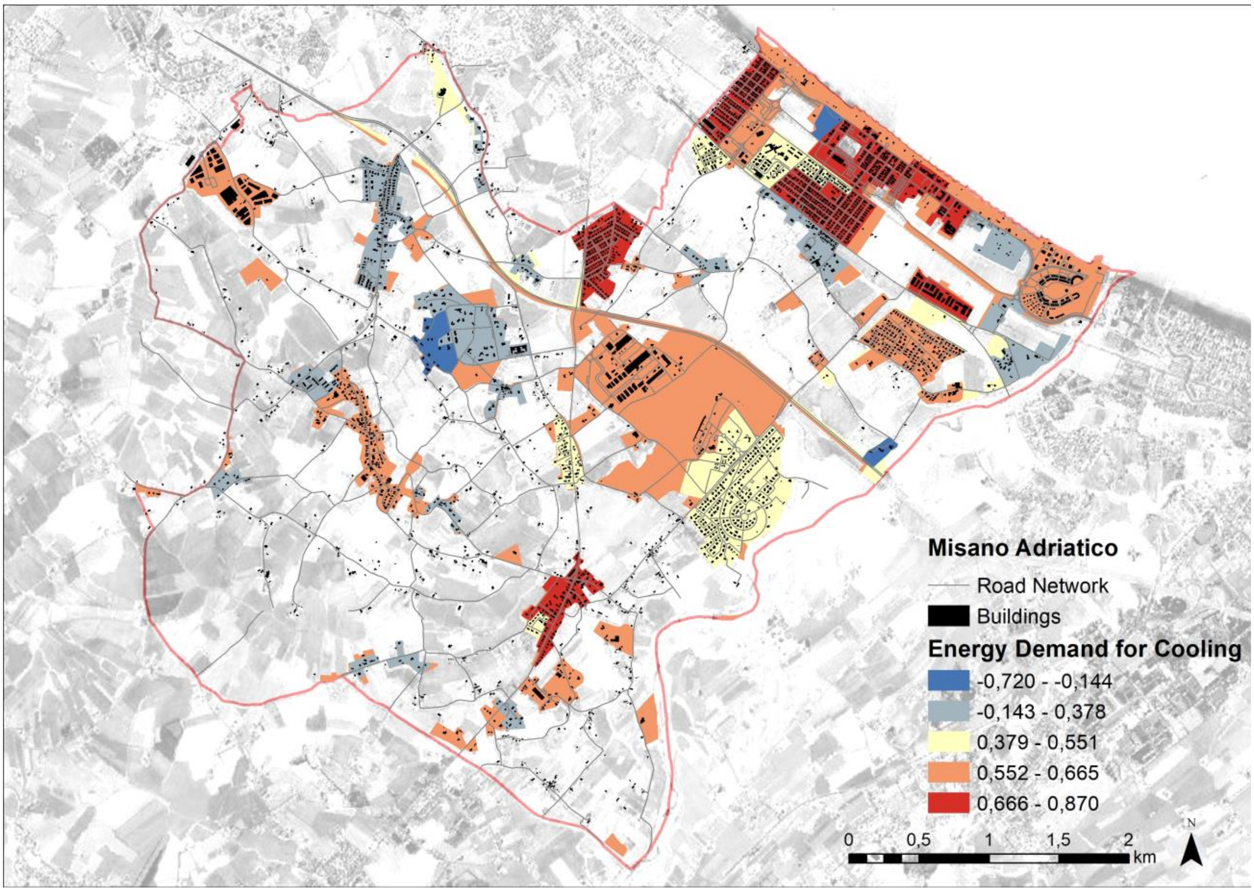
$$AC = Vs$$

$$V = S - AC$$

Where:

Is: Impermeable surfaces
LST: Land Surface Temperature (Average value within the census)
Nf: Number of flats
Vs: Vegetated surfaces

Figure 5 - Energy demand for cooling. Vulnerability Map.



4.4 Pesaro

4.4.1 Coastal erosion in natural areas

By agreement with the municipality of Pesaro, it was decided to focus the analysis of coastal erosion impacts on natural areas rather than man-made areas. “Coastal erosion” is here understood adopting a broad interpretation that includes several factors. The geographical unit of analysis correspond to 250m x 500m transepts (250 m along the shore line and 500m from the shoreline). Transept Area (TA)= 125.000 m^2. All the values have been normalized to be aggregated.

	Indicator	Calculation	Type of indicator
a	Floristic areas	$\frac{\mathrm{m^{\wedge}2}}{TA}$	Exposure
b	Public beaches	$\frac{\mathrm{m^{\wedge}2}}{TA}$	Exposure
c	Sites of Community Importance (SIC)	$\frac{\mathrm{m^{\wedge}2}}{TA}$	Exposure
d	Special Protection Areas (SPA)	$\frac{\mathrm{m^{\wedge}2}}{TA}$	Exposure
e	Dunes	$\frac{\mathrm{m^{\wedge}2}}{TA}$	Exposure
f	Coastal retreat	m	Sensitivity
g	Landslide	$\frac{\{[(\frac{P1m^{\wedge}2}{TA})*1]+[(\frac{P2m^{\wedge}2}{TA})*2]+[(\frac{P3m^{\wedge}2}{TA})*3]+[(\frac{P4m^{\wedge}2}{TA})*4]\}}{10}$	Sensitivity
h	Coastal protection infrastructures	m (calculated as the distance from the centroid of the infrastructure to the centroid of the transept)	Adaptive Capacity
i	Costal progression	m	Adaptive capacity

Table 4 - List of indicators used to calculate Risk and Vulnerability.

The formula for Exposure follows:

$$E = \frac{(a + b + c + d + e)}{5}$$

The formula for Sensitivity follows:

$$S = \frac{(f + g)}{2}$$

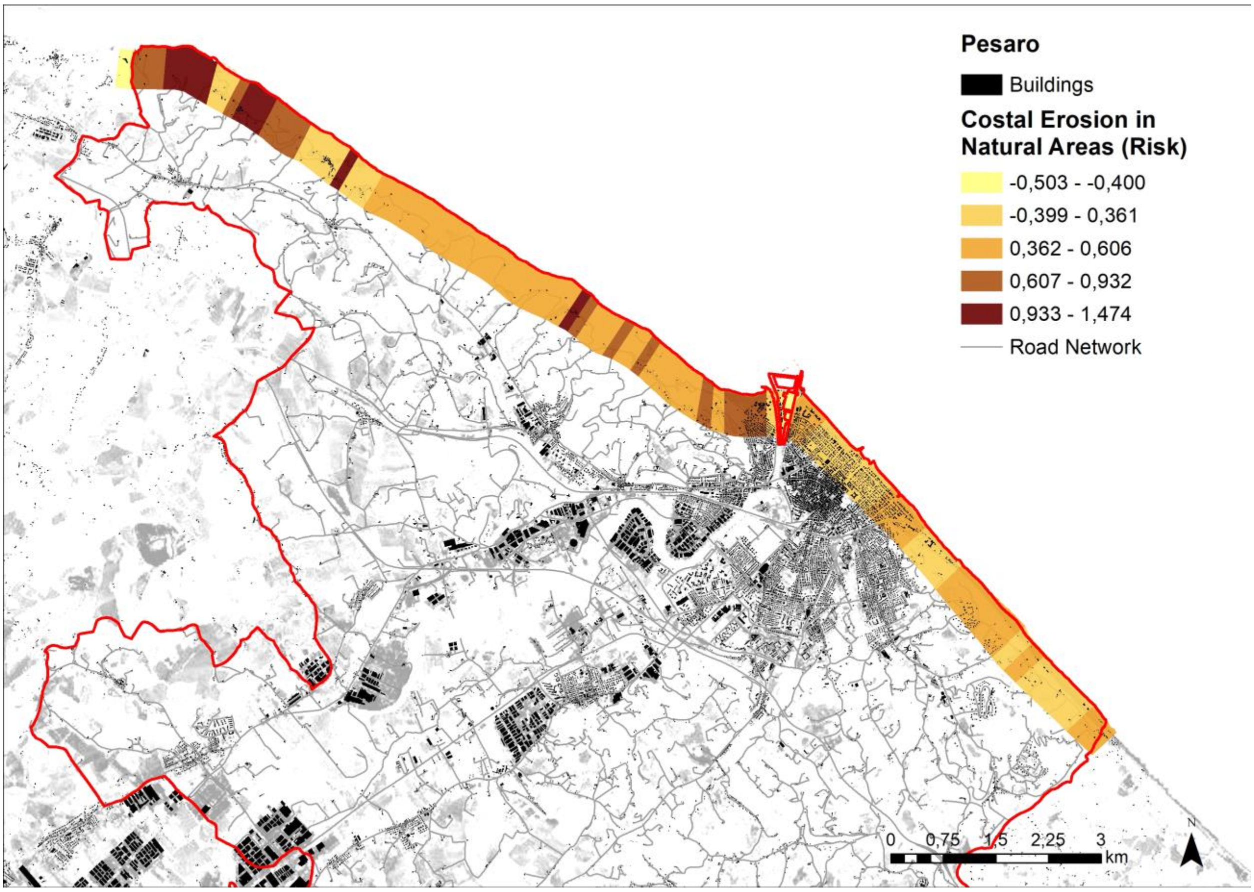
The formula for adaptive capacity follows:

$$AC = \frac{h + i}{2}$$

Therefore, the formula for risk and vulnerability related to coastal erosion in natural areas (calculated for every transept) goes by:

$$V = S - AC$$

Figure 6 - Coastal Erosion in natural areas. Risk Map.



4.4.2 Water competition

Water availability (for different uses) is an important topic in the face of the climate change also for the city of Pesaro. The possibility of increasing drought periods might also result in increasing competition for water between municipalities and sectors. Pesaro lies in the territory of AATO[3] 1 “Marche Nord Pesaro e Urbino” and it relies on this territory for its water supply (for what concerns domestic demand). 59 municipalities, including Pesaro, are located in the same AATO and the same water supply system (MarcheMultiservizi) provides water to 54 municipalities including Pesaro. Since the municipality of Pesaro shares the same water sources with other 53 municipalities for domestic consumption, in case of water scarcity it is plausible that competition for water sources could occur between municipalities. Therefore, data about water consumption of the municipalities that rely on the same water supply system were analyzed.

Data analyzed were gathered from the *Bilancio Sostenibilità 2016 – MarcheMultiservizi.* Pesaro water consumption is well beyond the average values compared to the the municipalities that are supplied by the same water supply system. Measures to reduce water consumption might be necessary to reduce the risk of competition for water during water scarcity scenarios.

[3] AATO: Autorità d'Ambito Territoriale Ottimale. It is a territory in which integrated public services, such as water or waste, are organized.

Figure 7 - Domestic residential water consumption (Liter / per person / day) of Pesaro compared to other municipalities supplied by the same water supply system.

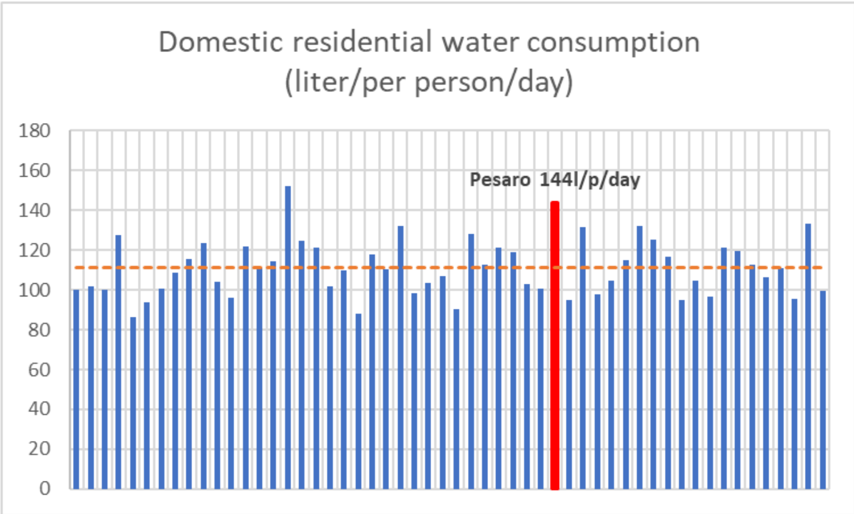
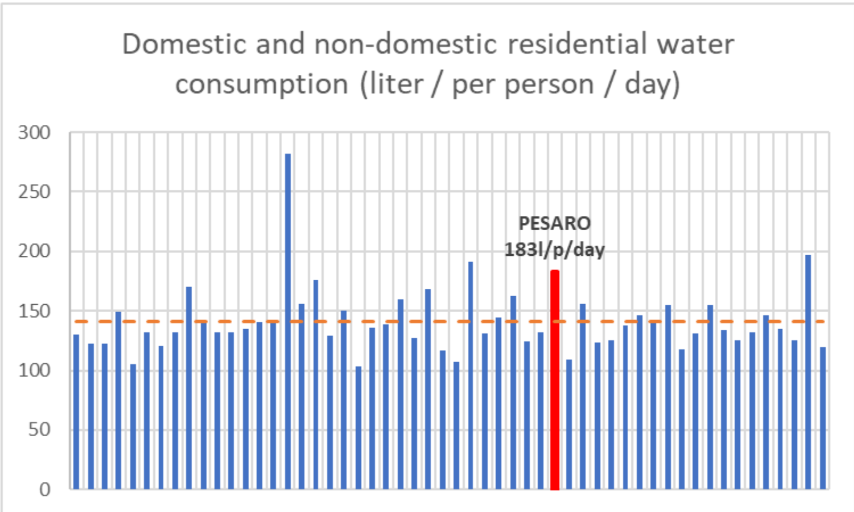


Figure 8 - Domestic and non-domestic residential water consumption (Liter / per person / day) of Pesaro compared to other municipalities supplied by the same water supply system.



From the analysis of the data of the service company, the daily consumption per inhabitant was obtained, the annual consumption differentiated for domestic use or for non-domestic use.

With reference to this differentiation, to represent a concentration of consumption, a ratio was used between the building count present in the ISTAT census units, residential and other destination (commercial, industrial), with the total number of consumption counter according to the type of use.

Figure 9 – Residential Water Daily Consume (liter/day)

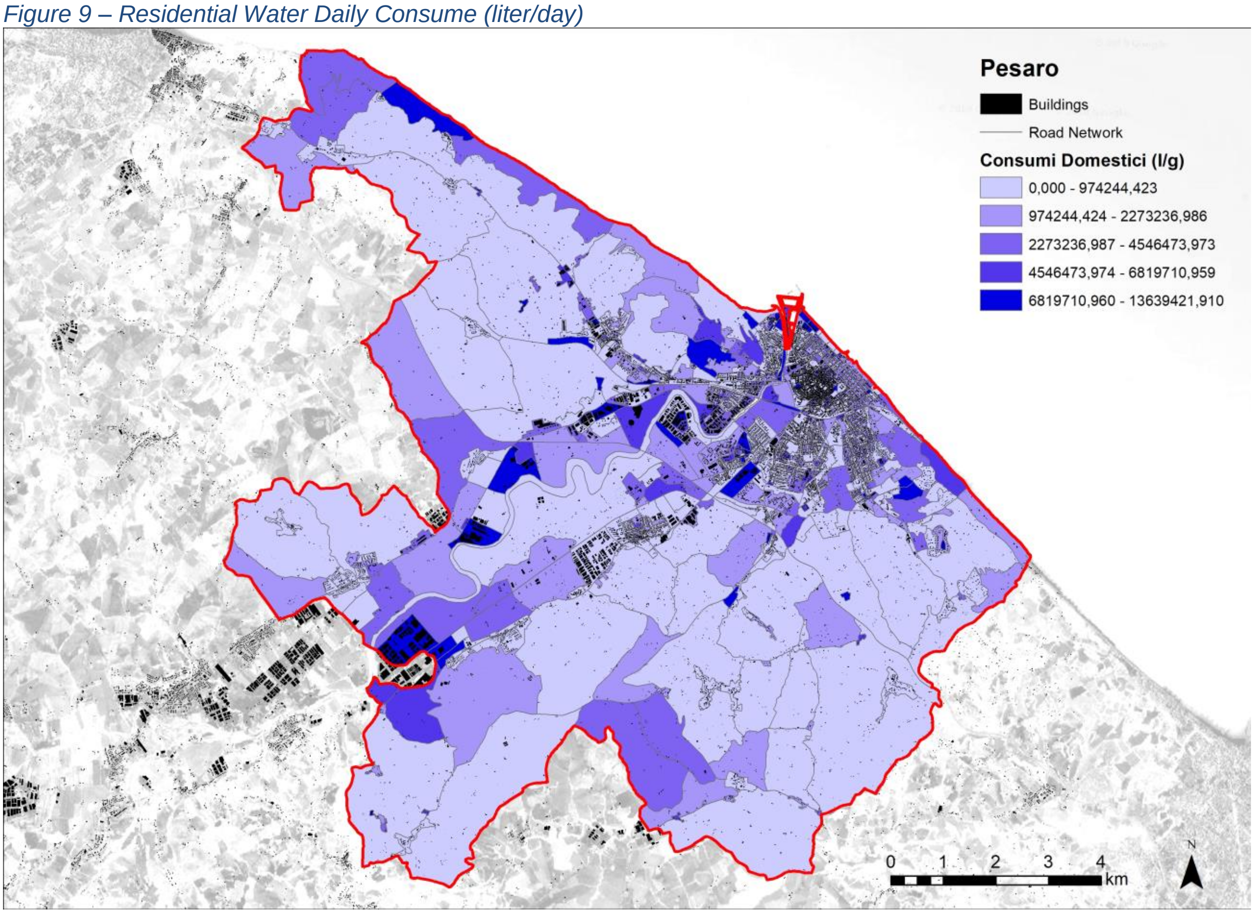
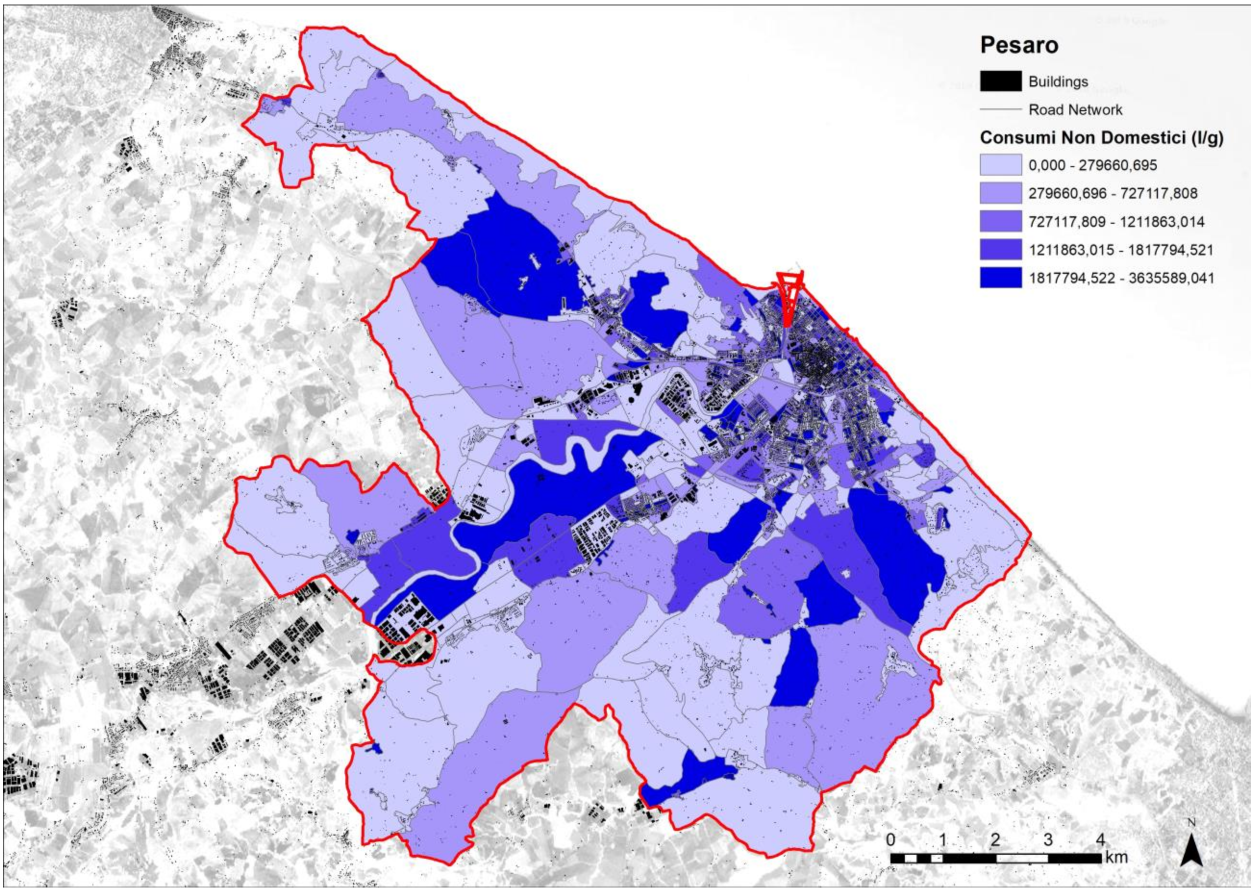


Figure 10 –Non-residential Water Daily Consume (liter/day)



4.4.3 Impacts on tourism sector

The methodology is here developed to assess risk and vulnerability of touristic assets and activities to increasing temperature, river flooding (from PAI) and flooding by coastal storms (from ICZM). Potential sea-level rise (>1m) was not included as, after a preliminary analysis, the vulnerable areas to sea-level rise overlapped with areas flooded by coastal storms giving redundant results. The focus of the analysis was on urban areas.

Touristic assets here considered are hotels, info points, museums and restaurants. The list in .csv format can be downloaded from the Marche Region database. The .csv file (including coordinates) was imported in GIS environment and converted into shape file.

The geographical unit of analysis here considered are the census geometry downloaded by the ISTAT website.

The points representing touristic assets were counted for each census. Census, PAI and ICZM (Tr100 – less frequent floods) were intersected. The points representing touristic assets were counted for each intersected area. According to the area in which the asset is located, a corresponding value is assigned to every asset. At this point, these values are transferred to the geographical unit of analysis as follows:

$$IndA = \left[\left(\frac{NTr100}{Ntot}\right) + \left(\frac{NP}{Ntot}\right)\right]$$

In this case, elements for adaptive capacity were not considered due to lack of data. Therefore, vulnerability value for the tourist sector correspond to the sensitivity.

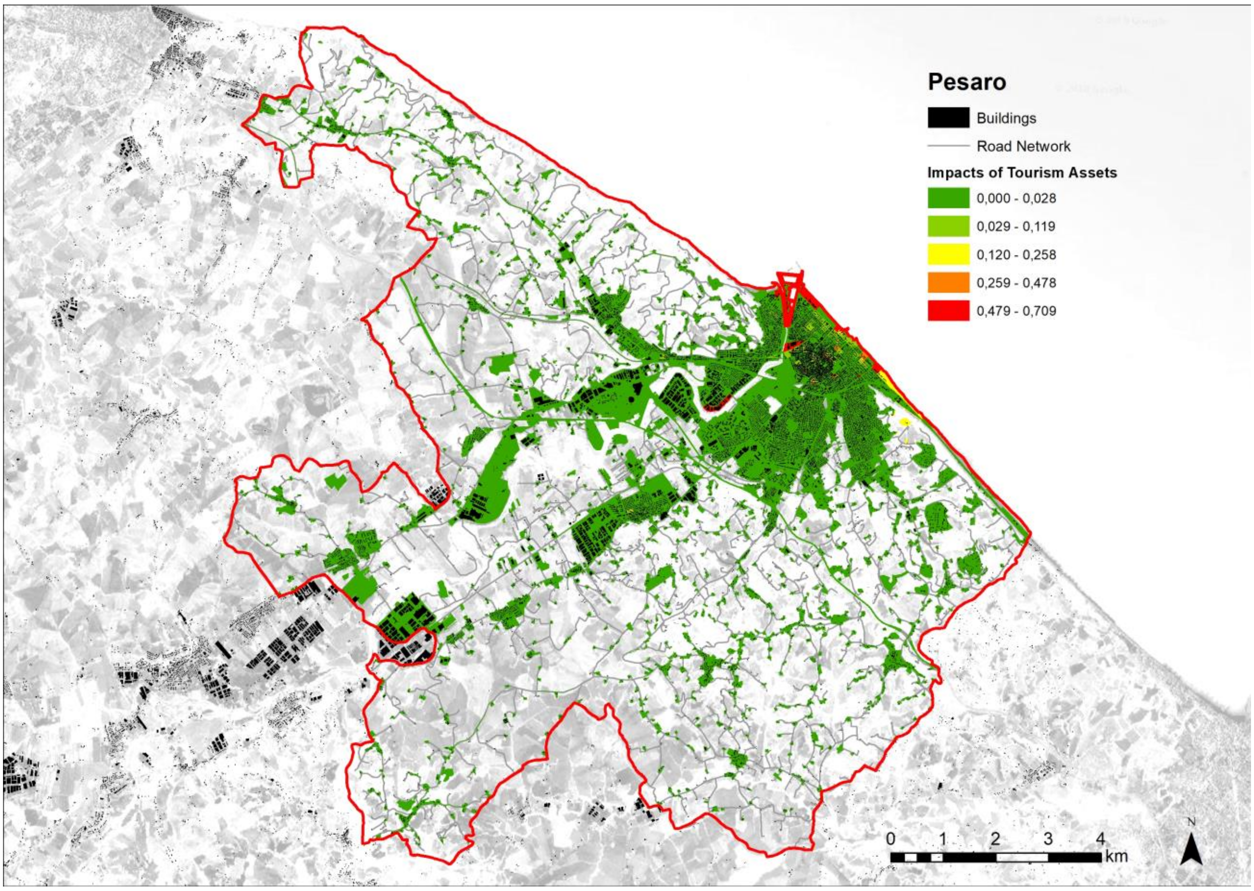
Sensitivity and Exposure elements are here considered together in an early stage of the process. In this case, elements for adaptive capacity were not considered due to lack of data. Therefore, vulnerability value for the tourist sector correspond to the sensitivity. Risk is then:

$$IndB = \left(\frac{LST}{Ntot}\right)$$

$$V = \frac{IndA + IndB}{2}$$

NTr100* = probable flooded area at 100 years
NP = fluvial floodable areas identified from PAI
LST = mean Land surface temperature on census unit
NTot = Number of tourist activities present for each census unit

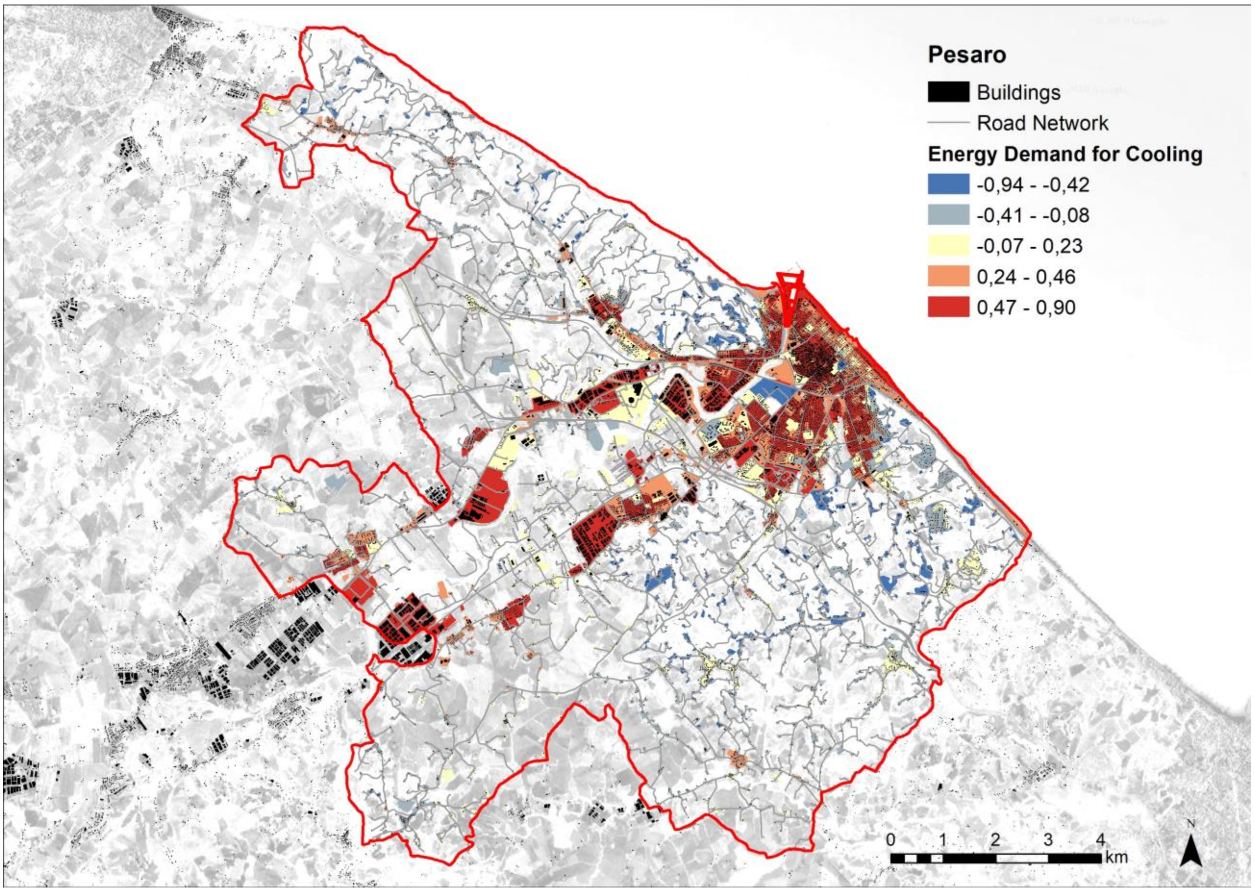
Figure 11 - Impact on Tourism sector- Risk Map.



4.4.4 Energy demand for cooling

The vulnerability assessment for the "energy demand for cooling" for Pesaro followed the same methodology as the case of Misano Adriatico. See section 4.3.4.

Figure 129 - Energy demand for cooling. Risk Map.



4.5 Parco delle Dune Costiere

4.5.1 Variation in crop yield

In order to determine the agricultural productivity are taken into account datasets from cartographic service of Region Apulia and land use from Corine Land Cover 2018 Project of Copernicus Monitoring Service.

The Land Capability Classification (A. A. Klingebiel, 1961) expresses the degree of possibility to conduct agricultural activity intensively in line with the biotic characteristics. The higher classes of Land Capability correspond to a minor vocation for the naturalization of an area.

The impact of climate change on agriculture has been analyzed considering the "*Programma di azione per la lotta alla siccità e alla desertificazione, indicazione delle aree vulnerabili in Puglia* ", always conducted by the Puglia Region. The environmental quality status, using the Medalus approach (Mediterranean desertification and land use) (Kosmas, 1999), is defined as the ESAI, Environmentally Sensitive Area Index, which summarizes soil status, climate, vegetation, management and human factors.

By observing these two indicators in conjunction with the extension of the rural area, classified by land use (Corine Land Cover, 2018), the vulnerability of the territory has been obtained in relation to agricultural productivity.

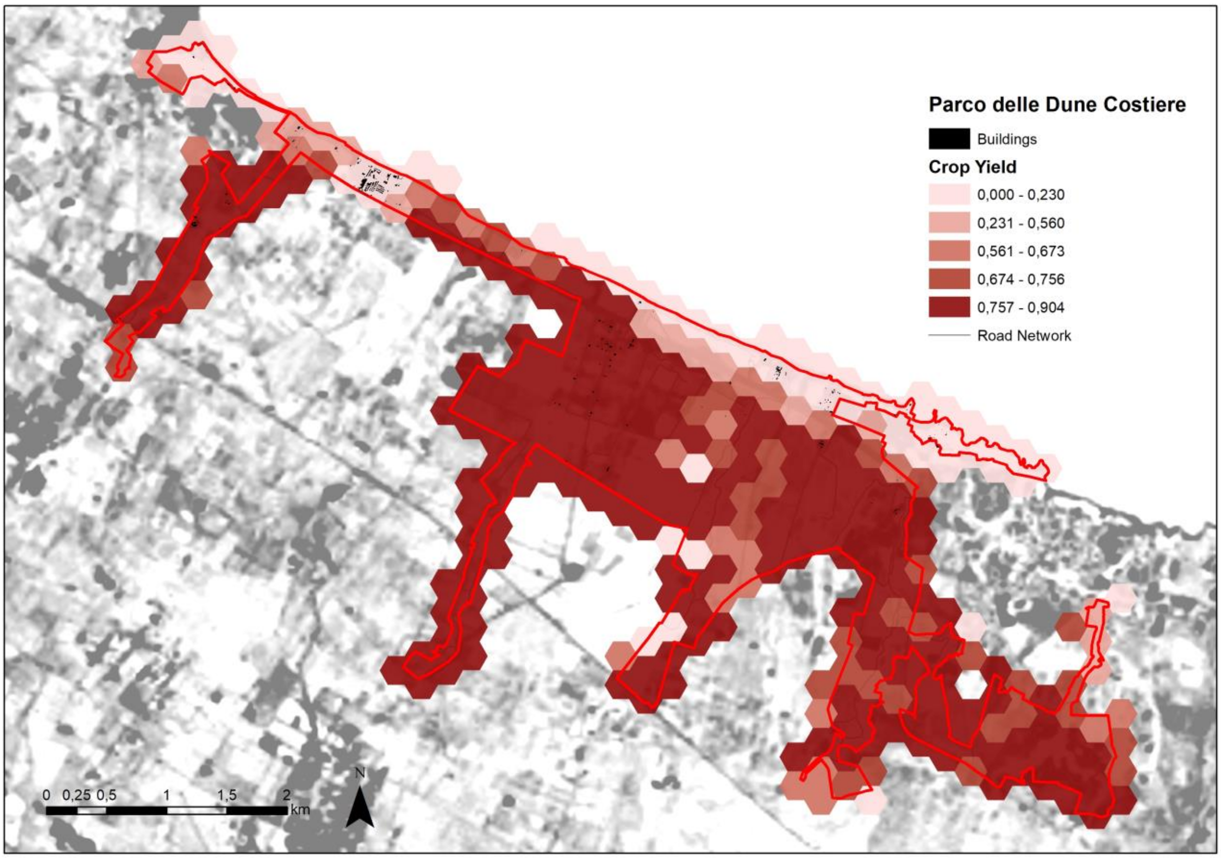
$$V_{CY} = \sqrt{\left(\sqrt{((1 - LCC) * ESAI)} * R_S\right)}$$

LCC = Land Capability Classification

ESAI = Environmentally Sensitive Area Index

Rs = Rural surfaces from Land Cover Classification 2018

Figure 13 – Crop Yield. Vulnerability Map

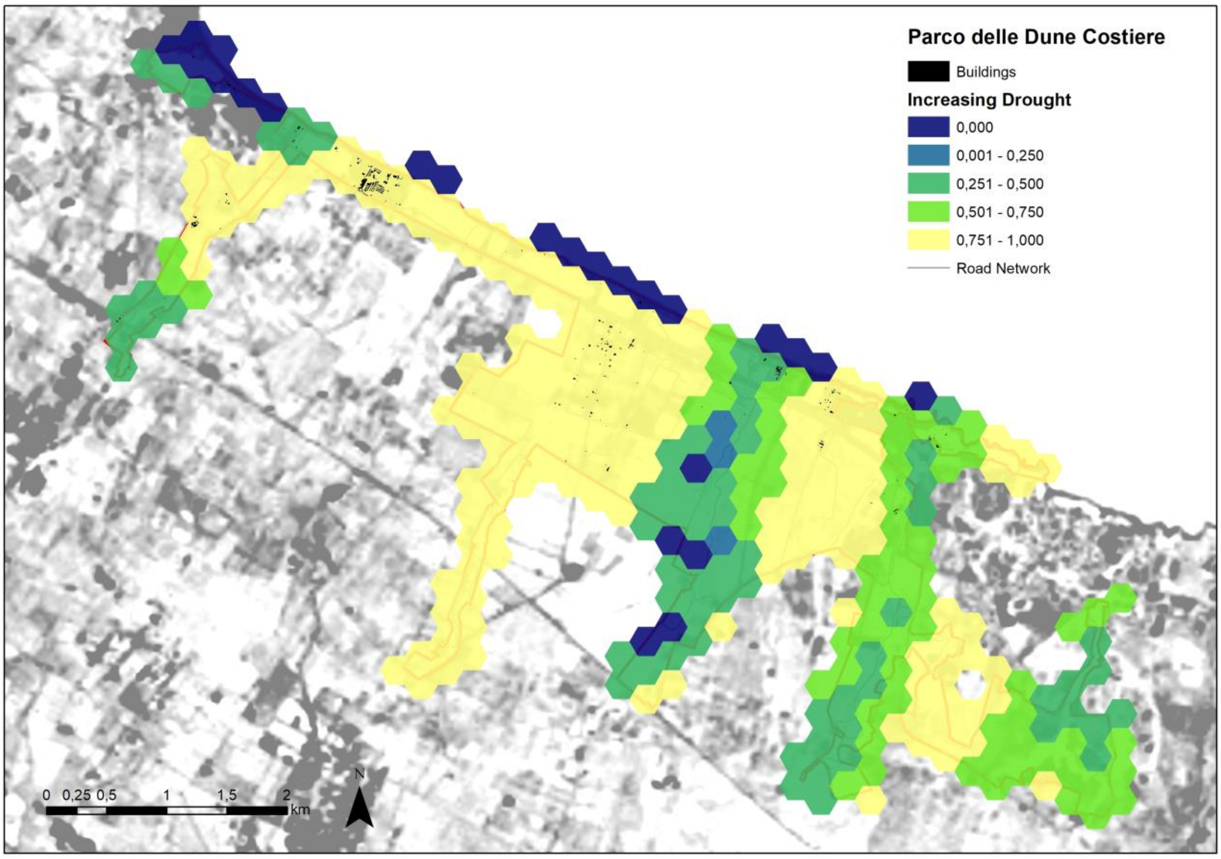


4.5.2 Increasing drought

Drought assessment has been analyzed for the entire park's extension, quantifying the variation of ESAI, the Environmentally Sensitive Area Index (Kosmas, 1999). In its assessment, rainfall and soil drainage capacity are considered among the environmental components.

The highest values, near to 1, represent areas that tend to be drier due to the pedological and climatic characteristics.

Figure 14 – Increasing Drought Vulnerability



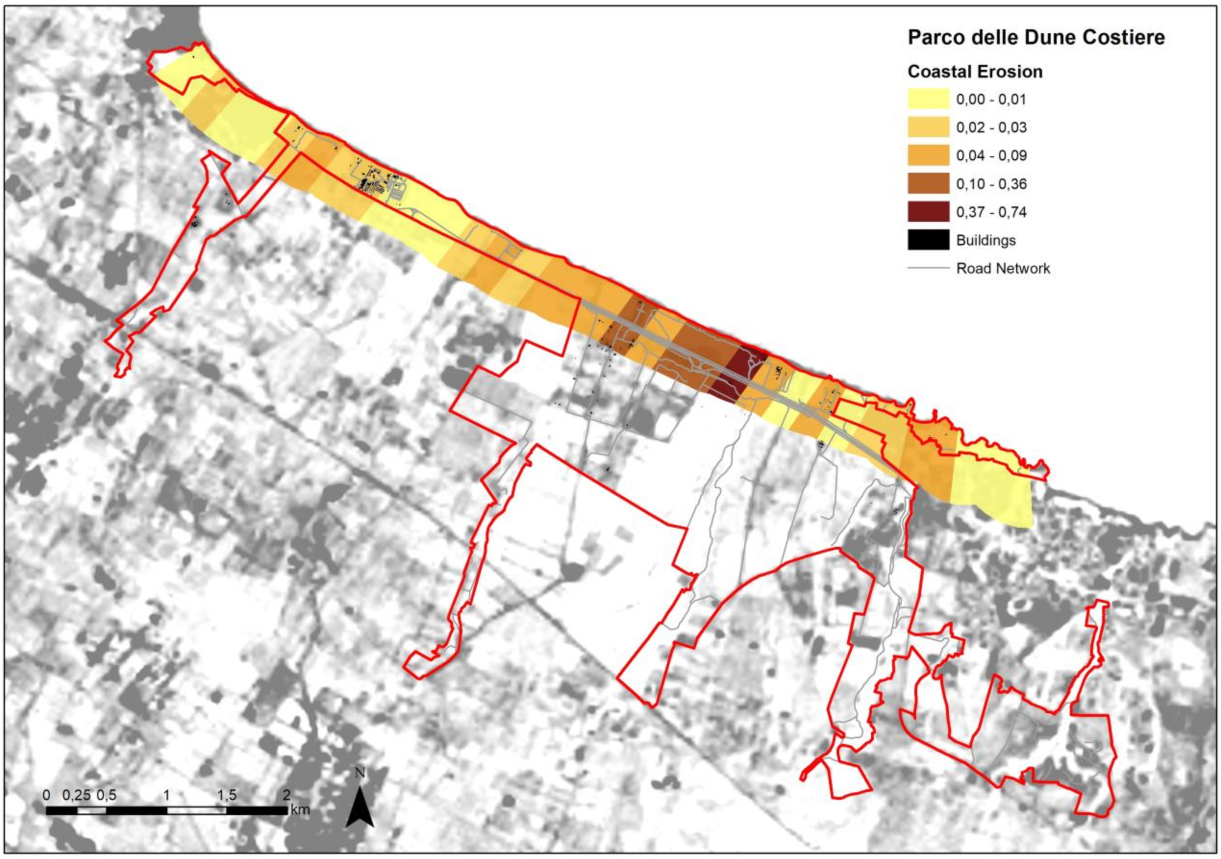
4.5.3 Coastal erosion

"Coastal erosion" is here understood adopting a broad interpretation that includes several factors. The geographical unit of analysis correspond to 250m x 500m transepts (250 m along the shore line and 500m from the shoreline). Transept Area (TA)= 125.000 m^2. All the values have been normalized to be aggregated.

The level of sensitivity is provided by the % of land <1m elevation within each transept. The % of surfaces <1m has instead been drawn from a DTM analysis. The combination of these two indicators provides the sensitivity value normalized.

The level of exposure is here represented by the sum of the built-up area (percentage of the transept area) and the population density. The coastal erosion on this stretch of coast cannot be considered in Sensitivity, as in the ability to adapt, as from the analysis of satellite images is an advancement of the coastline.

Figura 15 – Coastal Erosion. Vulnerability Map



4.5.4 Loss of habitat

Because of the lack of data, knowing the extensions of the current habitats surveyed by the Natural Ecological Networks and the assessments of Land Capability or vulnerability to desertification, the impact of anthropic action has been considered as the cause of habitat loss. Its radius of action was defined by extending the existing urbanized area from land use to multiple area levels.

The environmental status assessment consider the Land Capability Classification in conjuction with ESAI, Environmentally Sensitive Area Index, while the progression of the urban area is configured in three levels following a distance from perimeter:

- level 0: current extension
- level 1: buffer distance at 500 m
- level 2: buffer distance at 1 km

The areas of relevance generated around the urban environment are overlapped among them. By dividing them with a uniform hexagonal mesh, it is possible to quantify the extended area ratio on each single unit as vulnerability factor of habitat quality in relation to the proximity to the most anthropized zones.

$$Up = (A_0 + A_1 + A_2)$$

$$V_{HL} = \sqrt{\sqrt{\left((1 - LCC) * ESAI\right)} * \left(0{,}5 + \frac{Up}{2}\right)}$$

Up = Urbanization progress*, in Vulnerability assessment the values starts minimum from 0,5 to consider the areas far from the urbanization too.

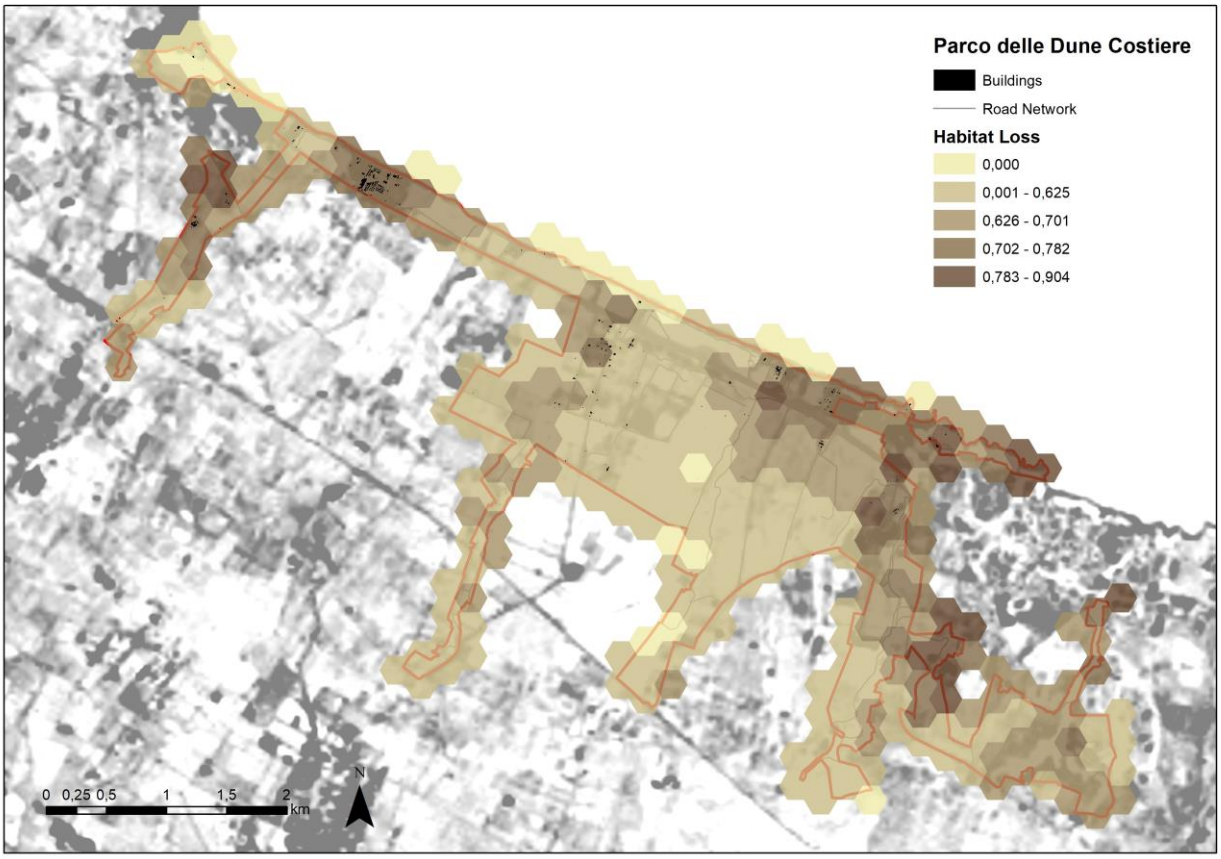
LCC = Land Capability Classification*, having regard to the decreasing relationship between the number of class and agricultural land use capacity, the indicator’s range must be reversed

ESAI = Environmentally Sensible Area Index

V_{HL}= Vulnerability to habitat loss

*those indicators are scaled from 0 to 1 to compare between different units

Figure 16 – Habitat Loss. Vulnerability Map



4.6 Dubrovnik - Rovinj, Vrsar, Poreč

Because the difficulties in aggregating data at the census level for the Croatian pilot areas, a hexagonal grid was prepared. The hexagons (160 m each side and an area of 66510.75 m^2) were used as geographical unit of analysis. Because the lack of data, a thorough risk and vulnerability assessment was not possible for the Croatian pilot areas. It was therefore decided, in agreement with the PPs, to focus on the analysis of phenomena such as “Urban Heat Island”, “Urban Flooding” and Sea-Level Rise. In these cases, it was possible to carry out qualitative assessments relying on open data. The same methodology and impacts are shared between the two pilot areas. The analysis was carried out on urban areas exclusively.

4.6.1 Urban Heat Island

Urban heat island (UHI) is a micro-climatic phenomenon that occurs within urban areas and that consist in higher temperature in artificial built-up areas compared to, for example, rural surroundings or green areas (Oke, 1982). Understanding the areas in which UHI might be more pronounced can help to identify areas subjected to impact on economic activities, energy consumptions, health, habitat, etc.

Impermeable surfaces (% within the hexagon) and Land Surface Temperature (average value within the hexagon) constitute the Sensitivity indicator. Whereas building area within the hexagon represents the exposure value. Adaptive capacity is represented by the Vegetated surface within each hexagon.

$$S = \frac{\frac{Is}{Ahx} + LST}{2}$$

$$E = \frac{Ab}{Ahx}$$

$$AC = \frac{Vs}{Ahx}$$

Where:

Ab: Buildings area within the hexagon

Is: Impermeable surfaces within the hexagon
LST: Land Surface Temperature (Average value within the hexagon)

Figure 1710 - Urban Heat Island Risk Map. Dubrovnik.

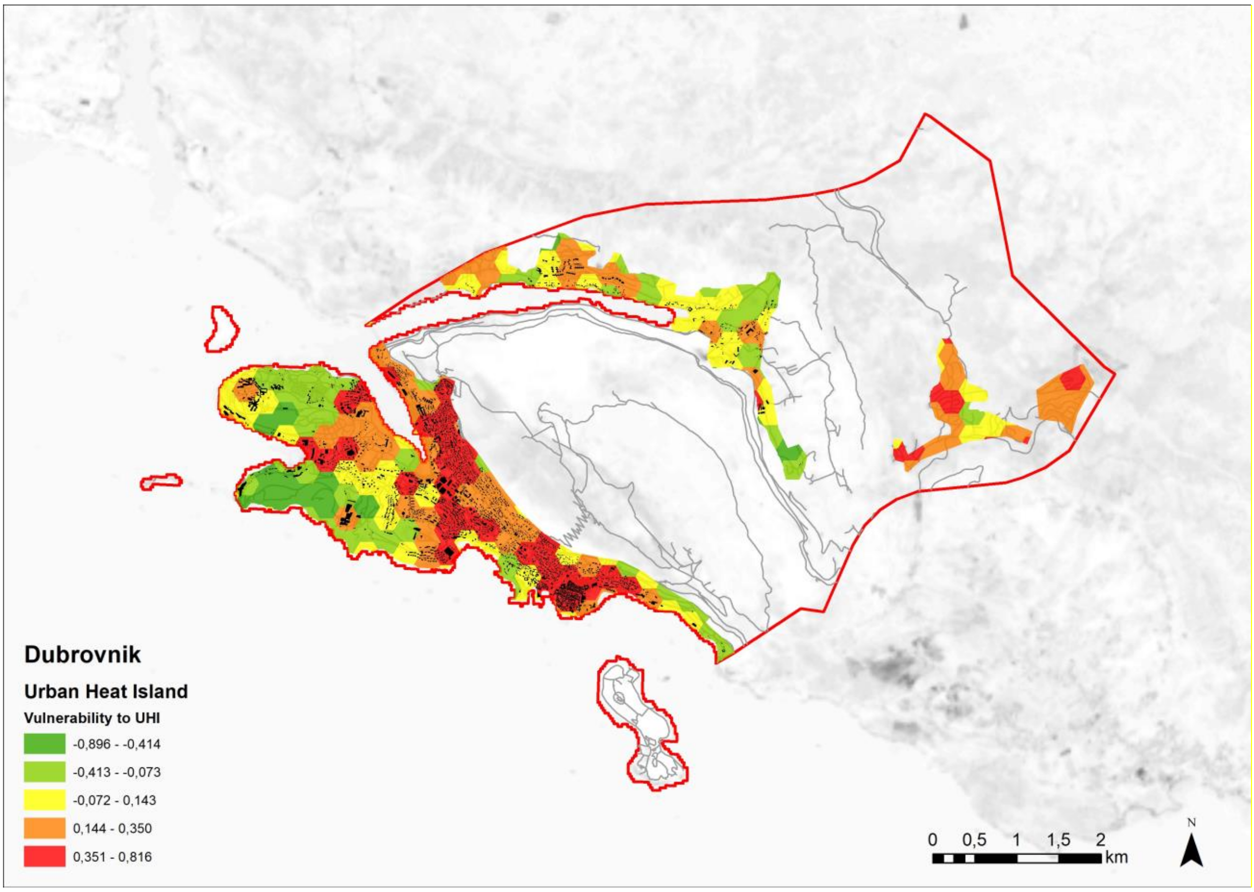
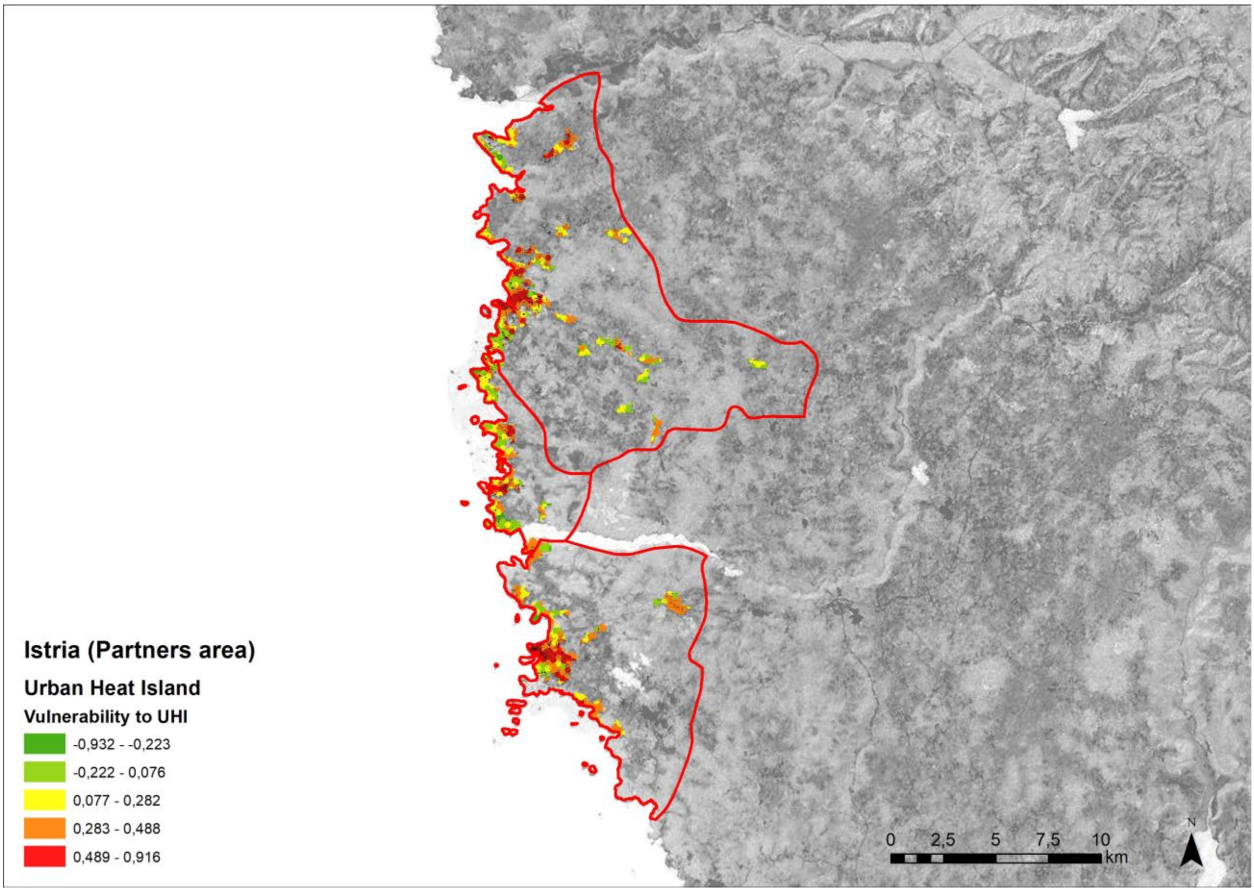


Figure 118 - Urban Heat Island Risk Map. Rovinj, Vrsar, Poreč.



4.6.2 Urban flooding

Urban flooding has been evaluated considering the presence of more constructed areas since natural runoff is disadvantaged by the concentration of impermeable surfaces referable to infrastructures or buildings.

Through remote sensing indices applied to a multiband satellite image (Landsat 8), it was possible to determine the presence of vegetation and built using the corresponding NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up Index).

Subtracting NDBI-NDVI, the most permeable areas will be excluded, obtaining a mapping of the most constructed areas (Zha, 2003) and therefore more critical in the event of flooding.

Figure 1912 - Urban Flooding. Risk Map. Dubrovnik.

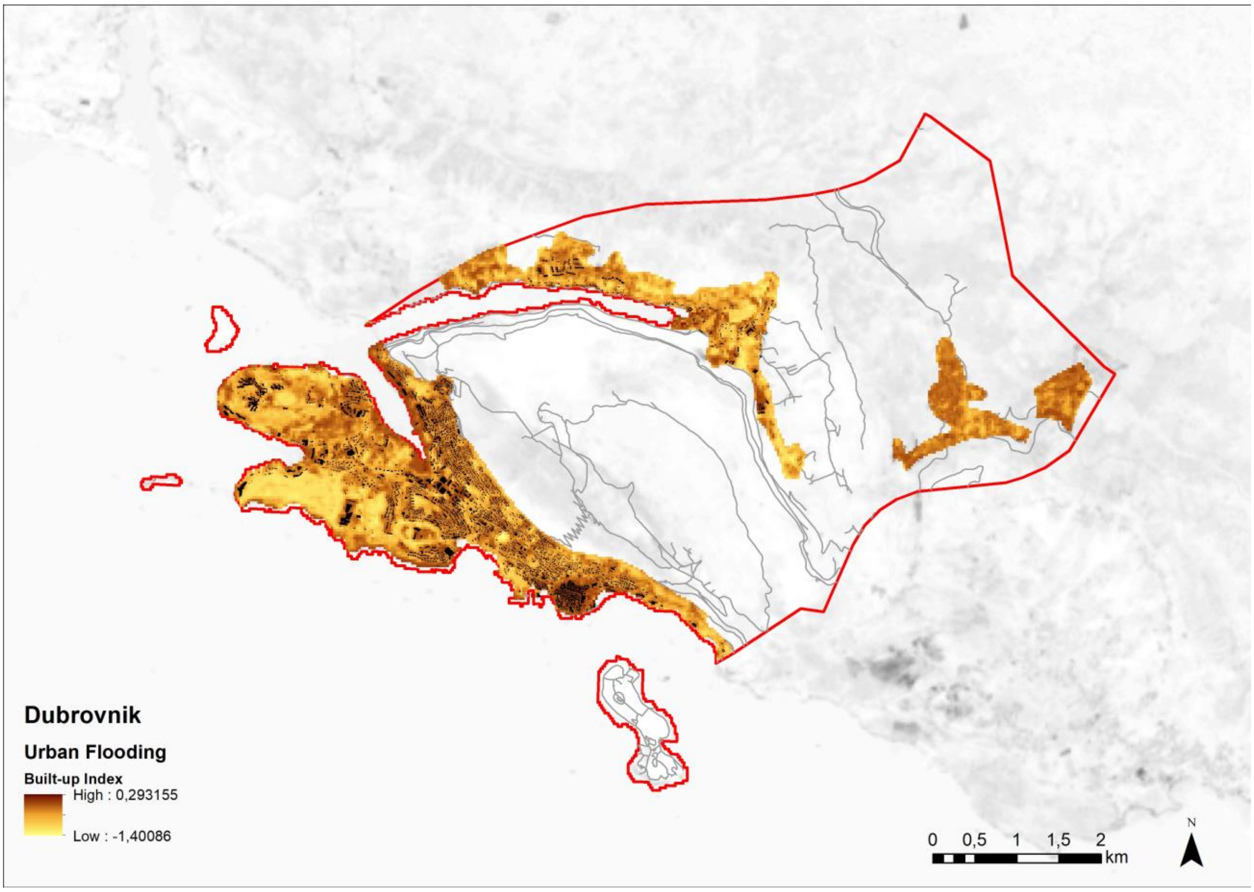
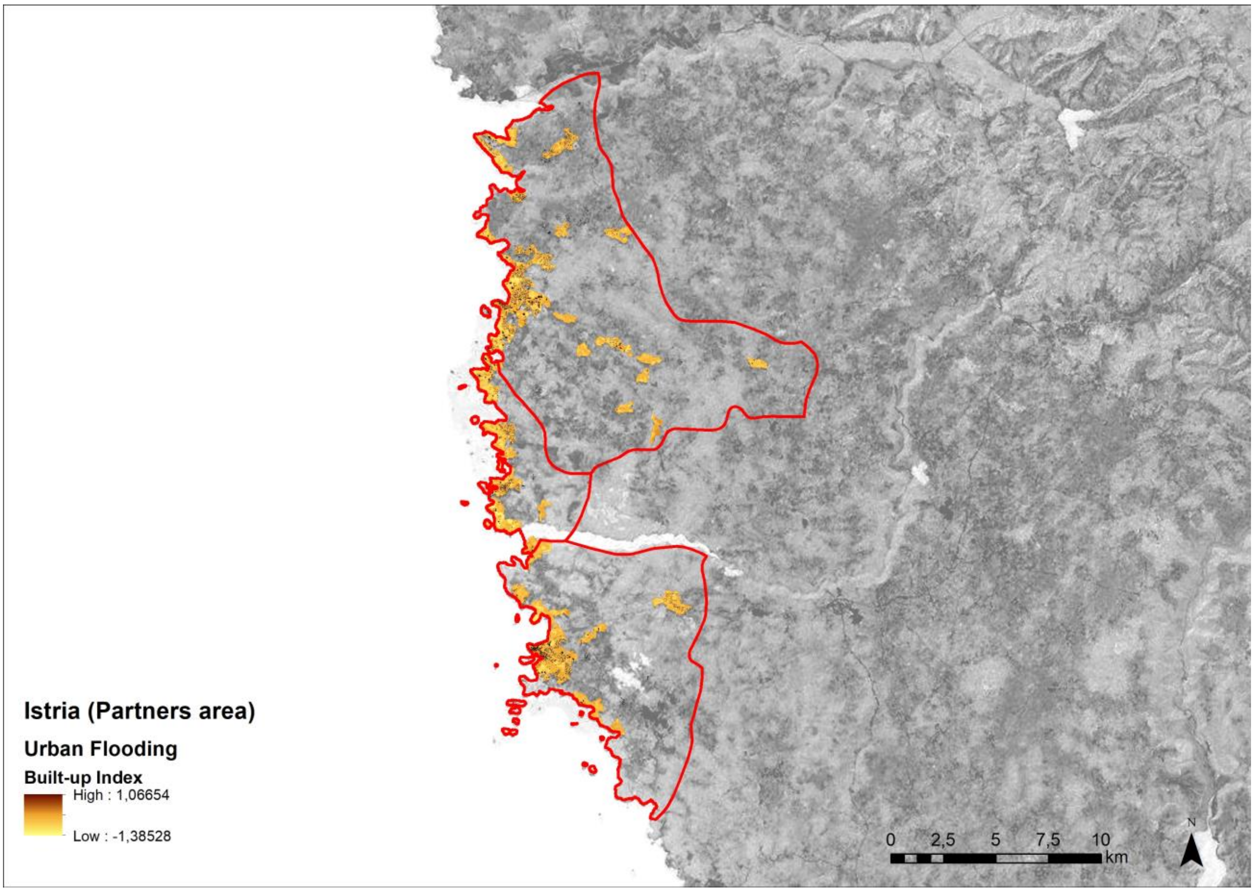


Figure 20 - Urban Flooding. Risk Map. Rovinj, Vrsar, Poreč.



4.6.3 Sea level rise

A scenario involving 1 m sea-level rise due to climate change was here considered. In order to identify those areas that might be affected by such a phenomenon, the SRTM Digital Terrain Model (30 m resolution) was downloaded from the United States Geological Survey website. Areas with less than 1m elevation were identified in GIS environment, and then the percentage of surfaces <1m within each hexagon area was calculated. Figure 15-16 identify those areas in the pilot areas that might be affected in a 1m sea-level rise scenario.

Figure 21 – Areas impacted by Sea Level Rise. Dubrovnik.

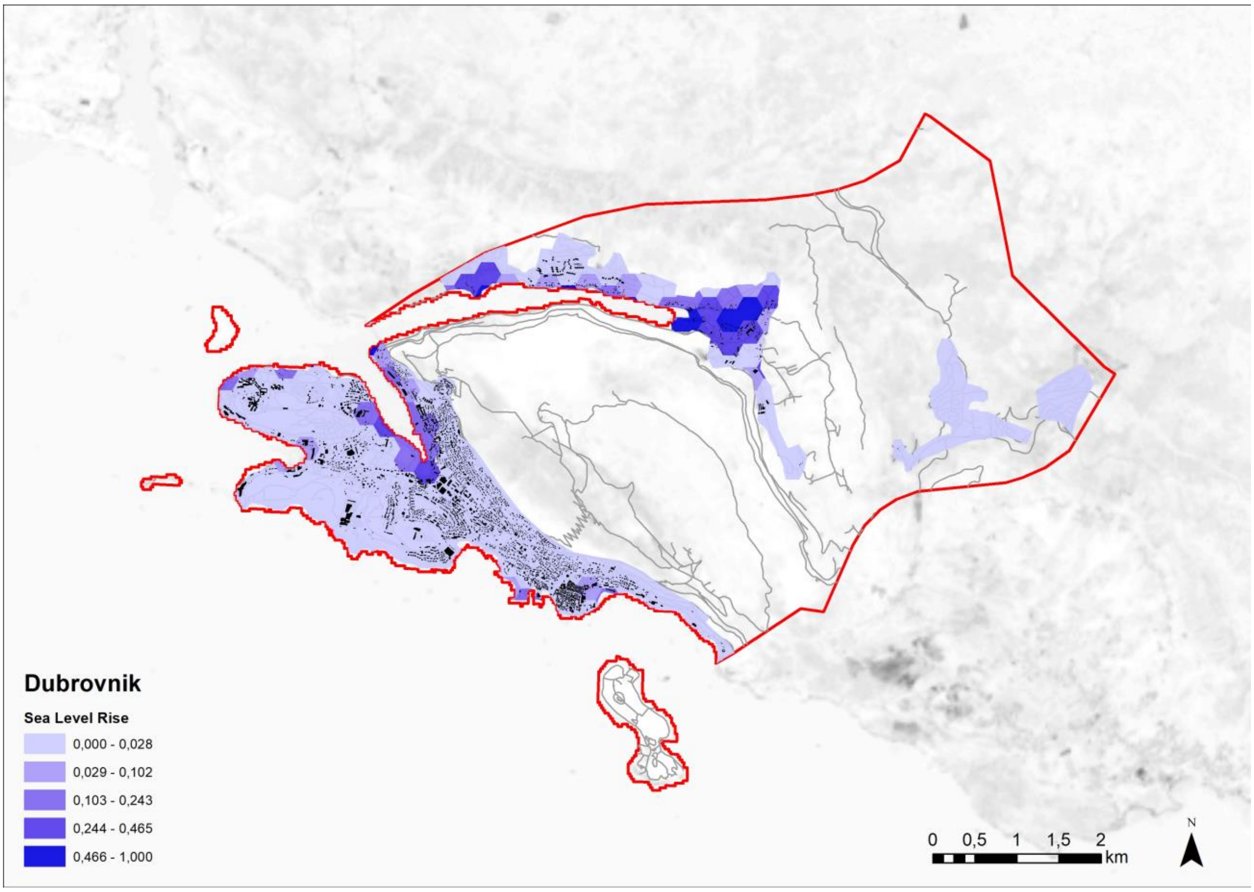
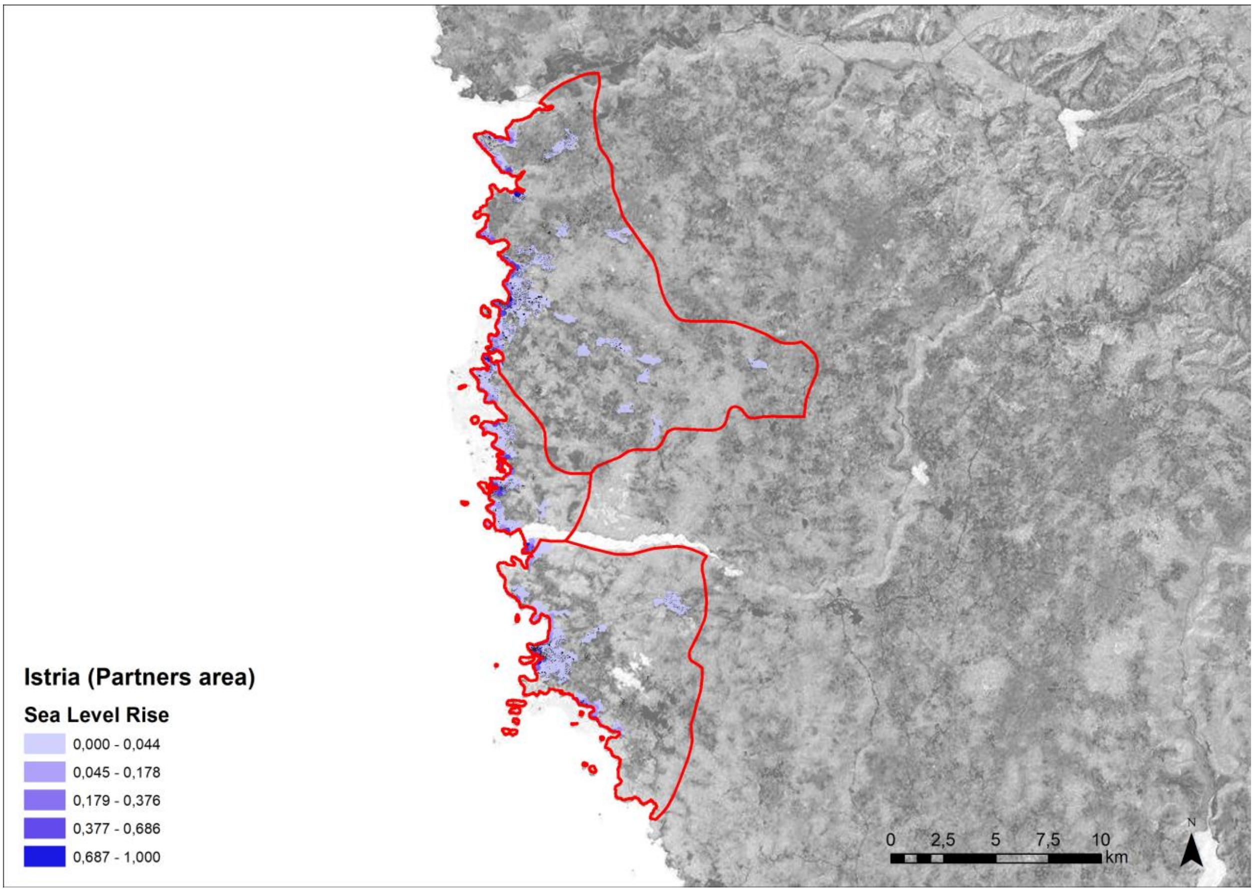


Figure 22 - Areas impacted by Sea Level Rise. Rovinj, Vrsar, Poreč.



Bibliography

A. A. Klingebiel, P. H. (1961). Land-capability Classification. *Soil Conservation Service*, 21.

Aguzzi, M., De Nigris, N., Preti, M., & Mallegni, R. (2012). Nuovi indicatori per lo studio e la gestione della costa emiliano-romagnola. *Studi costieri* 2012 - 20: 95 – 109.

Benali, A., Carvalho, A. C., Nunes, J. P., Carvalhais, N., & Santos, A. (2012). Estimating air surface temperature in Portugal using MODIS LST data. *Remote Sensing of Environment*, 124, 108-121.

EPA (2018). Climate Change Impacts by Sector. Available at: https://archive.epa.gov/epa/climate-impacts.html. Last accessed: 11/01/2019.

IPCC (2014). Climate Change 2014: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.

Kosmas, C. F. (1999). Methodology for mapping environmentally sensitive areas (ESAs) to desertification. The Medalus project: Mediterranean desertification and land use. *European Union, 1888*, 31-47.

Liu, L., & Zhang, Y. (2011). Urban heat island analysis using the Landsat TM data and ASTER data: A case study in Hong Kong. *Remote Sensing*, 3(7), 1535-1552.

Oke, T. R. (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*, 108(455), 1-24.

Zha, Y. G. (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. *International journal of remote sensing, 24(3)*, 583-594.