D.3.2.3 – Map of territorial hazards

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1. Introduction

Activities 2 in WP3 include the production of a map of hazard to salt intrusion in coastal aquifers. The map is intended to provide a broad range idea of the vulnerability of different areas in the northern Adriatic basin. The map will be then used in the upscaling of the evaluation obtained at case study level.

A survey was carried out to gather uniformly available information and to share with scientific partners the main aspects of the methodological approach.

2. Methodological approach

Salinisation of coastal aquifers can occur from multiple directions: from above due to inundation or storm surge, laterally due to encroachment of the freshwater/saltwater interface, and from below due to upcoming of saline groundwater caused by pumping (Klassen, and Allen, 2016).

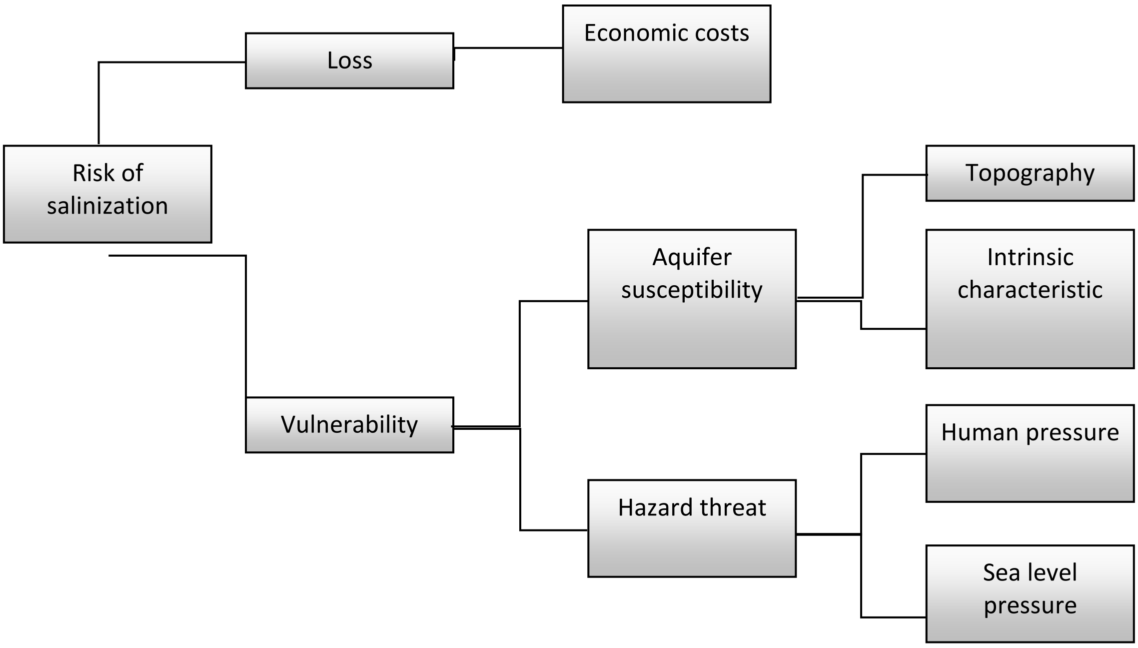
The assessment of risk of salinisation has to simultaneously consider vulnerability (that embeds also the probability of occurrence) and the potential loss (defined as economic consequences due to the contamination of groundwater supply, impacts on human health due to well contamination, or multiple consequences on ecological systems).

According to Simpson et al. (2014), the equation of risk assessments reads:

$$\textit{Risk } (R_H) = \textit{Vulnerability } (V_H) * \textit{Loss } (L)$$

where the vulnerability is defined as aquifer susceptibility and hazard threat, and the probability of occurrence is attributed to each hazard threats and where

$$\textit{Vulnerability } (V_H) = \textit{Aquifer susceptibility } (A_S) * \textit{hazard threat } (H_T)$$



Activity 3.2 is finalised at identifying and mapping territorial hazards.

Klassen and Allen (2016) identified hazard threats in coastal hazard and pumping. Two coastal hazards are defined:

1) flooding, which is associated with sea level rise, tidal fluctuations and storm surge, and
2) coastal morphology.

The risk of flood will be analysed in the following step of the project, which will implement a sea-level rise map (deliverable 3.3.1) and the historical trend of flood (storm surges).

Finally, morphological aspect (height of the coast to investigate the susceptibility to floods) will be analysed based on existing maps. In addition, aquifer susceptibility is also analysed in terms of characteristics of hydrogeological complex.

As emerged from survey (D3.2.1 and D3.2.2) information on wells is not available at a broad scale and it will be considered at the case study level.

In addition to natural hazards, human-driven hazards are considered here, including;

- touristic pressure;
- inhabitants pressure;
- soil use pressure.

The touristic vocation of the Adriatic Basin represents a possible source of criticalities, depending on the carrying capacity of individual sites and potential exploitation of wells at the maximum capacity – or over – for a defined period of time.

Sea level pressure, in particular sea level rise, is one of the focus of the project (WP4) and it will be introduced in the model at a later time, with the output of sea level models (D3.3.1.) developed for the project.

All the information is analysed along a 5 km buffer from the coast to the interior. We used a grid of 1 km X 1 km to analyse and combine the considered parameters.

3. Results

3.1 Aquifer susceptibility (AS)

3.1.1 Topography

Topographic **elevation** has been considered as a parameter for the characterisation of vulnerability of coastal aquifer in many works (see, i.e. Kennedy, 2012, Eriksson et al., 2017). Other authors (i.e. Klassen and Allen, 2016) use slope instead of elevation. Given the broad scale of the map and the complexity of coastal morphology, here we choose elevation as the most appropriate parameter.

The value chosen to assess vulnerability listed in the table below. Differently from Eriksson et al. (2017), who identified three classes of elevation, with maximum height 10 m.s.l.m., here, to account also for the low risks, we chose 5 classes, ranging from 0 to over 500 m.s.l.s.. Data are derived from the Copernicus database[1], and pertain to the EU-DEM v.10 products.

As an additional parameter, the distance from the coast is considered. This information is obtained drafting subsequent buffers from the coast. Value of vulnerability have been extended compared to Klassen and Allen (2016), in order to account for the regional dimension of this work as well as to consider lower risk results.

Table 1: Values of vulnerability for topography

Rating	Elevation (m)	Distance from coast (m)
5	E < 10	0 ≤ D < 50
4	10 ≤ E < 50	50 ≤ D < 250
3	50 ≤ E < 100	250 ≤ D < 500
2	100 ≤ E < 200	500 ≤ D < 1000
1	200 ≤ E < 500	1000 ≤ D < 1500
0	≥ 500	≥ 1500

3.1.2 Intrinsic characteristics

To assess the intrinsic characteristics of aquifers, different values of vulnerability have been attributed to **hydrogeology**. Data are from the International Hydrogeological Map of Europe from Federal Institute for Geosciences and Natural Resources[2]. The final rating, ranging from 1 to 5, results from the combination (rounded up average at the upper bound) of the ranking of two parameters: **aquifer type** and **lithology**.

[1] https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1-0-and-derived-products
[2] https://www.bgr.bund.de/ihme1500

Table 2: values of vulnerability for aquifer types

Aquifer type	Rating	Lithology (L3)
Highly productive fissured aquifers (including karstified rocks)	5	Gravel Limestones Limestones and marls Marbles
Highly productive aquifer	4	Quartzites Sands
Low and moderately productive fissured aquifers (including karstified rocks) Low and moderately productive porous aquifers	3	Marlstones and sands Sandstones and marls
Locally aquiferous rocks, porous or fissured	2	Clays Sandstones and clays
Practically non-aquiferous rocks, porous or fissured	1	-

3.1.3 Scenarios of aquifer susceptibility

The information obtained for each variable has been arranged to create three possible scenarios, as shown in the following table. The weights have been allocated considering that:

- for hydrogeology, the rank accounts for two interdependent variables, namely aquifer type and lithology;
- Elevation and distance are two not completely independent variables.

As a consequence, the AS_A scenario balances uniformly all the variables considered and it is our preferred scenario for the construction of the final map on territorial hazard.

Table 3: Weights for the scenarios of aquifer susceptibility

	AS_A	AS_B	AS_C
Elevation	0.25	0.2	0.2
Distance	0.25	0.4	0.3
Hydrogeology	0.25	0.4	0.5

3.2 Hazard threat (HT)

3.2.1 Human pressure

To account for human pressure, the first index used has been the **population density**. This has been computed as ratio between the number of inhabitants at the municipality level and the aera of the municipality (inhabitant/km2). Information on population have been extracted from national statistic databases for Italy[3], Croatia[4] and Slovenia[5]. The value of vulnerability associated to the population density is shown in table 4.

In addition to population, also **the touristic pressure** has been considered. The total tourist presence for year 2018 have been extracted from statistical databases at County level for Croatia[6] and at Province level for Italy[7].

[3] http://www.geofunction.it/academy/mappe-demografiche-istat/
[4] https://www.dzs.hr/default_e.htm
[5] https://www.stat.si/obcine/en/2016/Municip/Index/68
[6] http://www.dzs.hr/PXWeb/sq/7feeaf8e-aa7b-407b-825e-1b82426ad417
[7] www.istat.it

Table 4: values of vulnerability for population density and touristic fluxes

Rating	Population density (P)	Touristic presence (T) (million)
5	P>500	T>10
4	200<P≤500	5<T≤10
3	100<P≤200	2<T≤5
2	50<P≤100	1<T≤2
1	0<P≤50	T≤1

3.2.2 Soil use pressure

The use of soil represents a driver in use of water. The Corine Land Cover (CLC) map, which classifies soil uses, has been utilised as a basis for the analysis. Between the CLC classes, those which implied a potential use of water, have been associated with a rank for the hazard, as shown in the following table. All the other classes have been set to zero. “Urban fabric” class has not been considered here, since the information overlaps with resident population.

Table 5: values of vulnerability for soil use

CLC Class (II level)	CLC Class (III level)	Rating
12 Industrial, commercial and transport units	121 Industrial or commercial units	2
21 Arable land	212 Permanently irrigated land	2
	213 Rice fields	4
22 Permanent crops	222 Fruit trees and berry plantations	2
24 Heterogeneous agricultural area	241 Annual crops associated with permanent crops	2
	242 Complex cultivation patterns	2
	243 Land principally occupied by agriculture, with significant areas of natural vegetation	2
All other classes		0

3.2.3 Scenarios of Hazard threats

The information obtained for each variable has been arranged to create three possible scenarios, as shown in table 6. Comparison of the simulations obtained show that the three scenarios proposed are very similar. Since it is not currently possible to assess which of the three variables included in the analysis is the most relevant in terms of hazard for salt intrusion, the prefer scenario is the HT_A, in which the three components are weighted uniformly.

Table 6: Weights for the scenarios of Hazard threats

	HT_A	HT_B	HT_C
Land use	0.33	0.4	0.3
Population	0.33	0.3	0.5
Tourism	0.33	0.3	0.2

3.3 Modeling information

The information obtained have been combined together to obtain a final map that accommodates all the considered parameters. According to Klassen and Allen (2016), this final map can be obtained by the straight combination (sum of values) of the two maps obtained for hazard threats and Aquifer susceptibility. Considering that the parameters used for the vulnerability assessment were weighted and combined to obtain an overall ranking on the scale 1-5, the final map would scale on a rank from 1 to 10. Here, a similar approach has been used by weighting the variables for the production of the two maps of aquifer susceptibility and hazard threats. Nevertheless, for the combination of the two maps, we prefer a more cautelative approach, with the construction of three possible scenarios. The weight for the construction of the scenarios are shown in the following table. Applying this approach, each of the final maps would scale on a rank from 1 to 5. Of the 27 possible combinations (3 AS * 3 HT * 3 scenarios) we choose to reduce the options to only three final scenarios, utilising the preferred option for Aquifer susceptibility (AS_A) and for Hazard threats (HT_A). Results are shown in the annex.

Table 7: Weights for the final scenarios of Territorial Hazard

	S_A	**S_B**	**S_C**
AS_A	0.5	0.25	0.75
HT_A	0.5	0.75	0.25

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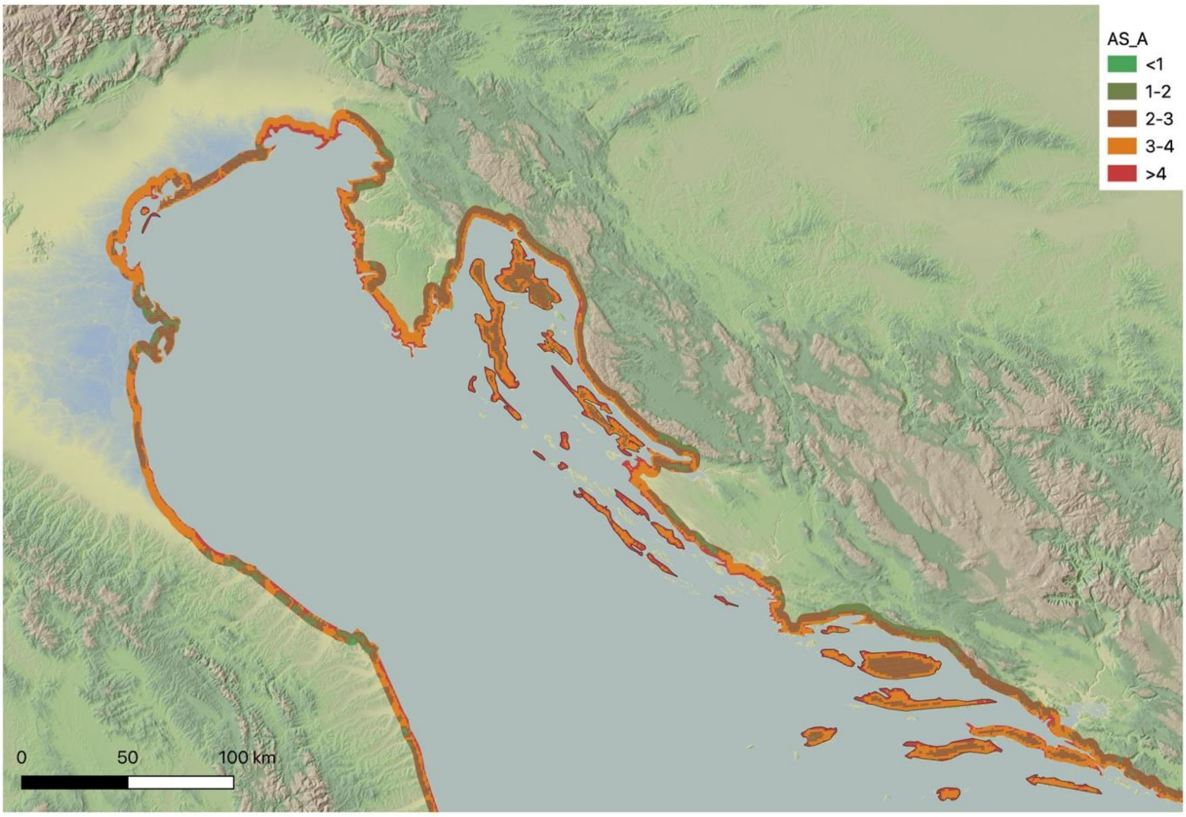
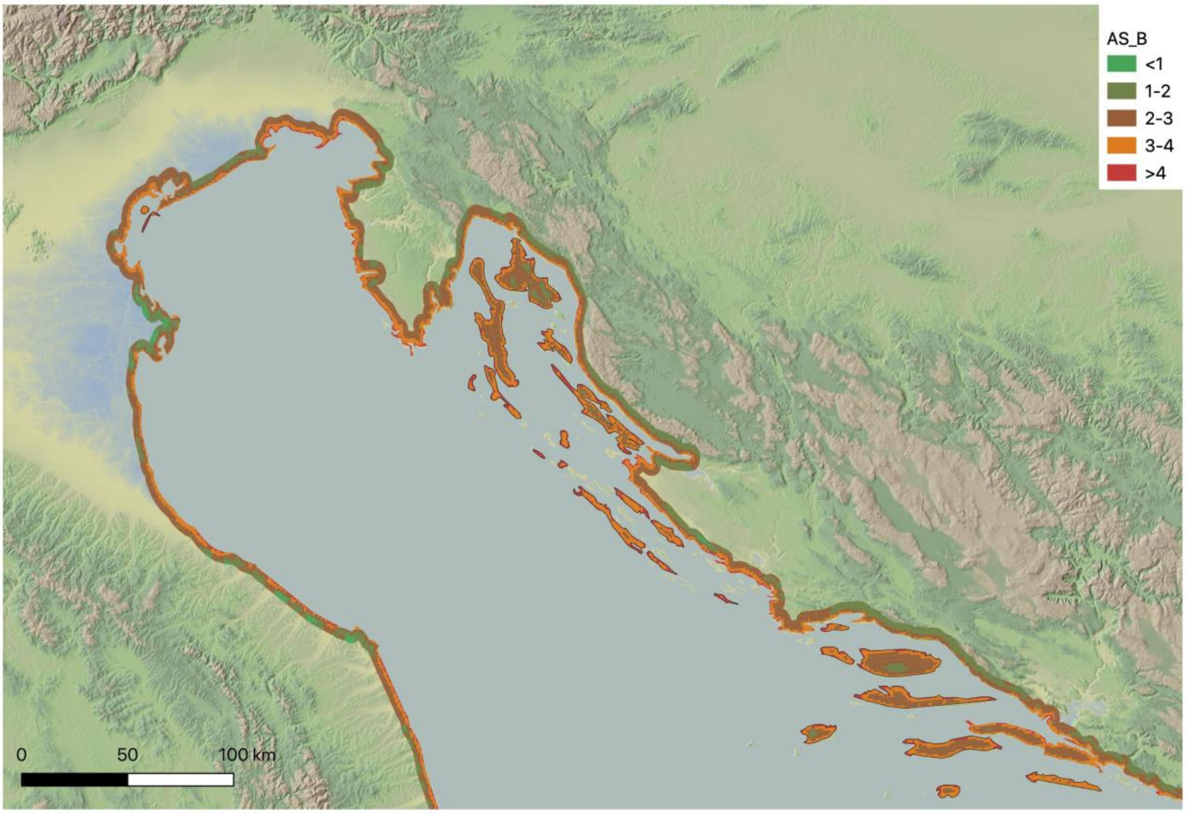
ANNEXES

Annex 1 A: Map of territorial hazards: scenario S_A



Annex 1 B: Map of territorial hazards: scenario S_B



Annex 1 C: Map of territorial hazards: scenario S_C