

## **D2.2 Technical report on the definition of the model ratings and weights**

# **DATASET**

**“Groundwater sAlinizaTion and pollution AsseSsmEnt Tool”**



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### EXECUTIVE SUMMARY:

The deliverable **D 2.2 Technical report on the definition of the model ratings and weights** presents ADI - AGL and ADI-SP factors weights and parameters classification calibration in 15 coastal areas representing different hydrogeological and climatic conditions worldwide.

D 2.2 is intended for use by DATASET project researchers only.

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# 1 General information

The goal of DATASET is to create an efficient tool that helps protect and manage the use of water resources in coastal aquifers, even under changing and challenging conditions. To achieve this goal, DATASET focuses on three main objectives:

**OBJ 1** - Better tools for better protection developing a new method to create vulnerability maps of coastal aquifers.

**OBJ 2** – Innovative water management forcing a paradigm shift in water governance by making data, models, and management tools available online.

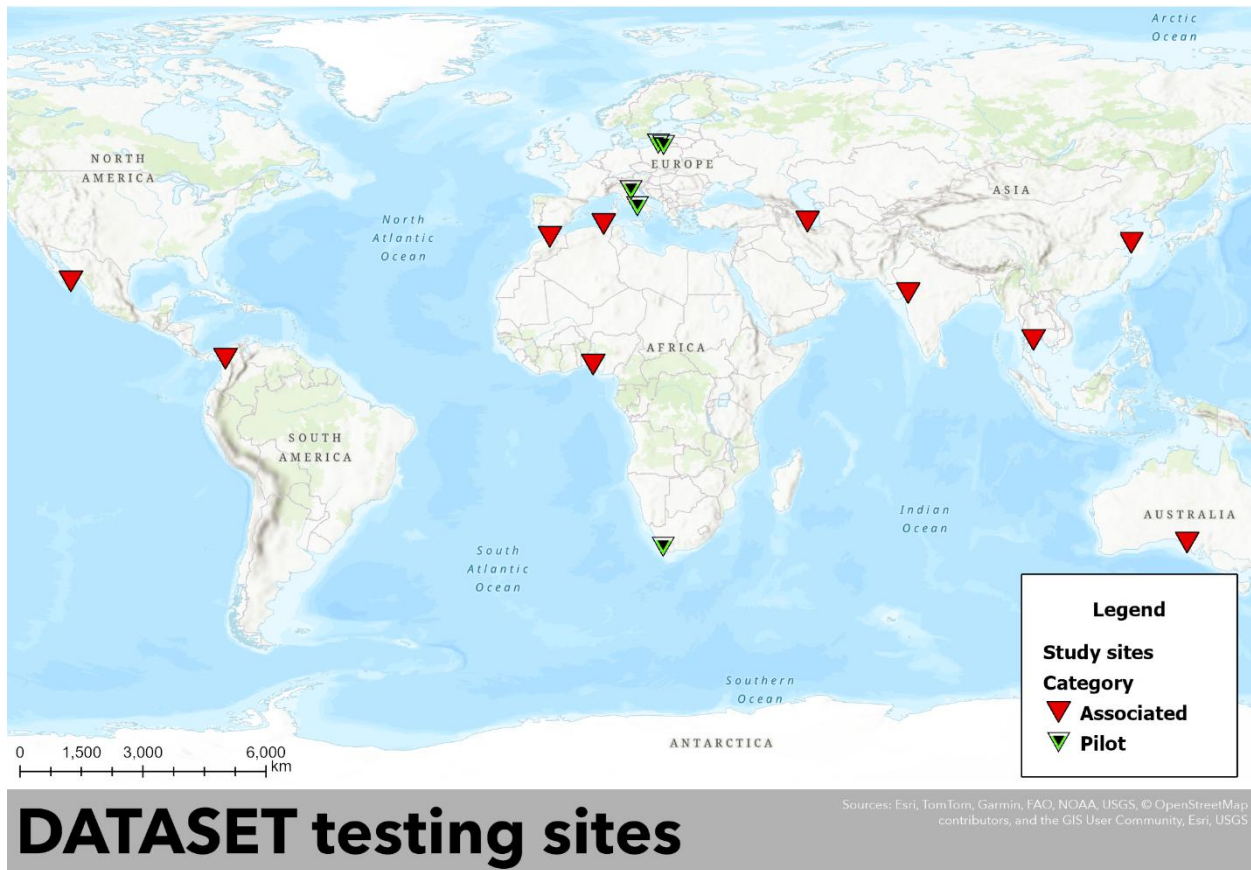
**OBJ 3** – Raising awareness highlighting the importance of groundwater and its vulnerability to climate change and extreme events.

To reach these three objectives, DATASET follows a multidisciplinary approach. This means bringing together expertise from different fields to identify the environmental factors that can harm groundwater quality. Using the best available knowledge, we also gather data from open-access databases to build a comprehensive picture of the challenges that coastal aquifers must face [D.1.1].

The research has led to the creation of a new index designed to evaluate groundwater vulnerability specifically to salinization and agricultural leaching [D1.3]. This index uses a simple and accessible formula that allows the use of global data, making it easier for researchers, planners, and policymakers to assess risks anywhere in the world.

The DATASET methodology has been developed and calibrated in 15 sites around the world: 5 under consortium responsibility and 10 selected by open literature (Fig. 1). These sites are in five continents with different hydrogeological, climatic, and land-use conditions. The selected pilot sites are the Campania Plain (Italy), the Po Delta Plain (Italy), the Puck Bay Catchment (Poland), the Vistula Spit (Poland), and the Cape Flats Aquifer System (South Africa). While, the associated sites are La Paz aquifer system (Mexico), Antioquia (Colombia), the Yellow River Delta (China), Gujarat alluvial plain (India), Phetchaburi Province (Thailand), Lagos lagoon aquifer (Nigeria), Taleza (Algeria), The Western Port Basin (Australia), Gialn aquifer (Iran), and Souss-Massa (Morocco). This diversity allows for a comprehensive evaluation of the DATASET methodology

and supports the assessment of its robustness and applicability under different environmental conditions [D2.1].



**Figure 1:** Pilot sites and associated sites

The purpose of Deliverable D 2.2, Technical report on the definition of the model ratings and weights, is to present the DATASET methodology to reach parameters weights and rating for AGL and SP. Moreover, this deliverable presents applications in 15 coastal areas (5 pilot sites and 10 associated sites) representing different hydrogeological and climatic conditions worldwide, supported by graphical outputs and interpretation.

## 1.1 Automated DATASET Index (ADI)

As stated in the D1.3, the DATASET index is designed to establish a standardized methodology for evaluating groundwater vulnerability assessment (GVA) to both salinisation processes (SP) and agricultural leaching (AGL) pollution, ensuring global accessibility and affordability for researchers.

The selection of key factors follows two mandatory criteria:

1. **Global Data Availability** – Factors must be accessible from open databases with worldwide coverage to enable broad applicability.
2. **Ease of Use** – The methodology should be straightforward to implement while maintaining a balance between accuracy and usability.

This index offers flexibility by allowing users to assess either SP or AGL by simply toggling relevant parameters on or off (Fig. 2). The selected parameters are based on systematic reviews (D1.1) and refined from established models such as DRASTIC, GOD, SINTACS and GALDIT, focusing on the most impactful, quantifiable factors while incorporating additional parameters used in specific local assessments.

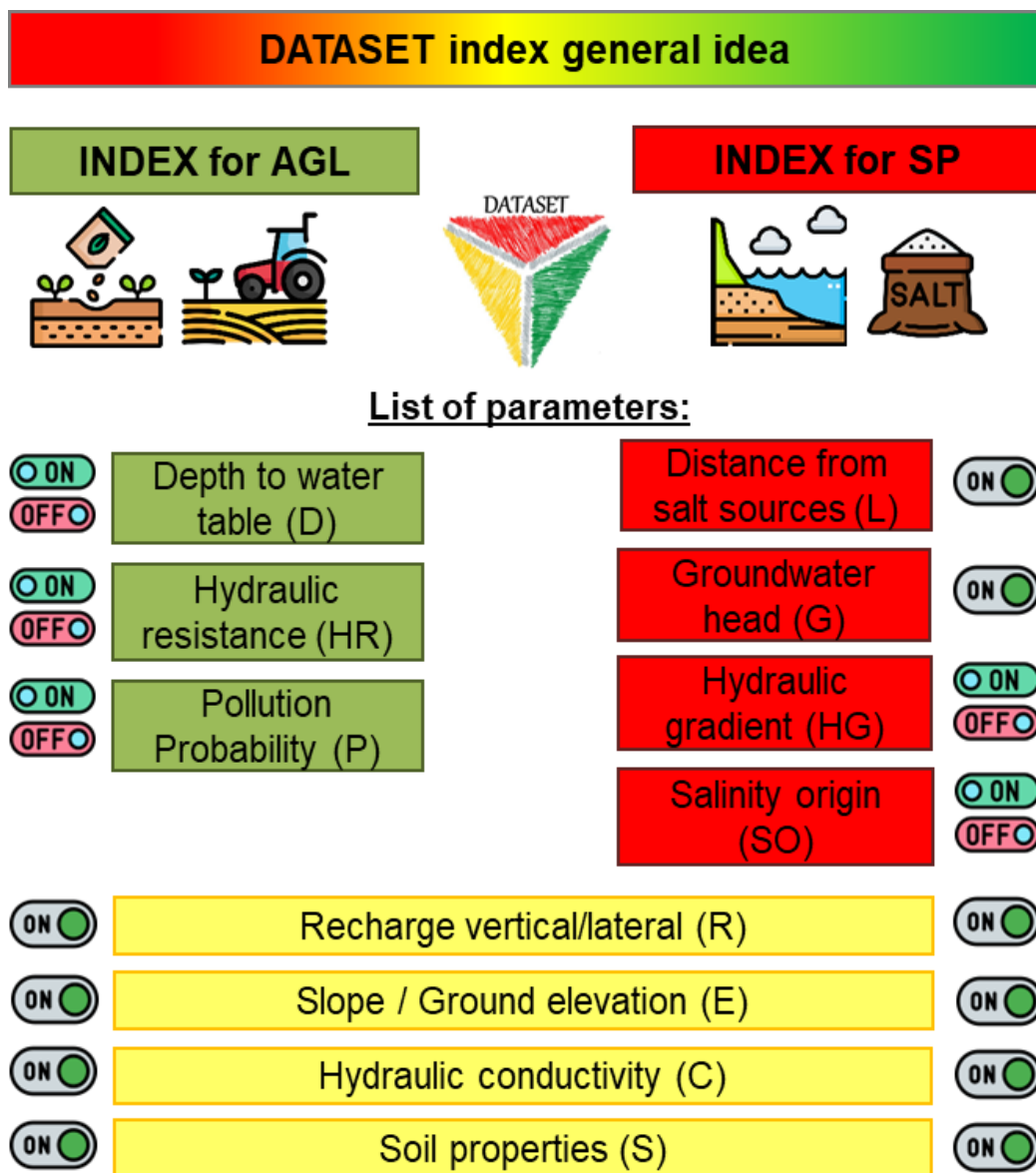
- **For SP assessment**, key parameters include distance from salt/freshwater sources, recharge, groundwater head, hydraulic conductivity, elevation, hydraulic gradient, salinity origin, and soil properties.
- **For AGL assessment**, factors related to pollutant transport and aquifer characteristics are prioritized, such as depth to the water table, recharge, elevation (slope), hydraulic conductivity, hydraulic resistance, background pollutant levels, and soil properties.

The DATASET index will be divided into two sub-indices: an Automatic DATASET Index (ADI) and an Improved DATASET index (IDI).

ADI is a fully automated tool that enables effortless groundwater vulnerability assessment (GVA) for SP and AGL, eliminating the need for manual input.

- **Fully Automated** – Relies exclusively on open-source data provided by the DATASET team for global accessibility.
- **Effortless Screening** – Users can generate vulnerability maps worldwide by selecting parameters from a predefined list.
- **Standardized Input Data** – Ensures consistency by utilizing parameters available through the **DATASET Project Website**.

The ADI includes **six parameters for SP assessment** and **five for AGL assessment**, aiming to provide a robust screening phase that is both accessible and sufficiently detailed, avoiding oversimplification (Foster et al., 2013).



**Figure 2:** General concept of the DATASET index.

As shown in Fig. 2 and described in Deliverable D1.3, the parameters used for AGL assessment are **depth to water table (D)**, **vertical recharge (R)**, **hydraulic conductivity (C)**, **slope (E)**, and **soil properties (S)**.

On the other hand, the parameters used for SP assessment are **ground elevation (E)**, **groundwater head (G)**, **vertical recharge (R)**, **hydraulic conductivity (C)**, **soil properties (S)**, and **distance from saltwater and freshwater sources (L)**. The readers can refer to the D1.3 and M1 for further details about index equation and structure.

## 2 Methodology

### 2.1 ADI index parameters ranking and weights

The ranking and weighting of the parameters included in the Automated DATASET Index (ADI) are based on the results of the systematic literature reviews carried out within the DATASET project and described in Deliverables D1.2 and D1.3. These reviews analysed existing groundwater vulnerability assessment methods and their modifications to identify the most influential factors controlling agricultural leaching (AGL) and salinization processes (SP).

The analysis showed that numerical hydrogeological parameters represent the most reliable indicators for vulnerability assessment. For AGL, factors such as depth to water, recharge, hydraulic conductivity, and topography were identified as the most influential variables controlling contaminant transport in aquifers. Similarly, for SP assessment, parameters related to groundwater flow, proximity to saline sources, groundwater head, distance from the shoreline, and aquifer hydraulic conductivity play a dominant role in controlling seawater intrusion processes.

The ranking was derived from the frequency and relative importance of parameters reported in modified vulnerability assessment methods. Based on this ranking, a set of normalized weights was assigned to each parameter to represent their relative contribution to groundwater vulnerability within the ADI framework. The sum of the weights is equal to 1, ensuring consistency in the calculation of the final vulnerability index. The expert judgement procedure integrates evidence

from numerous model applications and published studies, thereby reducing bias and limiting subjectivity.

## 2.2 ADI index parameters ratings

Following the approach described by Busico et al. (2017), the correlation between the vulnerability associated with each parameter and actual pollution occurrence was used to calibrate the ADI parameters rating. Nitrate ( $\text{NO}_3^-$ ) and chloride ( $\text{Cl}^-$ ) were selected as representative pollutants for agricultural leaching and salinisation process, respectively. Results from 15 sites worldwide (Fig. 1) were used for this purpose, based on both consortium data and literature sources (Table 1).

To improve the reliability and accuracy of the vulnerability assessment, GIS-based statistical methods were applied to adjust the class ranges of each parameter.  $\text{NO}_3^-$  and  $\text{Cl}^-$  concentration maps were first generated. Subsequently, a regular point grid (fishnet) with a spatial resolution of 100 m was created, and pollutant concentrations were extracted at each grid point using the GIS function “raster to point”.

Table 1. Overview of study sites chosen based on literature review.

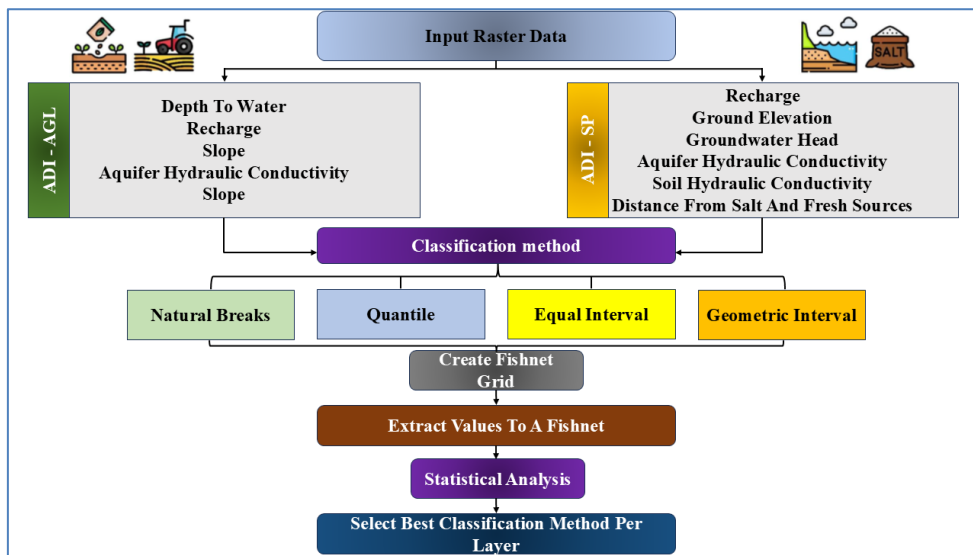
Site	Article Title	DOI
Morocco	Groundwater vulnerability and, risk assessment of seawater intrusion for the development of a strategy plan towards sustainability: Case of the Souss-Massa coastal area, Morocco	<a href="https://doi.org/10.1016/j.ejrh.2024.102128">https://doi.org/10.1016/j.ejrh.2024.102128</a>
Algeria	Identifying groundwater degradation sources in a Mediterranean coastal area experiencing significant multi-origin stresses	<a href="https://doi.org/10.1016/j.scitotenv.2020.141203">https://doi.org/10.1016/j.scitotenv.2020.141203</a>
Australia	Analysis of environmental isotopes in groundwater to understand the response of a vulnerable coastal aquifer to pumping: Western Port Basin, south-eastern Australia	<a href="https://doi.org/10.1007/s10040-013-1017-9">https://doi.org/10.1007/s10040-013-1017-9</a>
China	Geochemical and isotopic evidence of shallow groundwater salinization in a reclaimed coastal zone: the Yellow River Delta, China	<a href="https://doi.org/10.1007/s12665-016-5918-5">https://doi.org/10.1007/s12665-016-5918-5</a>
Colombia	A multi-tracer approach for understanding the functioning of heterogeneous phreatic coastal aquifers in humid tropical zones	<a href="https://doi.org/10.1080/02626667.2021.1882679">https://doi.org/10.1080/02626667.2021.1882679</a>
India	Geochemical and isotope tracing of groundwater salinity in the coastal Gujarat alluvial plain, India	<a href="https://doi.org/10.1016/j.jconhyd.2022.104000">https://doi.org/10.1016/j.jconhyd.2022.104000</a>
Mexico	Assessing seawater intrusion in an arid coastal aquifer under high anthropogenic influence using major constituents, Sr and B isotopes in groundwater	<a href="https://doi.org/10.1016/j.scitotenv.2017.02.137">https://doi.org/10.1016/j.scitotenv.2017.02.137</a>
Nigeria	Groundwater Quality around upstream and downstream area of the Lagos lagoon using GIS and Multispectral Analysis	<a href="https://doi.org/10.1016/j.sciaf.2022.e01126">https://doi.org/10.1016/j.sciaf.2022.e01126</a>
Thailand	Hydrochemical, geophysical and multivariate statistical investigation of the seawater intrusion in the coastal aquifer at Phetchaburi Province, Thailand	<a href="https://doi.org/10.1016/j.jseaes.2019.104165">https://doi.org/10.1016/j.jseaes.2019.104165</a>
Iran	Iranian Regional Water Authority (2018) Groundwater feasibility study for Gialn aquifer. Regional Water Authority, Iran	

The Input data required for the elaboration of ADI index parameters were obtained from the DATASET Open Database (DOD) (deliverable D1.1), available on the DATASET project website. Table 2 summarises the global datasets used for both ADI-AGL and ADI-SP indexes.

Table 2. Input global data from DATASET Open Database.

Database	Link	Spatial resolution
Depth to water	<a href="http://thredds-gfml.usc.es/thredds/catalog/GLOBALWTDFTP/catalog.html">http://thredds-gfml.usc.es/thredds/catalog/GLOBALWTDFTP/catalog.html</a>	1 x 1 Km
Precipitation	<a href="https://www.worldclim.org/data/monthlywth.html">https://www.worldclim.org/data/monthlywth.html</a>	4.6 x 4.6 Km
Soil properties	<a href="https://soilgrids.org/">https://soilgrids.org/</a>	250 x 250 m
Topography	<a href="https://download.geoservice.dlr.de/TDM30_EDEM/">https://download.geoservice.dlr.de/TDM30_EDEM/</a>	30 x 30 m
Hydraulic conductivity	<a href="https://borealisdata.ca/dataset.xhtml?persistentId=doi:10.5683/SP2/DLGXYO">https://borealisdata.ca/dataset.xhtml?persistentId=doi:10.5683/SP2/DLGXYO</a>	-

Four classification methods - natural breaks, equal interval, quantile, and geometrical intervals - were used to determine the optimal class ranges and to derive the final vulnerability indexes. Each parameter was ranked on a scale from 1 to 10, either in ascending or descending order depending on its contribution to agricultural leaching or salinization processes. High values indicate greater vulnerability to contamination. The selection of the most appropriate classification method was based on the strength of the correlation between parameter class values and  $\text{NO}_3^-$  or  $\text{Cl}^-$  concentrations extracted at the fishnet grid points. This calibration step was performed using Pearson's ( $r$ ) correlation coefficient. As this method assumes normally distributed data,  $\text{NO}_3^-$  or  $\text{Cl}^-$  concentrations were log-transformed prior to analysis (Kazakis and Voudouris, 2015; Panagopoulos et al., 2006; Potrykus et al, 2026) (Fig. 3). The final classification adopted for each parameter is presented in Section 3, and the detailed procedure is described below for both ADI-AGL and ADI-SP indexes.



**Figure 3.** Flowchart methodology for selecting the optimal classification method for each parameter in ADI-AGL and ADI-SP indexes.

### 2.2.1 SP parameters classification

**Vertical Recharge (R):** The vertical recharge was calculated by multiplying average yearly precipitation (Harris et al., 2020) by the soil coefficient of infiltration. At least yearly average precipitation calculated on period of 10 years is recommended. Input data for the latter were obtained from the global soil grid database (Batjes et al., 2020). Clay, silt, and sand layers for each study site were processed in SAGAGIS to derive soil texture. Coefficient of infiltration values were then assigned based on literature sources (Civita and De Maio, 2004). Both precipitation and coefficient of infiltration layers were resampled to 100 m, and vertical recharge was computed using the following formula (Eq.1) in the GIS raster calculator.

$$\text{Recharge (mm)} = \text{Precipitation} * \text{Coefficient of Infiltration} \quad (\text{Eq. 1})$$

Since a decrease in recharge can increase aquifer susceptibility to saltwater contamination (Costall et al., 2020), higher recharge values correspond to lower vulnerability. Therefore, the resulting layer was classified in descending order using natural breaks, equal interval, quantile and geometrical intervals methods.

**Ground elevation (E):** For each study site, the DEM taken from the global dataset (STRM X-SAR digital elevation model collected during the Shuttle Radar Topography mission) was resampled to 100 m resolution and reclassified using the four grading methods above mentioned. The reclassification follows a descending order, as flat and depressed morphologies are more prone to salinisation processes.

**Groundwater head (G):** Groundwater head was calculated by subtracting the depth to water raster from the ground elevation raster. Both rasters were created by resampling to 100 m the original layers taken from global data (STRM X-SAR DEM and global patterns of groundwater table depth database by Fan et al., (2013)). Since higher groundwater heads correspond to lower vulnerability to salinisation, the resulting layer was classified in descending order using the four grading methods (Fig. 3).

**Aquifer hydraulic conductivity (C):** Aquifer hydraulic conductivity was derived from permeability data from the GLHYMPS dataset (Gleeson et al., 2014), using the following formula (Eq. 2):

$$\text{Hydraulic conductivity (m/d)} = (10^{K/100}) * 10^7 * 86400 \quad (\text{Eq. 2})$$

Where: K is the permeability of the geological unit (LogK\_Ice\_x in the global database).

In the context of salinisation processes, high hydraulic conductivity implies higher vulnerability. Therefore, the raster was classified in ascending order using the four classification methods. Due to hydraulic conductivity data limitations and distribution, the selection of the most suitable grading method was primarily based on pilot sites (Campania Plain, Po Delta Plain, Puck Bay, and Cape Flats) and two associated sites (Morocco and Nigeria). For others study sites, the DRASTIC rating system was adopted (Table 3).

Table 3. Aquifer hydraulic conductivity rating according to DRASTIC application (Aller, 1987).

Hydraulic conductivity (m/day)	
Range	Rating
0.005 - 5	1
5 - 15	2
15 - 25	4
25 - 50	6
50 - 100	8
> 100	10

**Soil hydraulic conductivity (S):** Soil hydraulic conductivity influences the magnitude and speed of salinisation processes. The corresponding raster was generated by assigning literature-based soil hydraulic conductivity values (Table 4) to the USDA soil texture raster derived earlier. As

with aquifer hydraulic conductivity the optimal grading method was primarily determined in pilot sites (Campania Plain, Po Delta Plain, and Puck Bay) and one associated site (Morocco), using ascending classification. For other sites, the rating was based on Kazakis et al., 2019 (Table 5).

Table 4. Simplified soil hydraulic conductivity rating

ID	Soil texture	HC (m/d)
1	clay	7.6
2	silt Clay	7.1
3	silty Clay Loam	11.0
4	sandy clay	2.9
5	sandy clay loam	5.8
6	clay loam	4.2
7	silt	20.6
8	silt loam	9.5
9	loam	4.7
10	sand	92.2
11	loamy sand	26.1
12	sandy loam	12.6

Table 5. Soil hydraulic conductivity rating based on literature (Kazakis et al., 2019)

Soil hydraulic conductivity	
(m/day)	Rating
> 40	10
10 - 40	8
5 - 10	5
2.5 - 5	3
< 2.5	1

**Distance from salt and fresh water sources (L):** The ADI-SP index considers three types of saltwater sources; i) coastlines and large salty lagoons; ii) surface water bodies including small

lakes and wetlands; and iii) river sections with saline water. Depending on geomorphology, the surface water bodies and river sections above 2 m.a.s.l. are considered freshwater sources and vice versa. Spatial data for coastline, rivers and surface water bodies were obtained from global or local datasets and complemented by manual digitalisation. Euclidean distance rasters were generated for each source type. Correlation with chloride concentrations was then used to determine the radius of influence threshold and the appropriate classification method.

### 2.2.2 AGL parameters classification

**Depth to water:** Groundwater depth is a key factor influencing agricultural leaching processes. Shallow groundwater is more susceptible to contamination than deeper groundwater. Therefore, four classification methods were applied (natural breaks, equal interval, quantile, and geometric interval) (Fig. 3), assigning ten vulnerability classes ranging from 1 (deep groundwater) to 10 (shallow groundwater).

**Slope:** Topography has a significant impact on the movement of surface water toward the aquifer. Similarly, slope was classified into ten classes using the aforementioned classification methods, assigning low values (1) to steep slopes and high values (10) to flat areas.

**Recharge:** Recharge rate plays a significant role in the agricultural leaching process. Higher recharge rates increase the likelihood of contamination, whereas lower recharge rates reduce this risk. Low values (1) were assigned to areas of low recharge, while high values (10) were attributed to areas of high recharge.

**Aquifer hydraulic conductivity:** The aquifer matrix's ability to transmit water through its pores and fractures facilitates the diffusion and transport of contaminants. Layers of high hydraulic conductivity are more susceptible to contamination, whereas layers of low hydraulic conductivity exhibit reduced contaminant diffusion and dispersion. Based on this principle, the layers were classified on a scale from 1 to 10 using four different methods. This classification could not be applied uniformly across all sites, as some study areas lacked sufficient spatial data on hydraulic conductivity. In these cases, the rating established for the DRASTIC index was used to address this limitation (Table 3).

**Clay percentage:** Clay content is considered a proxy for soil characteristics. It plays an important role in controlling the movement of surface water toward the aquifer. A high percentage of clay

limits water infiltration due to its low permeability, whereas a low clay content facilitates the infiltration of surface water loaded with contaminants. Therefore, the soil layer was classified into ten classes using the aforementioned classification methods. Low values (1) were assigned to pixels with low clay content, while high values (10) were attributed to areas of high clay content.

### 3 Results

This section presents the results of the ADI parameters weight and classification for groundwater vulnerability to agricultural leaching (AGL) and salinization processes (SP) for the associated and pilot sites.

#### 3.1 Weights and rating results

- *ADI - SP parameters classification*

Table 6 summarises the optimal classifications for the ADI-SP parameters; ground elevation (E), groundwater head (G), recharge (R), aquifer hydraulic conductivity (C), and soil hydraulic conductivity (S). The **quantile** method was most frequently the optimal grading method for parameters G and R, while for E parameter **geometric interval** method was optimal in 12 study areas.

Due to data distributions and limitations, grading methods for parameters C and S were mainly determined in pilot sites. In these cases, **equal interval** was selected for aquifer hydraulic conductivity, and **geometric interval** for soil hydraulic conductivity.

Table 6. Optimal ADI-SP parameters classification methods across the 15 study areas (Classification methods: Q = Quantile, GI = Geometric Interval, EI = Equal Interval, N = Natural Breaks, RT = Reference Table)

Parameter	Algeria	China	Iran	Mexico	Nigeria	Australia	Thailand	Colombia	India	Morocco	Italy (1)	Puck	SA	Po	Vistula
E	GI	Q	GI	N	GI	GI	GI	GI	GI	GI	GI	GI	Q	GI	GI
G	EI	EI	Q	Q	Q	Q	Q	Q	GI	Q	GI	Q	Q	Q	GI
R	EI	GI	GI	EI	Q	GI	N	Q	Q	Q	Q	GI	Q	Q	Q
C	RT	RT	RT	RT	EI	RT	RT	RT	RT	EI	N	EI	EI	EI	RT

S	RT	RT	RT	RT	RT	RT	RT	RT	RT	RT	GI	EI	EI	RT	GI	RT
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For the distance parameter (L), the analysis identified a threshold of 2 km as the radius of influence, with Euclidean distance used for classification.

The final parameter weights and rating used to assess groundwater vulnerability to salinisation processes are summarized in Table 7.

Table 7. ADI–SP parameters ranking and weights

Parameter	Symbol	Classification method	Weight
Ground elevation (DEM)	E	Geometric interval	0.15
Groundwater head	G	Quantile	0.23
Recharge	R	Quantile	0.12
Aquifer hydraulic conductivity	C	Equal interval	0.1
Soil hydraulic conductivity	S	Geometric interval	0.12
Distance from coastline	L	Euclidean distance	0.21
Rivers (saltwater)	L (river-salt)	Euclidean distance	0.01
Rivers (freshwater)	L (river-fresh)	Euclidean distance	0.01
Lagoons/Lakes (saltwater)	L (lagoon-salt)	Euclidean distance	0.025
Lagoons/Lakes (freshwater)	L (lagoon-fresh)	Euclidean distance	0.025

**Notes:**

If rivers act exclusively as freshwater or saltwater sources along their entire length, a cumulative weight of 0.02 is assigned.

If lagoons or small lakes act exclusively as freshwater or only saltwater sources across their entire extent, a cumulative weight of 0.05 is assigned.

The ranking and weighting results for SP, considering only the parameters selected and applied in the ADI, show that the most influential parameters are numerical and related to groundwater flow and proximity to saline sources. Parameters such as groundwater head, recharge, and distance from the coastline play an important role, as they directly control groundwater flow and seawater intrusion. Their continuous nature allows for a more accurate spatial representation of vulnerability

across the study areas. In contrast, the bottom-ranked parameters (the impact of existing seawater intrusion) are typically associated with higher uncertainty or limited spatial variability. In many cases, these parameters remain relatively uniform across the study area or are difficult to quantify consistently, which reduces their contribution to spatial differentiation in vulnerability assessment. As a result, they are considered less reliable for broad-scale assessments and/or useless for homogeneous areas.

The final formulation of the ADI index for SP is as follows:

$$ADI - SP = 0.28 * L_{Euc} + 0.23 * G_Q + 0.12 * R_Q + 0.15 * E_G + 0.11 * C_E + 0.13 * S_G \quad (Eq. 3)$$

- *ADI - AGL parameters classification*

Table 8 summarises the optimal classifications for the ADI-AGL parameters. The correlation between  $NO_3^-$  concentrations extracted from the fishnet grid and the classification methods indicates that the **quantile** method provides the best performance, showing the highest correlation for parameters D (depth to water), R (recharge), and C (aquifer hydraulic conductivity).

Among the four classification methods used, the **geometric interval** method showed the best performance for the parameter E (slope). The analysis of the classification results in relation to  $NO_3^-$  concentrations also shows that the **equal interval** method provides the most suitable classification for the parameter S (clay percentage).

Table 8. Optimal ADI-AGL parameters classification methods in the 15 study areas (Classification methods: Q = Quantile, GI = Geometric Interval, EI = Equal Interval, N = Natural Breaks, RT = Reference Table)

Parameter	Algeria	China	Iran	Mexico	Nigeria	Australia	Thailand	Colombia	India	Morocco	Campania	Puck	SA	Po	Vistula
D	Q	Q	GI	N	EI	Q	EI	Q	Q	Q	GI	GI	Q	Q	N
E	Q	N	GI	Q	GI	EI	N	GI	GI	N	Q	GI	EI	GI	GI
R	Q	N	EI	N	Q	Q	GI	Q	Q	GI	Q	Q	Q	EI	N
C	RT	RT	RT	RT	Q	RT	RT	RT	RT	Q	Q	Q	N	Q	GI
S	EI	EI	GI	Q	EI	EI	Q	Q	Q	EI	N	EI	EI	EI	N

Table 9. ADI-AGL parameters ranking and weights

Parameter	Symbol	Classification method	Weight
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Depth to water	D	Quantile	0.56
Slope	E	Geometric Interval	0.14
Recharge	R	Quantile	0.12
Aquifer hydraulic conductivity	C	Quantile	0.11
Clay percentage	S	Equal Interval	0.07

A similar pattern is observed for AGL (Table 9), considering only the parameters selected and applied in the ADI, where numerical hydrogeological parameters (such as Depth to Water, Topography, Recharge, and Hydraulic Conductivity) clearly play a more important role than qualitative factors. Numerical parameters are continuous and can be directly measured in the field, which makes them more reliable and less dependent on interpretation. Although they may include some measurement uncertainty, this is usually linked to data resolution or instrumentation rather than subjectivity. In contrast, qualitative parameters are based on categorical descriptions and depend more on expert interpretation, which introduces greater uncertainty.

The final formulation of the ADI index for AGL is as follows:

$$ADI - AGL = 0.56 * D_Q + 0.12 * R_Q + 0.14 * E_G + 0.11 * C_Q + 0.07 * S_E \quad (Eq. 4)$$

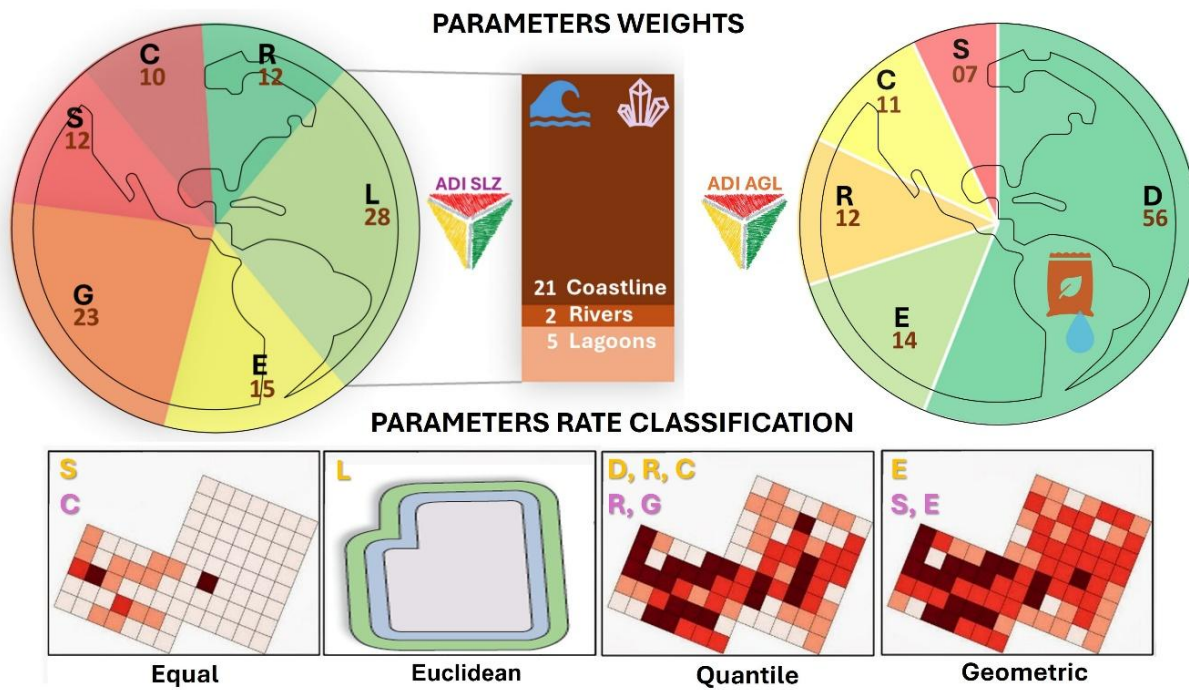
### 3.2 ADI index conceptual model

The conceptual model in Fig. 4 summarizes the ADI index methodology for both AGL and SP.

- **For SP assessment**, L (Distance from salt and fresh water) parameter represents 28% of the ADI-SP final weight, followed by G (Ground water head) with 23% and E (ground elevation) with 15%. Both R (Recharge) and S (Soil hydraulic conductivity) represent 12% of the ADI-SP final weight. Finally, parameter C (aquifer hydraulic conductivity) represents 10% of the final weight. Within the L parameter (28% total weight), 21% is assigned to distance from coastline and large saline lagoons, while 2% is assigned to rivers (1% to salt rivers and 1% to fresh rivers) and 5% to other surface water bodies (e.g. small lakes, wetlands.). These weights are split between freshwater and saltwater sources. If one type is absent, its weight is transferred to the existing sources (e.g., if no saline rivers are present, freshwater rivers receive the full 2%). The classification method in the case of L parameter is Euclidean distance. Areas closest to saltwater sources and farthest from freshwater sources are considered highly vulnerable (class 10).

For the remaining ADI-SP parameters, the final grading methods are Quantile for ground water head (G) and recharge (R), Geometric Interval for ground elevation (E) and soil hydraulic conductivity (S), and Equal Interval for aquifer hydraulic conductivity (C).

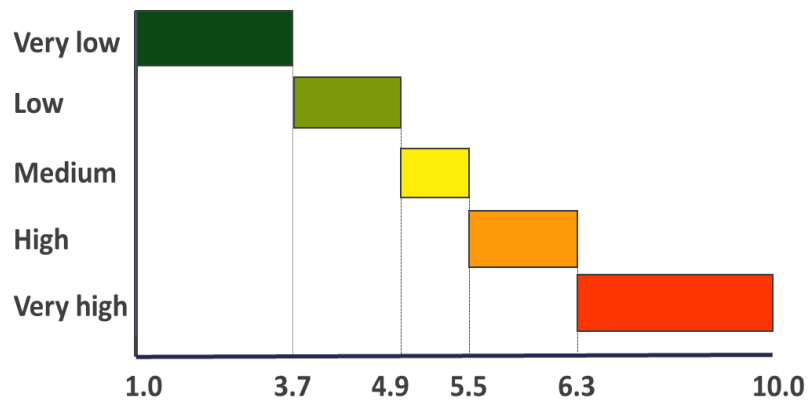
- **For AGL assessment**, the D (depth to water) parameter represents 56% of the final ADI-AGL weight, followed by E (slope) with 14%. The R (recharge) and C (hydraulic conductivity) contribute 12% and 11% respectively, while S (soil properties) represents the remaining 7%. The selected grading methods are i) quantile for D (depth to water), R (recharge), and C (hydraulic conductivity); ii) geometric interval for E (slope), and iii) equal interval for S (clay percentage).



**Figure 4:** Conceptual model of ADI index weights and grading methods

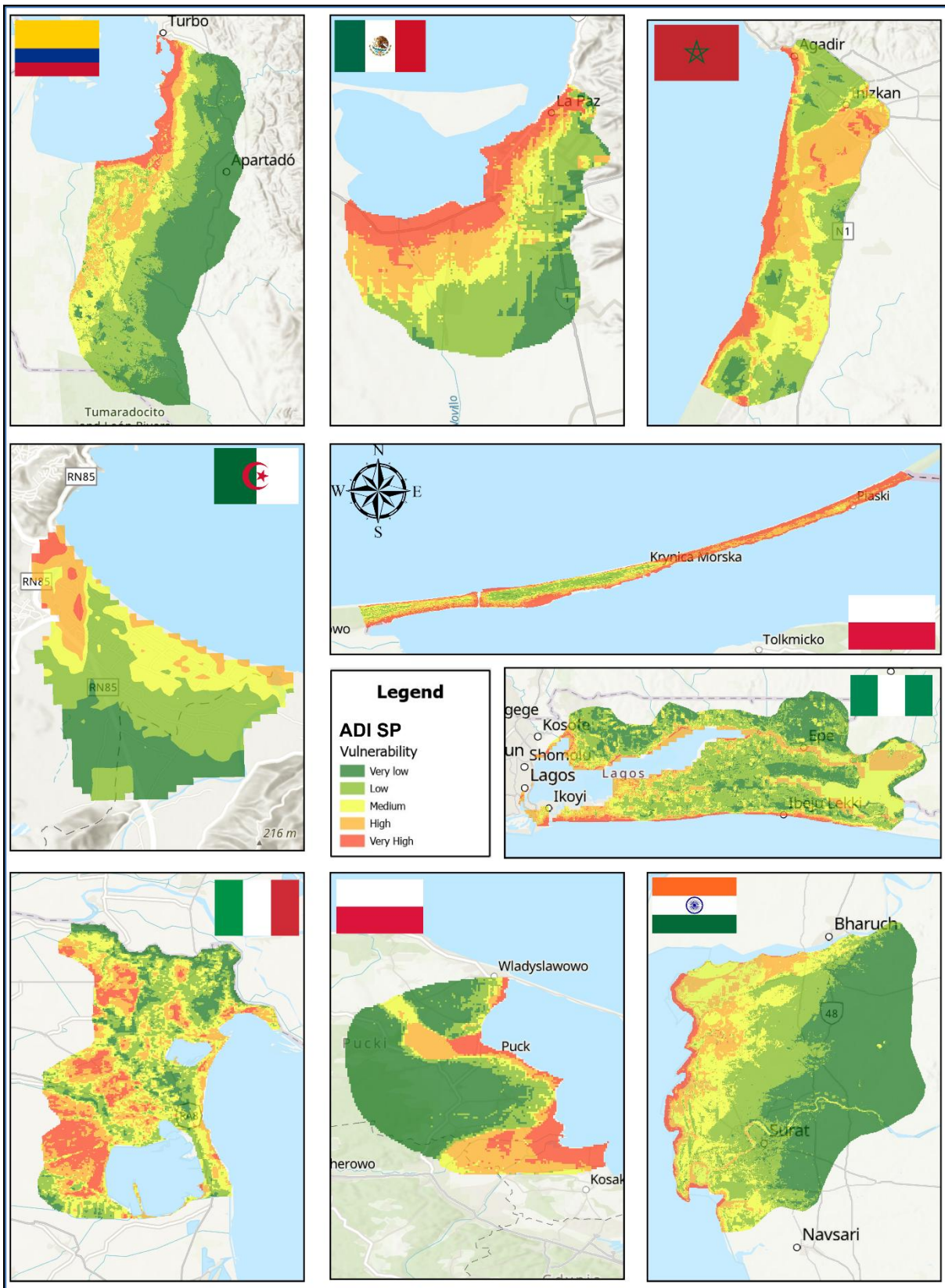
### 3.3 ADI- AGL and ADI - SP vulnerability maps

The resulting vulnerability maps for agricultural leaching and salinisation processes were classified in 5 classes very low (1 - 3.7), low (3.7 – 4.9), medium (4.9-5.5), high (5.5 – 6.3), and very high vulnerability (6.3 – 10) (Fig.5).

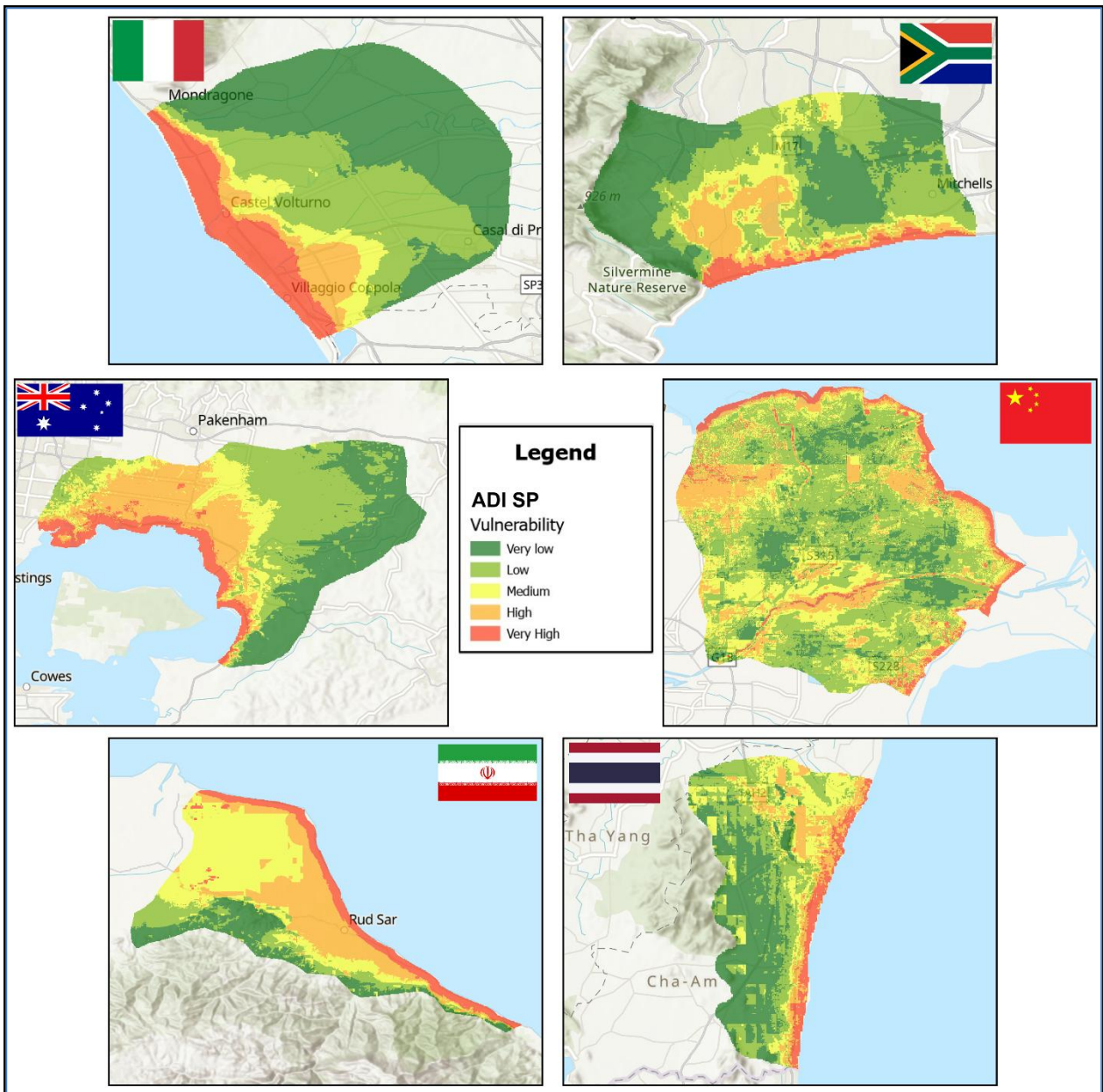


**Figure 5:** ADI AGL and SLZ final classification

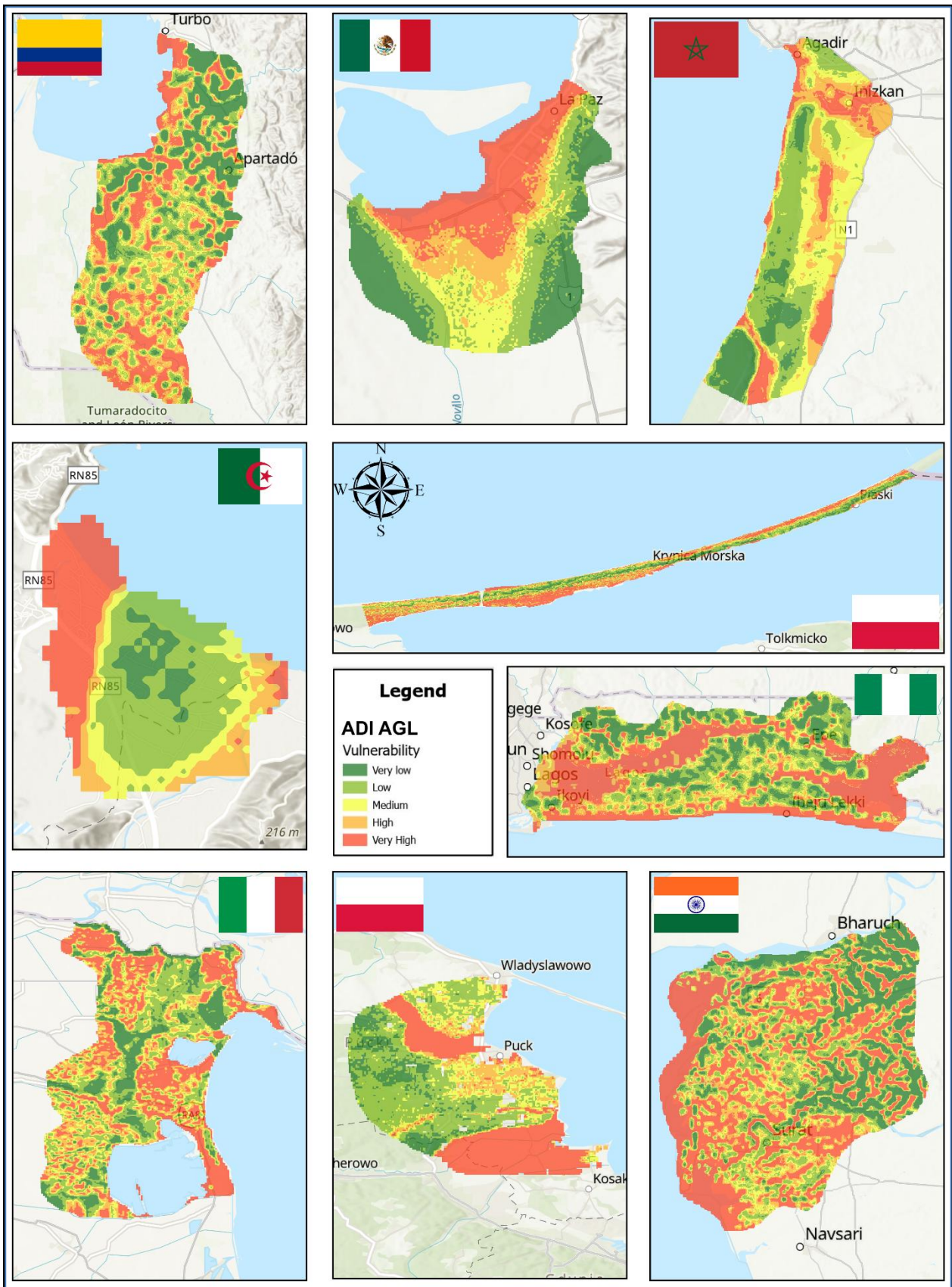
Fig. 6(a) and 6(b) present the resulting ADI-SP maps for the 15 study areas, while Fig. 6(a) and 6(b) show ADI-AGL vulnerability assessment maps.



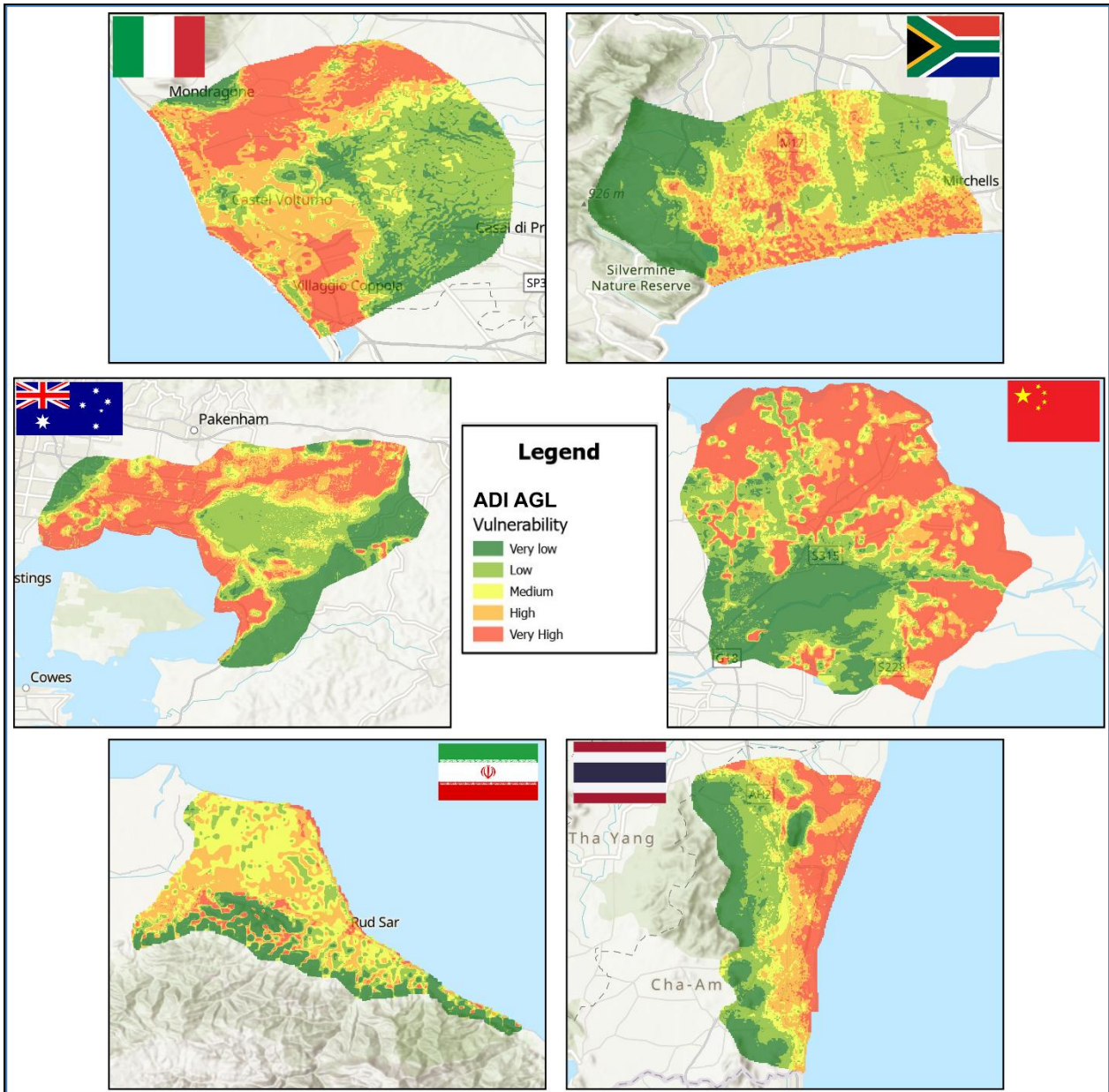
**Figure 5a:** ADI Index groundwater vulnerability map to salinisation processes for the pilot sites (Po Delta Plain, Vistula Spit, and Puck Bay) and the associated sites (Algeria, Morocco, Mexico, Nigeria, India, and Colombia)



**Figure 5b:** ADI Index groundwater vulnerability map to salinisation processes for the pilot sites (Campania Plain and Cape Flats) and the associated sites (China, Australia, Thailand, and Iran)



**Figure 6a:** ADI Index groundwater vulnerability map to agricultural leaching for the pilot sites (Po Delta Plain, Vistula Spit, and Puck Bay) and the associated sites (Algeria, Morocco, Mexico, Nigeria, India, and Colombia)



**Figure 6b:** ADI Index groundwater vulnerability map to agricultural leaching for the pilot sites (Campania Plain and Cape Flats) and the associated sites (China, Australia, Thailand, and Iran)

## 4 Conclusion

The deliverable D2.2 presents the complete calibration framework of the Automated DATASET Index (ADI), a globally applicable, open-access tool for assessing groundwater vulnerability to salinization processes (SP) and agricultural leaching (AGL) in coastal aquifers. The work described in this report constitutes a critical methodological step within the broader DATASET project, bridging the systematic literature reviews of D1.1–D1.3 with operational, georeferenced

vulnerability maps applicable across highly diverse environmental contexts. The ADI was successfully applied across 15 coastal areas “5 consortium pilot sites (Campania Plain, Po Delta Plain, Puck Bay, Vistula Spit, Cape Flats) and 10 associated sites spanning Africa, Asia, the Americas, and Oceania”. The final vulnerability maps, classified into five categories ranging from very low to very high, demonstrate the robustness and geographic transferability of the methodology. The diversity of hydrogeological, climatic, and land-use conditions represented among the study sites provides strong evidence that the ADI framework is not site-specific, but applicable to any coastal basin at a global scale. The conceptual model consolidating weights and grading methods for both ADI-SP and ADI-AGL offers a transparent and reproducible reference for future applications. Despite the strengths of the approach, some limitations must be acknowledged. Hydraulic conductivity data (both soil and aquifer) at global scale remain spatially heterogeneous, making uniform classification challenging and occasionally requiring recourse to reference-table rating schemes

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