HOVER

GeoERA GROUNDWATER

Hydrogeological processes and geological settings over Europe controlling dissolved geogenic and anthropogenic elements in groundwater of relevance to human health and the status of dependent ecosystem

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Compilation of the examination results of the data sets of input data for the respective methodologies assessing vulnerability of the upper aquifer to pollution

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1 INTRODUCTION

This deliverable is part of work package (WP) 7 in the overall project HOVER - **H**ydrogeological processes and Geological settings **over** Europe controlling dissolved geogenic and anthropogenic elements in groundwater of relevance to human health and the status of dependent ecosystems. WP7 deals with the harmonized vulnerability to pollution mapping of the upper aquifer, with 16 member states partners.

The vulnerability assessment will be carried out i) at a small scale to obtain a pan-European overview of the groundwater vulnerability and ii) in larger scales to achieve a more precise picture of the groundwater vulnerability situation in several pilot areas, with one of transboundary character, covering parts of Polish and German territory.

In a previous step (Broda et al., 2019) two index methods were identified from a set of proposed approaches to evaluate the intrinsic groundwater vulnerability.

The DRASTIC method (Aller et al., 1987) will be used for the continent-wide evaluation and for non-karstic regions in the pilot areas. In those parts of the pilot regions with karstic features dominating groundwater flow, the COP approach (Vías et al., 2006) will be applied.

Both methods require a set of spatially distributed input data. Subject of this report is the documentation of the input data/input layers that will be used for the pan-European (section 2) and the pilot scale (section 3) vulnerability assessments, respectively. The input layers are generated by rating the values or characteristics of source datasets according to given classification schemes.

Appendix A1 summarises the types of input data and the respective rating system required for DRASTIC (Depth to water table (D), Recharge (R), Aquifer media (A), Soil media (S), Topography (T), Impact of vadose zone (I), Hydraulic conductivity (C)). All input layers of this deliverable were prepared based on the same rating, on which all WP partners agreed. Appendix A2 provides a scheme on how to determine the factors Concentration of flow (C), Overlying layers (O), and Precipitation (P), all of them consisting of a combination of several types of source data, to establish a groundwater vulnerability assessment based on the COP methodology.

For each pilot area, appendix B1 provides tables of data sources and applied methodologies to generate the DRASTIC input layers including main characteristics, supplemented by small maps of the respective input layers. Appendix B2 provides the same information on the input data for the application of COP. However, for reason of clarity the provided maps restrict on the three main factors C, O, and P (see appendix A2).

2 DRASTIC INPUT DATA FOR THE PAN-EU MAP

The input data for the pan-EU assessment of aquifer vulnerability to pollution (Günther et al., 2018) are mostly derived from the "International Hydrogeological Map of Europe 1:1.5 Million" (IHME1500) and raster products from the "European Soil Geographical Database of Europe 1:1 Million" (SGDBE). The individual raster data described below are available at a 1 x 1 km resolution, but for the depth to water information, data at a 10 x 10 km resolution will be used in the future.

Depth to water (D)

Depth to water information for the presented Pan-EU map must be considered preliminary since it is rather patchy. In the future, the information described below will be replaced by data from the GeoERA RESOURCES project that is compiled on a 10 X 10 km basis.

The depth to water information was derived from piezometric contour line information provided by the "European Groundwater Resources Map 1:500k" (https://esdac.jrc.ec.europa.eu/content/groundwater-resources-maps-europe; Hollis et al., 2002) and selected IHME1500 map sheets. Furthermore, the derived groundwater table depths have been validated and completed for the regions of the WP7 partners with the data generated by the GeoERA project Resource (WP6 Pan-EU Groundwater Resources Map).

Recharge (R)

The Pan-European groundwater recharge information presented in this report is also preliminary because it is produced using a rather speculative approach based on global climatic information. In the future, this data will be replaced by a recharge layer that will be supplied by the GeoERA TACTIC project.

The Pan-European groundwater recharge information was derived using an approach borrowed from Döll & Flörke (2005), where diffuse groundwater recharge R_g is estimated from total land runoff R_l using

$$R_g = min(R_{gmax}, f_g R_l) \qquad (1)$$

with f_g the product of attenuation factors derived from geological (IHME1500; Duscher et al. 2015, Günther & Duscher 2019), soil (SGDBE, Panagos et al., 2012), land cover (GlobCover 2004-2006, ESA 2008), permafrost (Global Permafrost Zonation Map; Gruber et al., 2013) and topographic information derived from GTOPO30 (USGS, 1996) that are classified and weighted as proposed by Döll & Flörke (2005; WaterGAP). R_{gmax} is the soil-texture specific maximum groundwater recharge (mm/d). For simplification, R_l is calculated on an average monthly basis for the climatologic normal period 1961-1990 using climate data (temperature, precipitation) from global IPCC Worldclim 1.4 information (Hijmanns, 2005) and applying a temperature-based approach after Hargreaves & Samani (1985) to calculate potential evapotranspiration on a monthly basis. The Pan-European DRASTIC evaluation was conducted on a 1 x 1 km mapping unit (pixel) basis with all input layers rasterized or resampled to this resolution.

Aquifer Media (A)

The aquifer media information were derived from the legend classes of the Level 2 aggregation of the IHME1500 information (Duscher et al., 2015; Günther & Duscher, 2019), consisting of 88 classes in total.

Soil media (S)

For a Pan-European characterization of the ’S’-parameter, the Soil Mapping Unit (SMU) geometry of the Soil Geographical Database of Europe (SGDBE, Panagos et al., 2012; https://esdac.jrc.ec.europa.eu/content/european-soil-database-derived-data) at scale 1:1 Million is exploited. SGDBE SMU carries numerous attribute information from which the “SOIL” legend name is used to dissolve the data.

Topography (T)

The global GTOPO30 elevation information was used (http://www.temis.nl/data/gtopo30.html) for deriving topographic gradient/slope using the algorithm of Zevenbergen & Thorne (1987).

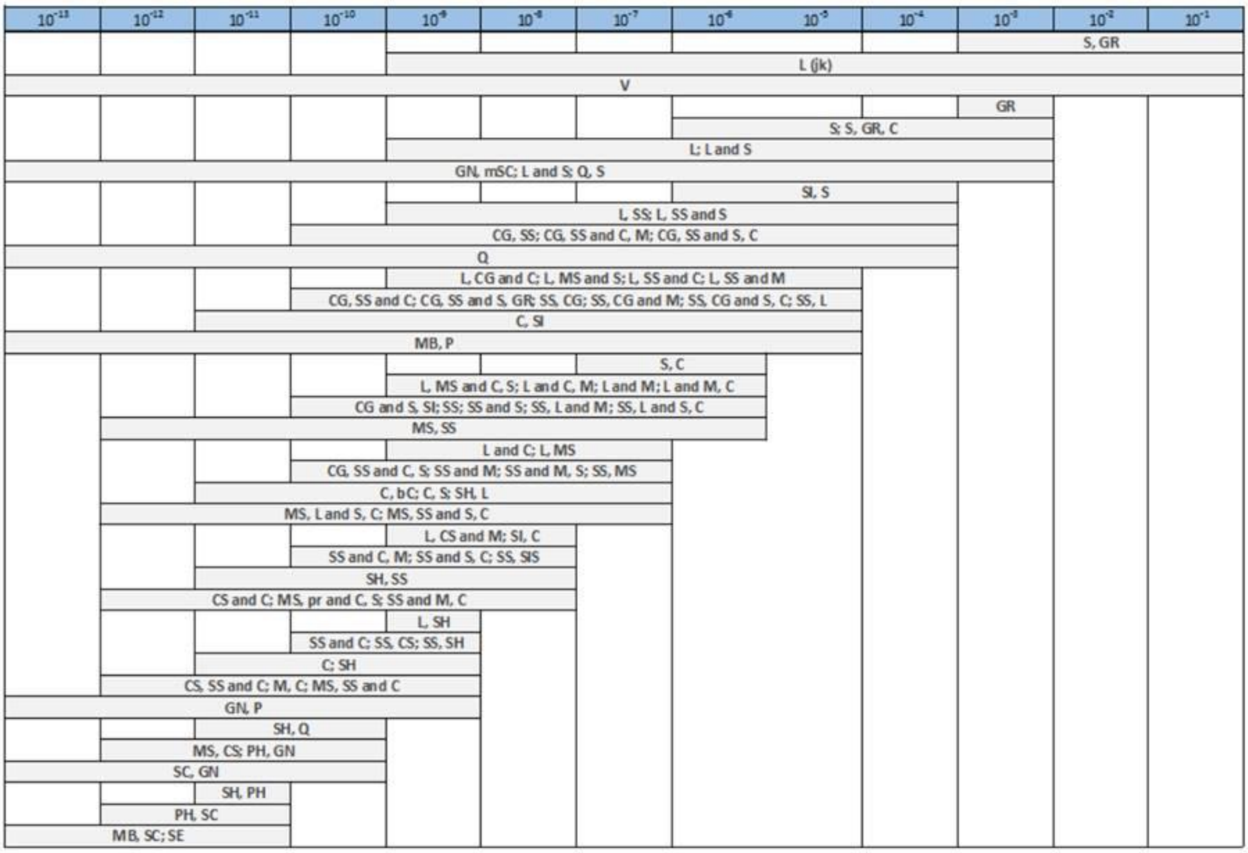
Impact of vadose zone (I)

For a Pan-European delineation of scores for the ’I’-parameter, again the SGDBE is used with the dominant soil parent material of the SMU information. Günther et al. (2013) proposed a classification of the rather unsystematic soil parent material information of the SGDBE, resulting in 13 soil parent material classes.

Hydraulic conductivity (C)

A Pan-European hydraulic conductivity layer does not exist. Therefore, again the IHME1500 Level 2 legend classes are used to derive the respective hydraulic conductivity classes for the lithological successions based on review of literature information. This was done by using a Table from Heath (1998) as a template to assign hydraulic conductivity value spans from literature for the different consolidated and unconsolidated lithotypes that are present in IHME Level 2 legend classes (Table xx.). For partially consolidated materials (combined lithotypes), meaningful averaged values were chosen. It has to be acknowledged here that this assignment of unique hydraulic conductivity information to generic IHME 1500 Level 2 lithotypes must be regarded highly speculative since no site-specific information is available and the parameter must be considered to vary in one or more orders of magnitude within a specific lithotype.

Table 1: IHME 1500 Level 2 lithotypes and conductivity value spans from broad literature review.



Abbreviation	Lithotype	Abbreviation	Lithotype
C	Clays	**Q**	Quartzites
CS	Claystones	**S**	Sands
bC	Boulder clays	**SS**	Sandstones
C	Conglomerates	**SC**	Schists
GN	Gneisses	**SE**	Serpentinites
GR	Gravels	**SH**	Shales
L	Limestones	**SI**	Silts
MB	Marbles	**V**	Volcanic rocks
M	Marls	**mSC**	Mica schists
MS	Marlstones	**Jk**	Jointed, karstified
PH	Phyllites	**Pr**	Pyroclastic rocks
P	Plutonic rocks		

3 PILOT AREAS

Figure 1 depicts the location of the eleven pilot zones to assess the intrinsic groundwater vulnerability implementing the DRASTIC and/or COP methodology. Additionally, Table 2 provides an overview of the contributing work package partners and their respective pilot regions, including basic specifications such as pilot area size and scale.

The assessment scales are varying from 1:1,000 to 1:250,000 between the pilot regions, since some partners investigate single catchments (e.g. Denmark 293 km²), while other pilot areas cover the territory of a whole country (e.g. Finland 338,440 km²).

In each pilot area, the DRASTIC method will be applied. In five pilot areas, karst features are dominant and require the implementation of the COP methodology. In this case, the application was disparate, as the assessment of COP or DRASTIC was carried out for the entire pilot area or only parts of it.

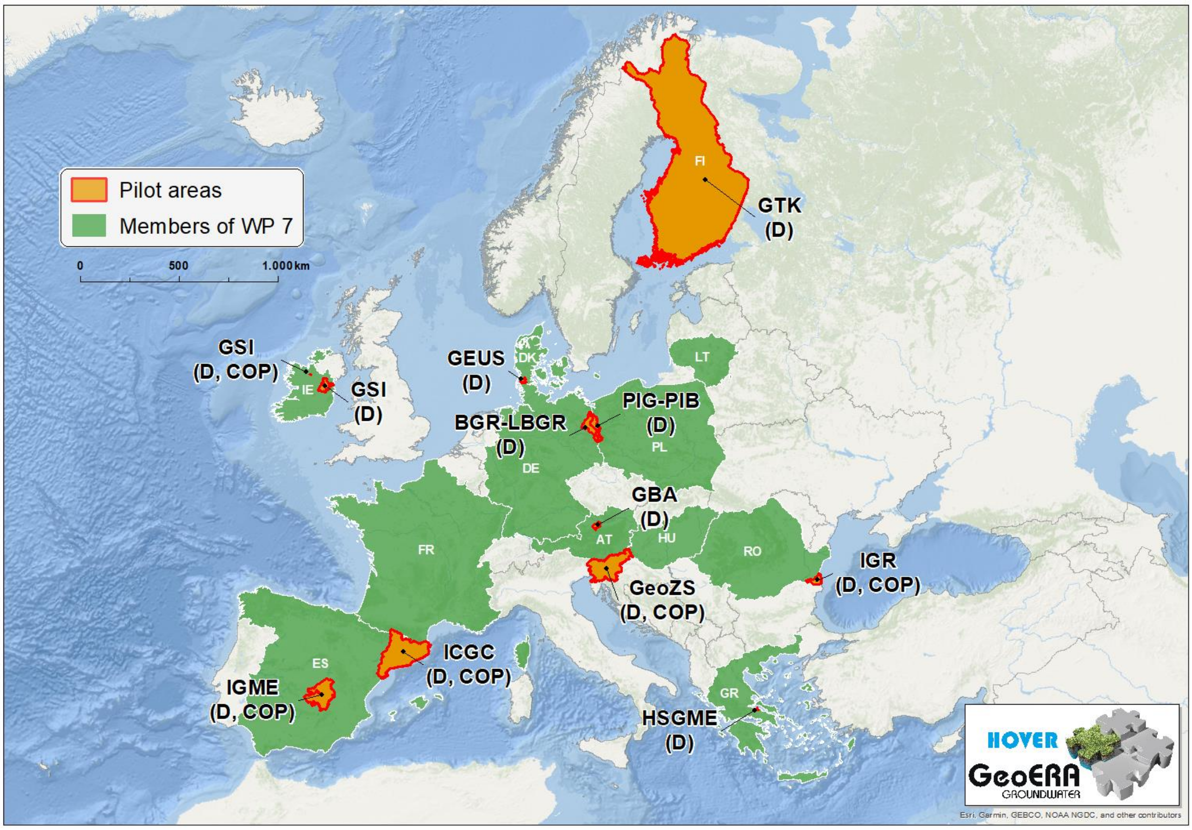


Figure 1: Pilot areas indicating vulnerability assessment methods (D = DRASTIC, C = COP)

Table 2: Overview table and major characteristics of HOVER WP7 pilot areas

Participant	Country	Pilot area	DRASTIC	COP	Area [km^2]	Grid cell size [m]	Scale[2]	Cross-border
HSGME	Greece	Atalanti alluvial aquifer	X	-	54	50	1:10,000	-
GSI	Ireland	Boyne Study Area	X		2,693	50	1:1,000	-
ICGC	Spain	Catalonia	X	X	32,112	50	1:100,000	-
IGR	Romania	Cobadin-Mangalia	X	X	2,192	50	1:200,000	-
GTK	Finland	Finland	X	-	338,440	200	1:200,000	-
PIG-PIB	Poland	Lower Oder/Odra river Polish part	X		2,821	200	1:250,000	X
LBGR[1]	Germany	Lower Oder/Odra river German Part	X	-	4,553	200	1:250,000	X
BGR	Germany							
GSI	Ireland	Rockingham Spring Catchment	X	X	15	10	1:50,000	-
GeoZS	Slovenia	Slovenia	X	X	20,273	100	1:250,000	-
GEUS	Denmark	Tønder	X	-	293	100	1:25,000	-
GBA	Austria	Traun-Enns-Platte	X		810	100	1:100,000	-
IGME	Spain	Upper Guadiana basin	X	X	14,093	100	1:50,000	-

[1]non-funded partner; [2]scale rather refers to the respective data sources

3.1 Input data of DRASTIC pilot areas

3.1.1 Atalanti alluvial aquifer (Greece) – HSGME

The study area is located at Eastern Central Greece. The complex geomorphology of Atalanti basin area (approximately 250 km²) consists of areas with little or no slopes in valley where alluvial deposits are met and areas with very high and almost vertical slopes in rocky formations. The study area is open to the sea at Northeast surrounded by higher or lower mountains and hilly areas. The water's erosive – weathering ability combined with the regional geology and tectonics are the main factors which form the current geomorphological conditions including both areas with mild slopes across the alluvial deposits and those with almost vertical slopes where the rocky cliffs prevail (e.g. carbonate rocks, ophiolites).

One of the main causes for the study area's geomorphological setting is the water corrosion and its contribution to the weathering process. A very important factor is the intensive tectonic strain of rocks causing an extensive surface discontinuity, through which the erosion and weathering process begins.

The hydrogeology of the study area consists of two main groups of rocks in which the groundwater flow mechanism and the storage capacity vary considerably (Figure 2). The first group consists of granular formations in which the hydraulic conductivity is based on the pores between the grains. The second group is composed by hard basement rocks which are limestones and igneous rocks, the hydraulic conductivity of which depends on fractures, cracks, karst pipes and other discontinuities that cross their mass. The main aquifer is developed in carbonate rocks; on the other hand, aquifers of lower hydrocapacity are developed in the Quaternary-Neogene formations and igneous rocks. It is estimated that there is lateral communication between aquifers in carbonate rocks and the Neogene-Quaternary deposits, forming unconfined and semi-confined aquifers. Unconfined aquifers are developed in carbonate rocks as well in granular formations with large effective porosity. On the other hand, the confined aquifers are developed within Neogene formations. The alluvial deposits due to their heterogeneity may be considered unconfined or semi-confined aquifers. The lowland aquifer is intensively exploited through numerous boreholes (approximately 650, mostly for irrigation use). The depth to water table in the alluvial aquifer ranges from 1.2 to 86 m below ground level (m b.g.l.) or from 2.2 to 47 m above sea level (m a.s.l.).

The input data for DRASTIC were collected from various governmental institutions as well as studies of the area (see Lappas (2018)).

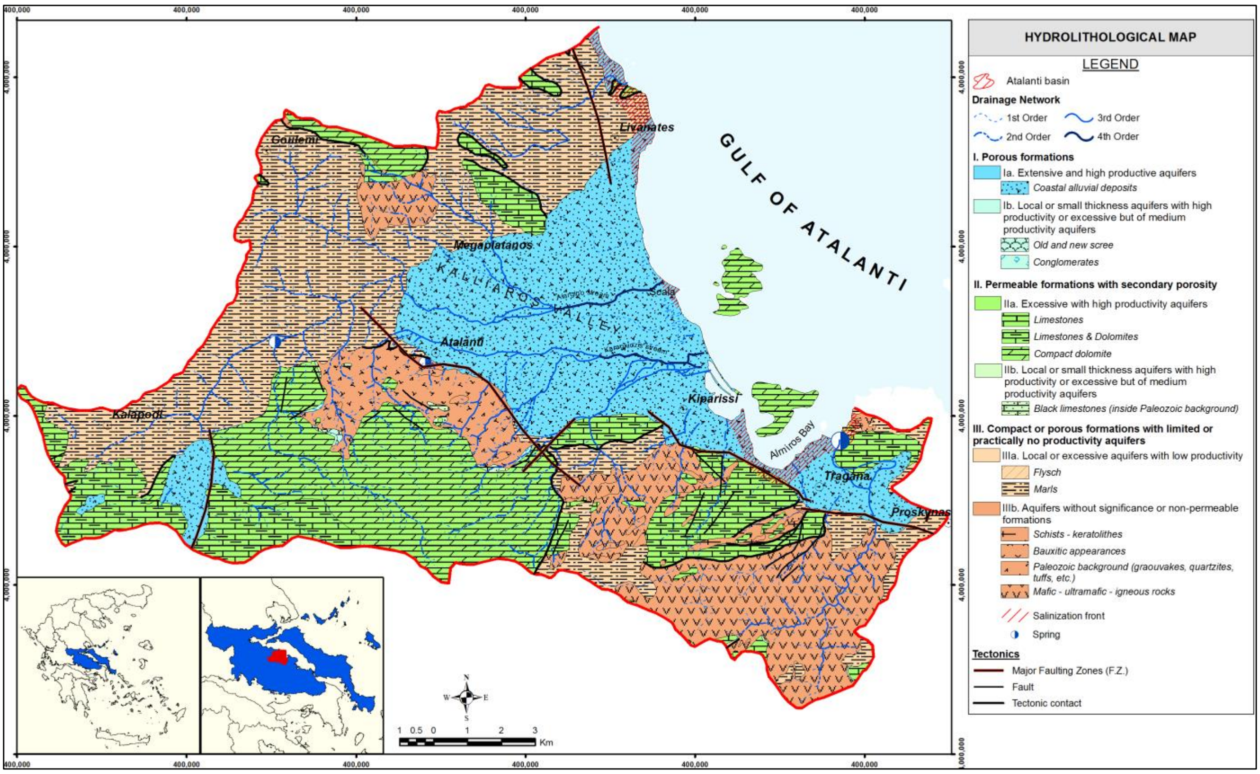


Figure 2: Hydrogeological map of Atalanti area, central Greece.

3.1.2 The Boyne Study Area (Ireland) – GSI

The Boyne catchment is located in the East of Ireland, predominantly Northwest of Dublin. The catchment has an area of 2,693 km² and is the catchment to the River Boyne.

The majority of the catchment is relatively low lying with elevation typically below 200 m a.s.l., with the highest elevation of 330 m a.s.l.. Due the generally flat topography, the majority of the catchment is assigned the higher 'T'-values.

Depth to water table bases on water level information from over 400 boreholes in the catchment area. The depth to water table ranges from 1.4 m to 26 m with the mean value being 6.5 m to water and with a 'D'-value of 7.

Annual average rainfall (based on the Met Eireann 1981 to 2010 annual average rainfall grid) varies between 732 and 1,169 mm across the catchment. The highest rainfall is in the north and north-west of the catchment. Rainfall decreases to the south-east and east of the catchment. Groundwater recharge (GSI National Groundwater Recharge Map) varies between 14 mm/a and 573 mm/a across the Boyne catchment. Areas underlain by peat have the lowest groundwater recharge. The highest groundwater recharge occurs in areas where recharge 'caps' do not apply and where rock is at near the surface or the area underlain by well drained soils and sand and gravels and are assigned the highest ‘R’-values.

There is a wide range in geology in the Boyne Catchment, from Lower Palaeozoic rocks, limestones, volcanics, up to Quaternary sand and gravel, and this gives rise to a range of aquifer types (Figure 3). The metamorphic and igneous rocks were given the lowest ‘A’-value of 3 and the karstified limestone is given the highest value of 10. The majority of the catchment can be grouped into bedded sedimentary rocks and given a value of 6.

The majority of the pilot area (80 %) is covered by subsoils > 5 m thick, with further 10 % subsoils are > 3 m thick. The majority of the catchment is given the lower ‘S’-ratings due to soil and subsoil cover, with areas of little or no soil given a value of 10. Even though the peat deposits have very low permeability, they were given a value of 8 as per the DRASTIC classification.

In areas covered by subsoil deposits, the vadose zone media classification (the ‘I’-rating) was based on soil and subsoil type. In areas of exposed bedrock and subcrop or areas with < 3 m of subsoil coverage, the characteristics of the vadose zone was taken from the aquifer characteristics. Large areas of the catchment are considered confined due to thick low permeability subsoil deposits and are given an ‘I’-rating of 1.

The ‘C’-values were a direct assignment of C index values for each aquifer based on hydraulic properties of the aquifer as per the GSI’s National Aquifer Map and the karst landforms and karst database. Any aquifer with significant evidence of karst was given a ‘C’ value of 10.

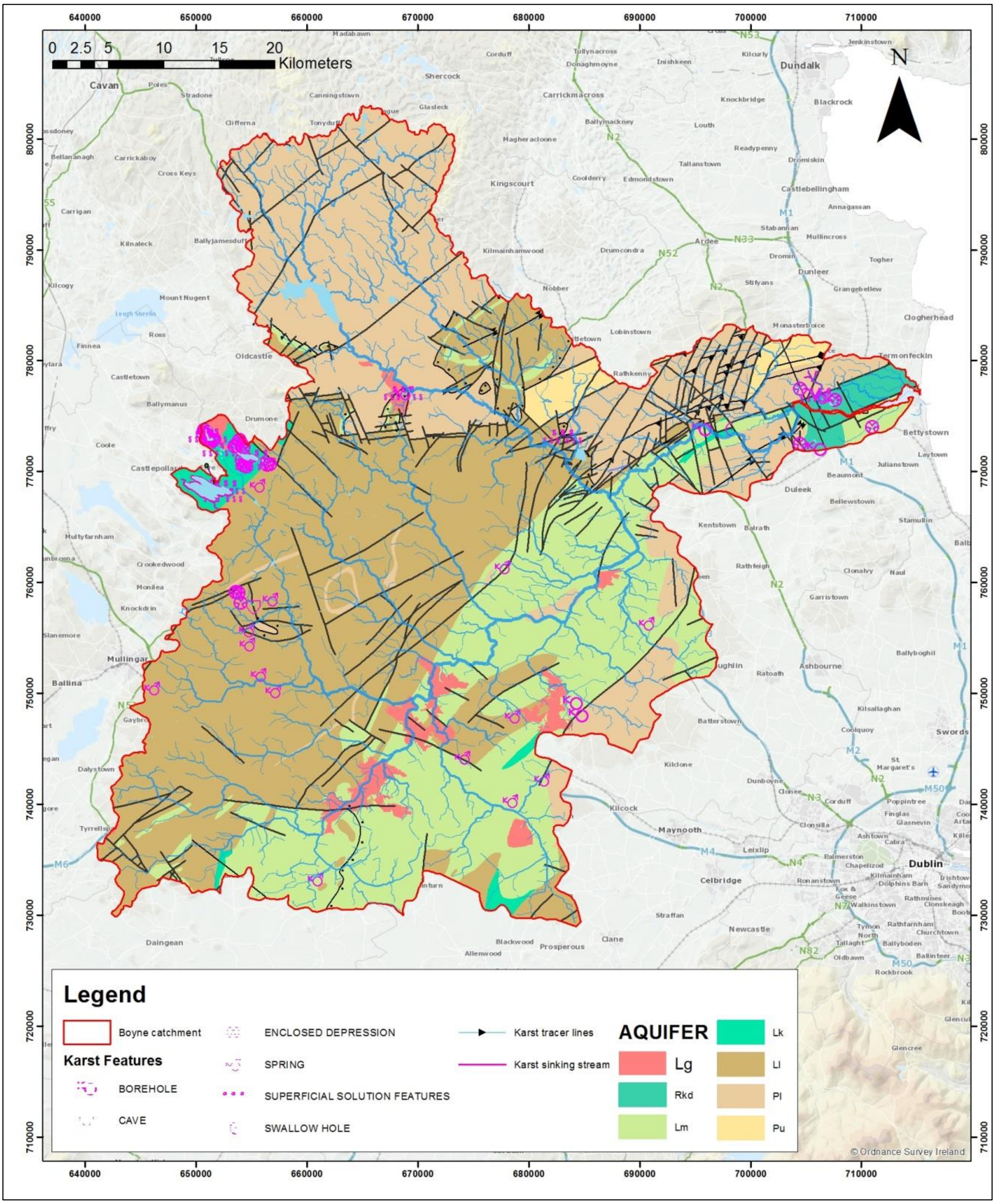


Figure 3: Aquifer type and karst in the Boyne Catchment, Ireland. Rkd = Regionally important karstified aquifer, Lm = Locally important aquifer that is moderately productive, Lk = Locally important karstified aquifer, Lg = Locally important gravel aquifer, Ll = locally important aquifer that is moderately productive only in local zones, Pl = Poor aquifer that is unproductive except for local zones, Pu = Poor aquifer that is generally unproductive.

3.1.3 Catalonia (Spain) – ICGC

The pilot area of Catalonia (32,110 Km^2) corresponds to the entire autonomous community located in the NE of Spain. It is a complex territory determined by its geological history with a very wide range of hydrogeological settings (see Figure 4). The region boundaries are defined by a mountain range to the North (the Pyrenees and pre-Pyrenees) reaching a height of 3,141 m a.s.l., the Catalan Coastal Ranges and the Mediterranean Sea to the East and by the *Noguera Ribagorçana* river to the West. The Ebro Basin is a central depression delimited by these morphostructural units with low altitudes and a smooth relief (Figure 4).

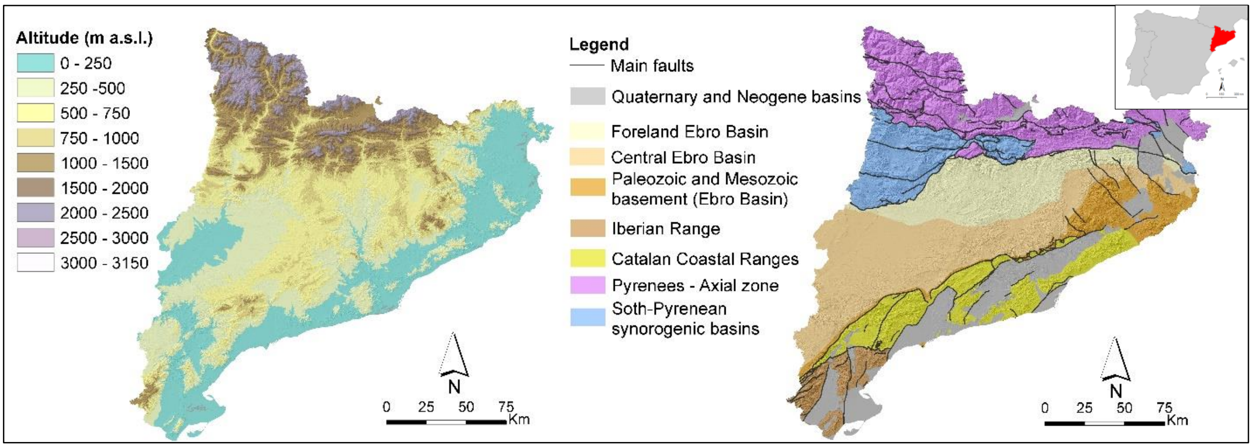


Figure 4: Hypsometric distribution (left) and morphostructural units distribution (right) of Catalonia determining the main hydrogeological settings of the pilot area.

The first aquifer vulnerability to pollution assessment of the entire Catalonia was made by Carreras, X. et al. (2015) using DRASTIC with the available data at different representative scales. Two different coverages of vulnerability were calculated from different weightings according to the original method: generic pollutants and pesticides. New available data for net recharge (R), depth to groundwater level (D), type of soil (S) and topography (T) parameters have been used in this HOVER WP7 project to improve upper aquifer to pollution vulnerability assessment in Catalonia (Appendix B1).

To calculate 'D' at least 16,000 groundwater level measurements have been considered. More than half of the territory has a depth to groundwater level greater than 50 m (rating of 1 for 'D'-index) and only the 6 % of the pilot area has shallower groundwater level less than 1.5 m (rating of 10). These areas are mainly located in quaternary alluvial and delta plain aquifers, near the coastline and in some specific inland areas where the target aquifers are near the surface.

The aquifer net recharge 'R' in Catalonia is closely related with its relief and hypsometric distribution (see Figure 4). The lowest recharge values (< 50 mm, rating of 1 for 'R'-index) are located in the central Ebro Basin and in low altitude areas, while the values greater than 175 mm (ratings of 8-10) are mainly located in the Pyrenees and the highest mountain ranges on the south.

The aquifers media distribution also has a high geodiversity. The highest ratings of the 'A'-parameter (7-9) correspond mainly to unconsolidated detrital aquifers and karstified aquifers, which are mainly located along the pre-Pyrenees and the Catalan Coastal Ranges. On the other hand, the lowest value (rating 1) corresponds to loam formations and evaporitic deposits that are mainly placed in the central Ebro Basin. It is worth mentioning that most of the pilot area (almost the 77 % of Catalonia) is characterized by a hydraulic conductivity less than $1.5x10^{-4}$ m/s (ratings from 1 to 3 for ‘C’-index).

The Pyrenees and the Catalan Coastal Ranges contain the highest slopes of the pilot area (> 18 % rating 10 of the ‘T’-index) which represent 13 % of the surface. The lowest values (ratings 1-2) are located in the central Ebro Basin and other minor inland basins and delta plains (37 % of the territory). In addition, this surface is covered by a minimal soil protection in nearly half of the region, taking the median value of 9 for the ‘S’-index.

For more details, see the geographic distribution in Appendix B1.

3.1.4 Cobadin-Mangalia (Romania) – IGR

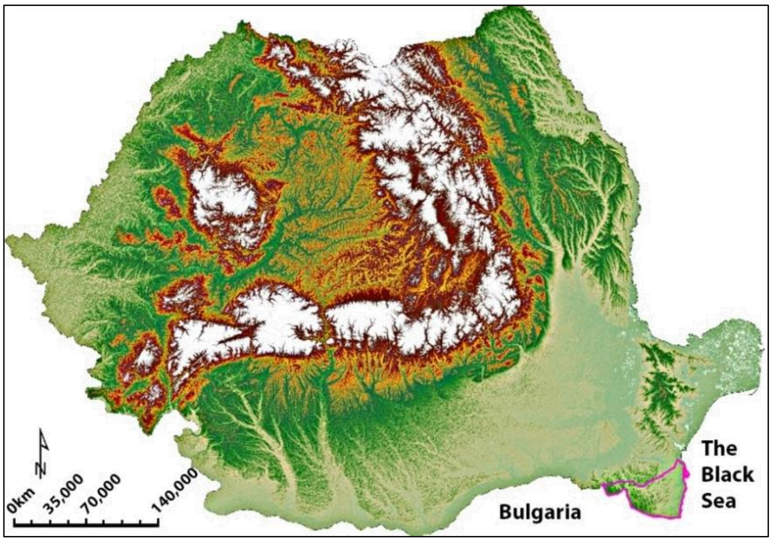
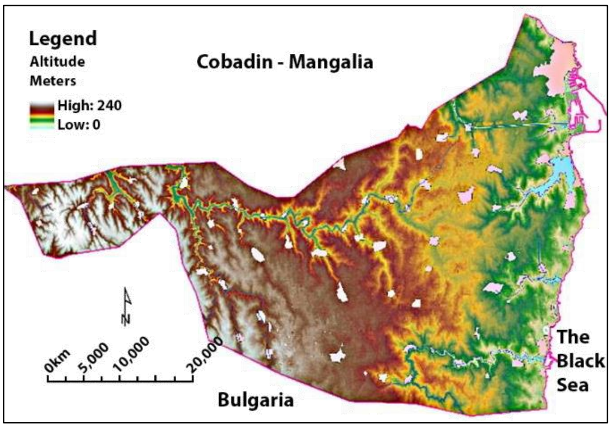


Figure 5: Topographic map of Romania and location of the study area

The Cobadin-Mangalia groundwater body is situated in the south-eastern part of Romania, at the border with Bulgaria, and near the Black Sea (Figure 5). This groundwater body is one of the most important aquifer structures for water supply in the region of South Dobrogea, being one of the main drinking water sources for the localities and tourist resorts situated on the Romanian Black Sea coast.

This shallow aquifer is hosted in Sarmatian (corresponding to Serravallian-Tortonian) calcareous deposits, and it is covered by quaternary porous loess deposits. The Sarmatian deposits cover Lower Cretaceous sediments (Barremian to Albian), Upper Cretaceous deposits, and, in some places, Paleogene ones, (i.e. Eocene) and Miocene, that host the deep aquifer. Organogenic limestones, oolitic limestones, and, subsequently, sands, rudites, clays, and marls compose the lithological assemblages of Sarmatian deposits (Figure 7).

The Sarmatian aquifer is classified as a fissure-karstic type. Its thickness is up to 150 m. The aquifer is mainly unconfined, except certain small sectors where the aquifer is covered by impermeable quaternary deposits, and it becomes confined. The Sarmatian aquifer represents the shallow aquifer of South Dobrogea. At its base, Senonian chalk separates it from the Upper Jurassic – Lower Cretaceous (deep) aquifer hosted in carbonated complex. Both shallow and deep are transboundary aquifers, regions from Bulgaria representing recharge areas for them.



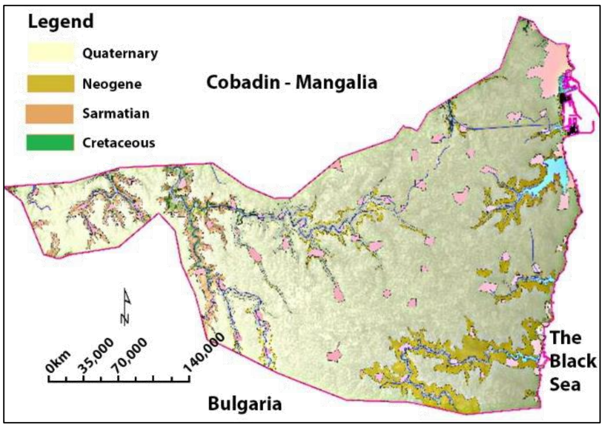


Figure 6: Topography of the study area *Figure 7: Geology of the study area*

The Sarmatian aquifer is recharged from precipitation, and from diffuse infiltration of losses from irrigation systems. In addition, in those areas where the hydraulic head of shallow aquifer is lower than that of the deep aquifer, there is a drainage from deep Upper Jurassic – Lower Cretaceous aquifer to Sarmatian aquifer. In fact, a hydraulic connection in both ways between these two aquifers intensifies the karstification process. The karst-aquifer discharges into Black Sea and into the lakes system along the coast.

The main flow direction is E-W, with SW-NE components in the northeaster sector. According to Zamfirescu et al. (2010), the transmissivity of the karst-aquifer is between 50-5,000 m^2/d and the hydraulic gradients are between 9-14 ‰. The main characteristics determine the DRASTIC index values as follows: the depth to water table varies between 0.12 m in the outcrop area of the Sarmatian deposits and 88 m in interfluve areas. Effective infiltration that resulted from interpolation of data provided by 7 meteorological stations varies between 38 and 73 mm. The annual precipitations are low, varying between 452 and 511 mm during the period 2011-2016. Chernozem and rendzina soil types are specific to the region, as well as sylvan soils in the southern part. The altitudes are up to 240 m (Figure 6), and in the region, limestone is predominant. Hydraulic conductivity has high values in areas with large water abstractions.

3.1.5 Finland (Finland) – GTK

For the Finland case, data used for the interpretation were obtained from a variety of sources as shown in Table 3. The detailed calculations of the DRASTIC parameters are described in the following section. Data of each parameter were converted to a raster map with grid cell size of 200 m by 200 m using the ArcMap program, covering an area of 338,440 km^2 for the whole of Finland. Maps of DRASTIC parameters with ratings for the Finland case are presented in Appendix B1.

The depth to water parameter grid map was produced by subtracting the topographic (DEM 10 m grid size) and groundwater level grid maps (Figure 8). A grid map of the mean groundwater level was produced from the interpolation of mean groundwater levels from 13 057 observation wells obtained from the SYKE-POVET database (SYKE, 2020) and groundwater level map data from the GTK-Lähde database (GTK, 2020a) using inverse distance weighted (IDW) technique in ArcMap program. The average depth to water grid map during the period 1960-2019 ranges between 0 and 14.5 m, with an average value of 4 m.

Table 3: Data sources for DRASTIC application in Finland

Data	Source	Description / Coverage
Land use and land cover map	Finnish Environment Institute (SYKE)	Polygon map of Corine-Land use data.
Digital Elevation Model	National Land Survey of Finland (NLS)	Grid map of DEM 10 m grid size.
Superficial deposit map	Geological Survey of Finland (GTK)	Polygon map at scales 1:20K (covers 44.3 % of Finland) and 1:200K (covers 100 %).
Groundwater level data	SYKE-POVET and GTK-Lähde database	Intensive groundwater level data points from 13,075 observation wells during 1960-2019 throughout the groundwater areas in Finland.
Drilled borehole data	GTK-Lähde and SYKE-POVET databases	Information of soil types and grain-size analysis data of soil samples.
Climate (temperature and precipitation) data	Finnish Meteorological Institute (FMI)	A 30-year mean of daily weather data (temperature and precipitation) during 1981-2010
Snow water equivalent data	SYKE	Regional data from monitoring stations throughout the whole of Finland during 1981-2010.
Surface runoff data	SYKE	Regional data from monitoring stations throughout the whole of Finland during 1981-2010.

Groundwater recharge is an important process that can transport contaminants into the subsurface and towards the water table. In the Finland case, groundwater recharge was estimated by using the water balance approach of a 30-year mean of climate data (temperature and precipitation) during 1981-2010 (Pirinen et al., 2012) and the infiltration coefficient of different soil types:

$$Recharge = (P - PET - Roff) \times infiltration\ coefficient \qquad (2)$$

where *P* is precipitation (rainfalls and snowmelts), *PET* is potential evapotranspiration, and *Roff* is surface runoff. Precipitation (rainfalls and snow-water equivalent) and surface runoff data were obtained from FMI and SYKE database (Pirinen et al., 2012; Korhonen and Haavanlammi, 2012), while the infiltration coefficient was applied based on soil types data obtained from the superficial deposit of Finland from GTK. Annual mean precipitation in Finland varies between 400-750 mm. High infiltration coefficient could be around 40-60 % of precipitation in sandy and gravelly soils and 5-15 % in clay soils. The potential evapotranspiration (PET) was estimated using a temperature-based method (Hamon 1963) as follow:

$$PET\ (mm/d) = 29.8 \times D \times (ea/(T+273.2)) \qquad (3)$$

where *D* is day length (hour), *T* is mean daily temperature (^{o}C), and *ea* is saturation vapour pressure (kPa) at mean daily temperature;

$$ea = 0.6108\ exp[17.27\ T / (T + 237.3)] \qquad (4)$$

In Finland, the shallow groundwater areas are accumulated in the porous gravelly and sandy sediments in the end moraine complexes, eskers, outwash plains or littoral beach ridges and terraces, deposited during or immediately after the deglaciation of the last Weichselian glaciation of the Scandinavian ice sheet. However, glacial till is the most common sediment in Finland. The aquifer media data originated from drilled borehole information from the GTK-Lähde database (GTK, 2020a) and the SYKE-POVET database (SYKE, 2020). However, this data is not available for the whole of Finland. For the areas where no drilled borehole information exists, the aquifer media derive from the superficial deposit maps of Finland (GTK, 2020b), at scales 1:20,000 and 1:200,000. The lower resolution 1:200K superficial deposit map covers the whole country (Figure 8), while the higher resolution 1:20K superficial deposit map covers only 44.3 %

of total area. The map scale 1:20K was first used for the interpretation. In the areas that lack data from map scale 1:20K, the data from map scale 1:200K was used.

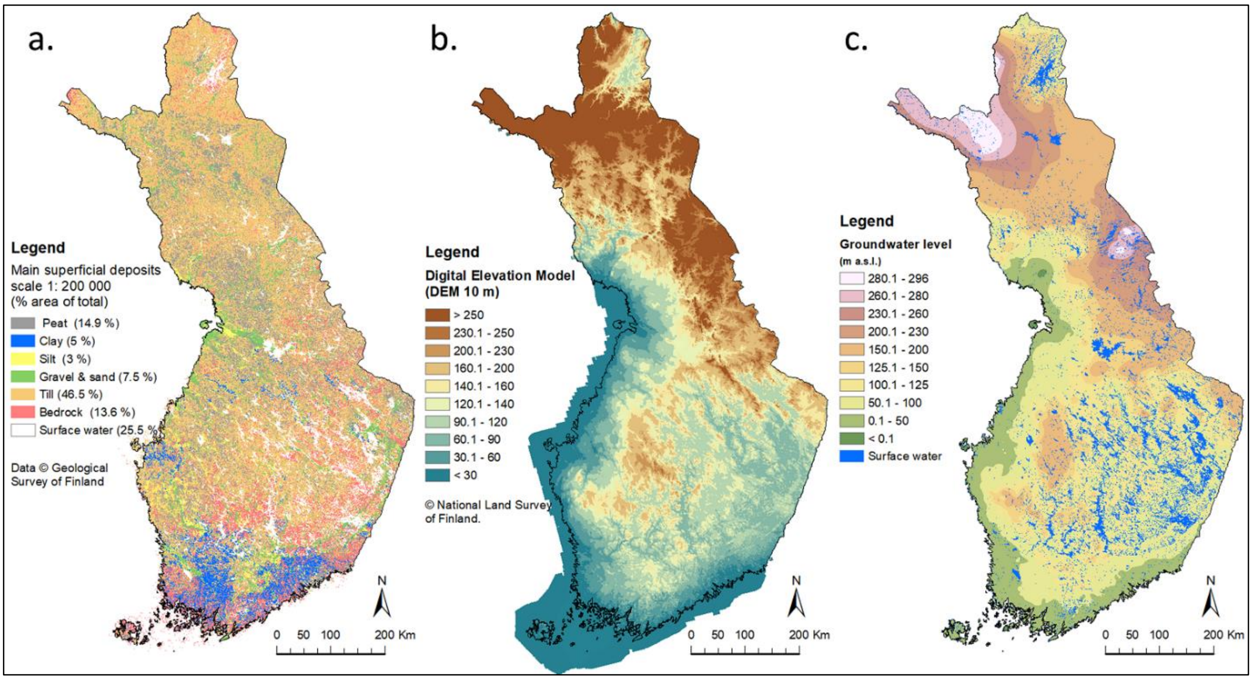


Figure 8: a) superficial deposits map of Finland; b) topographic map of Finland; and c) interpolated map of the mean groundwater level of the shallow groundwater in Finland during 1971-2020 (n = 13057 data points). Digital Elevation Model of Finland © the National Land Survey of Finland. Geological data © Geological Survey of Finland.

Similar to the aquifer media, the soil material was determined based on the surface sediment of the superficial deposits of Finland (GTK, 2020b), at the scales 1:20,000 and 1:200,000, which include thin layers of sand, gravel, fine-grain sediments (silt and clay), till and peat. In the bedrock exposed areas or soil material excavation pits, soil media is very thin or absent.

The vulnerability due to topography was assessed based on the percentage slope of the land surface. The greater the slope, the more potential there is for runoff and the less potential for infiltration of contaminants, which translates as lower vulnerability (Aller et al., 1987). The Digital Elevation Model (DEM) from the National Land Survey of Finland (NLS, 2020) was used for the slope calculation (in percentage, %) of the topography by using the Spatial Analyst module in ArcMap. The topography of Finland is relatively flat (except somewhat higher altitudes in some parts of Finnish Lapland) with the mean percentage slope of 2 %. This causes the high vulnerability ratings for topography (9-10) for most part of Finland.

The attenuation capacity of the unsaturated zone or the vadose zone was rated based on the permeability of the aquifer materials. The more permeable the material, the shorter the transit time and lower the attenuation capacity, making the aquifer more vulnerable (Aller et al. 1987). Similar to the aquifer media, the unsaturated zone material was identified from the drilled borehole information and the base sediment of the superficial deposit of Finland (GTK, 2020b), at the scales 1:20,000 and 1:200,000.

Hydraulic conductivities of aquifer media (‘K’-values) were obtained from grain-size analysis of 294 soil samples from drilled borehole data in the GTK-Lähde database (GTK, 2020a). The variations of the ‘K’-values in different soil types are presented in Figure 9. Those soil samples were taken from the groundwater areas and did not represent all soil types in Finland. Therefore, the ‘K’-values of different soil types from literature (e.g. Ronkainen, 2012) were also used for the interpretation. Due to inadequate ‘K’-value data available for the whole of Finland, the median ‘K’-values of each soil type were then applied directly to the base sediment of the superficial deposit of Finland scales 1:20K and 1:200K.

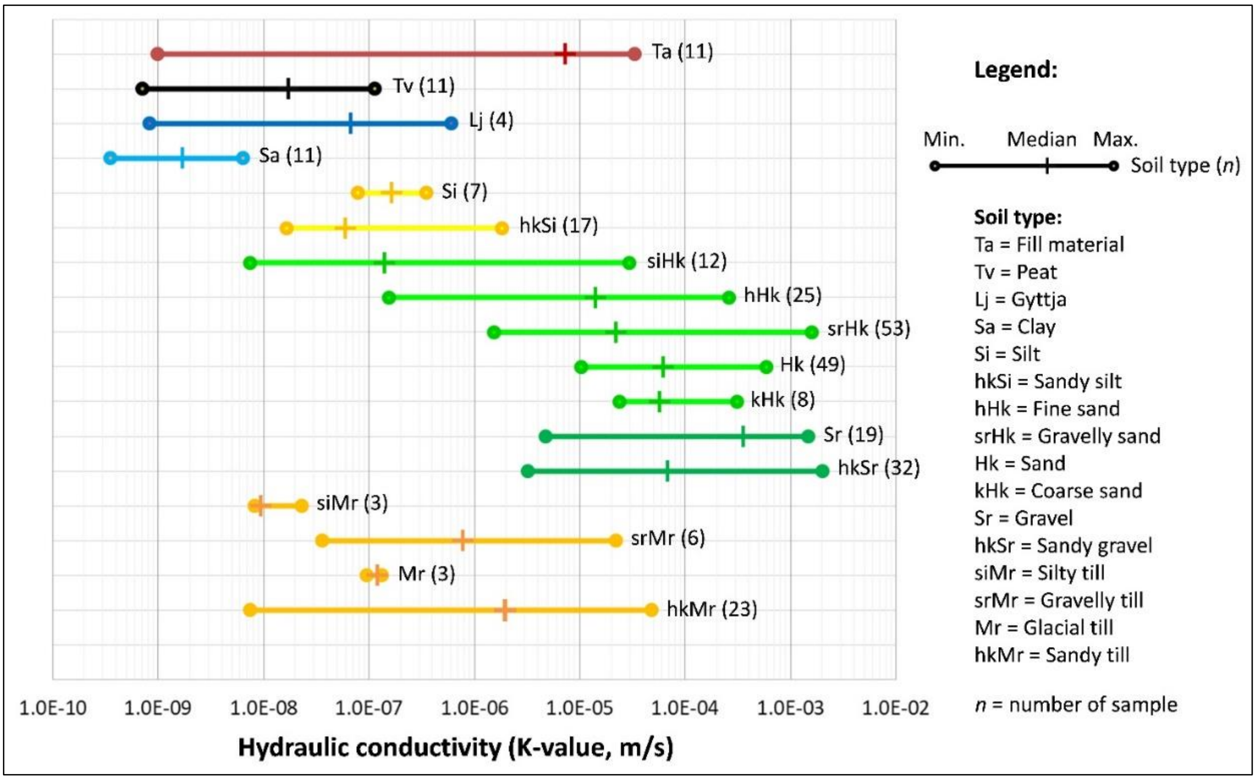


Figure 9: Hydraulic conductivity values in different soil type from soil analysis (n = 294) obtained from the GTK-Lähde database.

3.1.6 Lower Oder/Odra river (Poland / Germany) – PGI/LBGR/BGR

The cross-border pilot area is located in the border region of Poland/Germany, Central Europe. The pilot area has an extent of about 7,374 km^2 and comprises parts of the groundwater catchment of the Middle and Lower Oder/Odra river of Western Poland and Eastern Germany (Poland – 2,821 km^2; Germany (Brandenburg) – 4,553 km^2).

The whole pilot area was strongly influenced by the Pleistocene glaciations and the deposition of unconsolidated rocks. The near-surface geology comprises unconsolidated glacio-fluviatile, glacial (morainic) and post-glacial deposits. During the Holocene aeolian sands, loess and alluvial sediments such as gravel, fine sands, silt and clay covered most of the Pleistocene sediments. In the floodplain of the Oder/Odra river, a natural river landscape was formed under the influence of erosion and sedimentation processes. Floodplains, river terraces and upland areas are the most characteristic landforms in this area.

The assessment aims on the groundwater vulnerability to pollution of the upper useful aquifer, which is not necessarily the uppermost aquifer. The groundwater of this aquifer is primarily used for drinking water and irrigation purposes.

In the river valley, the depth to groundwater table (‘D’-parameter) is very low at < 1.5-5 m b.g.l. (‘D’-index = 10 and 9). In the adjacent lowland areas and river terraces the depth to groundwater is between 5 to 15 m (‘D’-index is 5 and 7). The upland areas can be characterized as recharge areas with deep groundwater tables from 25 to over 50 m b.g.l. (‘D’-index = 1-3).

The climate of the pilot area is humid continental/temperate transitional with warm summers. Mean annual precipitation is around 450-600 mm. Groundwater net recharge (‘R’-parameter) occurs mainly due to precipitation infiltration and due to groundwater exchange within hydraulically adjacent aquifers. For most of the pilot area the groundwater net recharge was estimated at > 50-175 mm/a (‘R’-index = 1-6). Locally, there are areas where the net recharge is over 250 mm/a (mainly SE part of the pilot area) (‘R’-index = 9).

In the pilot area, the upper useful aquifer consists of gravelly to sandy, fluviatile or glacio-fluviatile deposits with high permeability (‘A’- and ‘C’-parameters; ‘A’-index = 7 and 8; ‘C’-index = mainly 3-4). In contrast, the aquifer permeability is often slightly lower (‘C’-index = 2) in the upland areas due to the occurrence of clayey sediments such as boulder clays and the depositional conditions disturbed by glacial processes.

The formation and distribution of soils (‘S’-parameter) are closely linked to the near-surface geology of the pilot area. In the Oder/Odra river valley and its tributary valleys there are soils such as: fluvial sands, gravels, muds, peats and silts (‘S’-index = 8 and 7). The lowlands are dominated by outwash sands and gravels (‘S’-index = 9) and the uplands by tills, clays, glacial sands and gravels (‘S’-index = 5 and 6).

The topography (‘T’-parameter) is dominated by areas with a slope of 0-6 % (‘T’-index = 10 and 9) and locally between > 6-12 % (‘T’-index = 5). Areas with steep slopes ranging from >12-18 % (‘T’-index = 3 and 1) are mainly located on the flanks of the uplands.

The upper useful aquifer is mostly covered with permeable material in the valleys (mainly on the east side of the Oder/Odra river) and lowland areas (vadose zone is formed by sand and gravel, locally with significant silt and clay; ‘I’-parameter; ‘I’-index = 8 and 6). In the upland areas, the aquifer is widely covered by till deposits and therefore well protected (‘I’-index = 3). Locally, there are silt and clay deposits in the Oder river valley (mainly on the west side of the Oder river) and the adjacent lowland areas (‘I’-index = 3).

3.1.7 Rockingham Spring Catchment (Ireland) – GSI

The Rockingham pilot area is located in the northern edge of a large expanse of karstic limestone, covering much of the midlands and west of Ireland. The whole catchment is relatively low-lying with the Plains of Boyle to the south (rising to 120 m a.s.l.) and relatively low hills to the north. Lough Key Forest and Recreational Park covers a large proportion of the area to the north and agricultural activity dominates the rest of the area, with most of the land used as grassland for grazing.

A total of 120 boreholes with water levels were used to calculate the ‘D’- Depth to water table variable of DRASTIC. The water table is deeper in the uplands in the south and west of the pilot area, with depths of greater than 30 m to water, and very shallow in the north and northeast, with karst springs representing where the water table is at the surface.

The area is covered by Quaternary subsoil deposits, which vary in thickness from bare rock to over 10 m and are composed of clay rich, low permeability material. There is a high proportion of rock outcrop or subcrop (bedrock within 1 m of the surface) with the drumlins representing areas of thicker till (Lee & Kelly, 2003). This information was used to calculate the ‘S’ soil media value.

The climate in the area is temperate/maritime and receives just over 1000 mm/a, with about 650 mm/a available to recharge the groundwater (Met Eireann, 2001). The ‘R’ recharge value is calculated from GSI ‘Groundwater recharge map’ (GSI, 2011) and is highest where the karstic rock is at the surface or at karst landforms and lowest over thick impermeable till deposits.

The bedrock underlying the whole study is made up of limestones, 97 % of which is a pure bedded Dinantian age limestone and 3 % of which are impure limestones. The pure bedded limestone is classified as Rkd – Regionally Important Karst Aquifers dominated by conduit flow - and the impure limestones are classified as Ll - Locally Important Aquifer Bedrock which is moderately productive only in Local Zones -, by the GSI. This aquifer classification was used to calculate the ‘A’ Aquifer media values and ‘I’ Impact of the vadose zone, for DRASTIC.

There is a high density of karst landforms in the Rockingham area, including enclosed depressions (dolines), swallow holes, springs and turloughs (Figure 10). Water tracing was also carried out to define the zone of contribution to the spring, which resulted in groundwater velocities of at least 6.7 km/d (> 280 m/h) (Hickey, 2008). This and other values were used to estimate the ‘C’ hydraulic conductivity values for the application of DRASTIC.

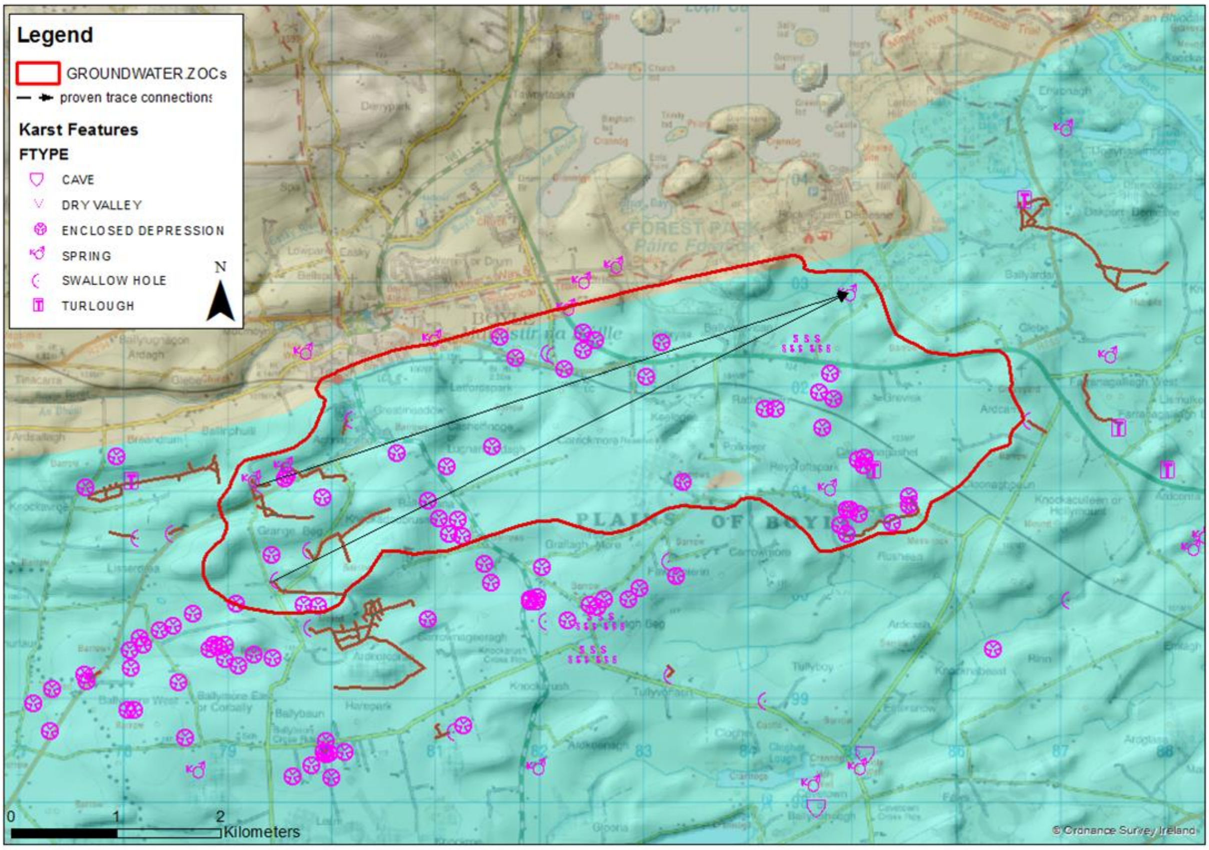


Figure 10: Aquifer, karst landforms and water tracing in the Rockingham Catchment ZOC.

For more details, see the geographic distribution in Appendix B1.

3.1.8 Slovenia (Slovenia) – GeoZS

The Slovenian case study is the entire territory of Slovenia. The DRASTIC method was applied on non-karstic areas, which cover more than half of the Slovenian territory (10,876 km^2).

Aquifers in porous unconfined media, which cover 3,726 km^2, are presented by Pleistocene and Holocene gravel and sand sediments. Extensive porous aquifers can be found on plains of the upper Sava River at thicknesses of more than 100 m, while shallower aquifers can be found near the plains. Thicknesses range between 10 and 20 m of Quaternary gravel and sand sediments. Quaternary intergranular aquifers are presented with high hydraulic conductivity with values between $5x10^{-3}$ and $1x10^{-5}$ m/s. Sandstones, claystones and marls occur in the central, south-western and north-eastern parts of Slovenia, of which only the marls are locally important for water supply. Less significant aquifers of local and limited groundwater occur in sandstone, shale, igneous and metamorphic rocks. Some 3-4 % of Slovenian territory is comprised of igneous, pyroclastic and metamorphic rocks. These rock types can be found predominantly in the Eastern Alps macro region and exhibit low to no groundwater bearing properties. At those areas hydraulic conductivities are between $5x10^{-5}$ and $5x10^{-7}$ m/s, and depth to water table is higher than 10 meters in most of the area.

The mean annual recharge varies between 50 and more than 250 mm/year. The highest recharge is evaluated in the northwestern part of the study area.

The unsaturated zone is formed by relatively high permeable lithologies in the areas where alluvial valleys are present. In areas (N, NE and E) with less significant aquifers of local and limited groundwater, lower permeability values can be found.

The soils in the non-karstic territory belong to the dystric cambisol on the hilly and mountain region and the non-carbonate flysch. Eutric cambisols interwoven with rendzic leptosols also cover gravel deposits and alluvial fans. Dystric leptosols, shallow skeletic soils are developed on the non-carbonate gravel and sand and on the non-carbonate rocks of steep slopes. Sandy or silty loamy fluvisols are common along rivers and larger creeks. On low permeable clayey deposits with shallow groundwater, table gleysols are present. In eastern parts of Slovenia planosols and stagnosols form on gentle slopes, while in southern part of Ljubljana basin peat soils or histosols are spread. The soil texture in the study area is predominantly silty-loam, while the soil in the individual parts of the area is composed by clay-loam, loam and sandy loam.

The average altitude of the Slovenian territory is 557 m a.s.l.. The highest altitudes in the study area are found in the north (approx. 1,500 m a.s.l.), while the lowest altitudes stretch along the coast in the southwest, and in the east, on the Pannonian plains. Slope values varies between 2 on alluvial aquifers and more than 18 degrees on mountain areas.

3.1.9 Tønder (Denmark) – GEUS

The Danish pilot area (293 km^2) is located close to the border with Germany. It was studied extensively as part of a nitrate vulnerability assessment (Hansen et al., 2016; Naturstyrelsen, 2014). A detailed 3D geological voxel model (Jørgensen et al., 2015), a groundwater flow model (Rasmussen and Sonnenborg, 2015), and a hydrogeochemical model (Hansen et al., 2015) were developed for this area. Most of the input data originate from these models (Appendix B1), and we kept their native resolution (100 m).

Arable land used for intensive agriculture dominates the area (80.3 %). The topography is flat (slopes of 0-2 %) with highest elevation at 62 m a.s.l. The climate is coastal temperate with an average precipitation of 1000 mm/y (Hansen et al., 2016) and an average groundwater recharge of 394 mm/a for the period 1991-2010 (Rasmussen and Sonnenborg, 2015). The subsurface structure is complex, featuring glaciotectonic deformation, deep buried glacial tunnel valleys, and a deep-seated graben (Jørgensen et al., 2015). A large part is categorized as a "*particularly valuable groundwater abstraction area for drinking water production*" (Naturstyrelsen, 2014). The sandy units within the Glaciotectonic Complex are the primary drinking water aquifer, which is assessed here. It reaches depths of max. 40-150 m b.g.l. and has a thickness of max. 90 m (Figure 11).

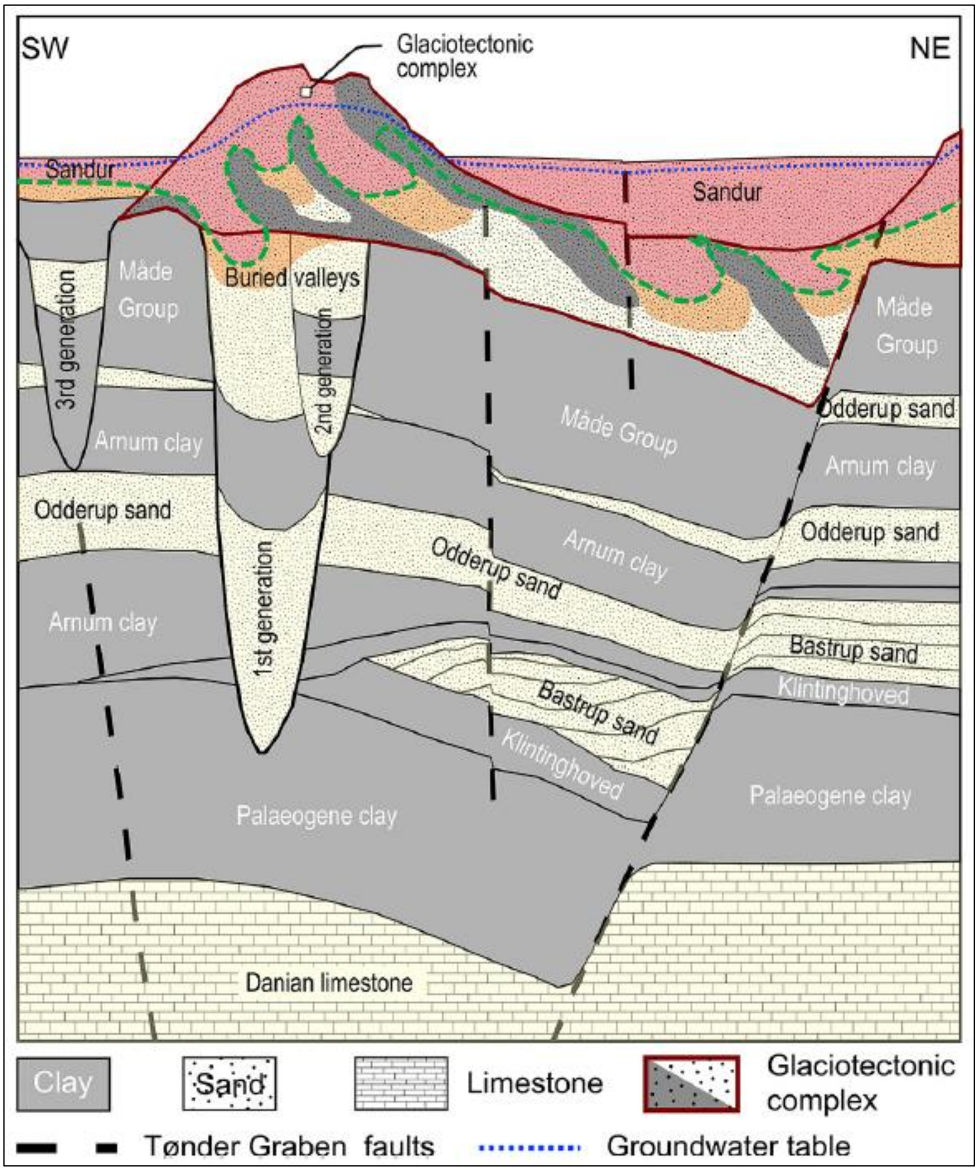


Figure 11: Conceptual diagram showing the geology in the Glaciotectonic complex with a complex redox architecture (conceptualised) and nitrate aquifer vulnerability (modified from Hansen et al. (2016, 2015).

Methodological details on the source-data and derivation of each of the parameters is provided in Voutchkova et al. (2020). The only change introduced here is the simplification of parameter 'A' and 'I'. For parameter 'A', instead of using the "sandiness" measure accounting for the vertical heterogeneity of the aquifer, we have used the typical rating for "*Glacial till*" (5) over the entire area. For parameter ‘I’, we use here only the typical ratings for the classes “*Sand and gravel*” (8), “*Sand and gravel with significant silt and clay*” (6) and “*Silt/clay*” (3). We assumed that if there is ≤ 5m accumulated thickness of the clay covering the aquifer, then the rating 8 was assigned. Respectively, the rating 6 was assigned for 5-15 m thickness, and rating 3 was assigned when there was > 15 m clay protecting the aquifer. These simplifications were done so we can ensure comparability between the pilot areas, as all other partners used the typical ratings for the ‘A’- and ‘I’-parameters.

Appendix B1 shows the parameter rasters.

3.1.10 Traun-Enns-Platte (Austria) – GBA

The Water Framework Directive-groundwater body Traun-Enns-Platte is a mostly plane landscape in Upper Austria which is situated between the Traun valley in the northwest and the Enns valley in the east. In the north, there is the Danube valley where the rivers Traun and Enns flow in. In the south, the Traun-Enns-Platte borders on the Alps. In the west, the valley of the river Alm builds the boundary. The Alm comes from the Alps and flows into the river Traun. This region is used intensively by agriculture – consequently the elevated concentrations of nitrate and Desethyl-Desisopropylatrazin in the groundwater are observed (https://www.ris.bka.gv.at/eli/lgbl/OB/2018/23/20180228).

Mostly gravels of the early Pleistocene cover the plain of Traun-Enns-Platte (Figure 12). These gravels have a several meters thick cover of loamy loess. Within the early Pleistocene gravels, there exist several streamless valleys; there is no surface runoff; all water which does not evaporate infiltrates into the subsurface. Due to the low permeability and high porosity of the loamy loess, the surface water normally needs several years to reach the groundwater table. Beneath the gravels there follow Neogene, silty and sandy marls which form an aquitard. In the deeper valleys, which cut the plain of Traun-Enns-Platte the groundwater of the early Pleistocene gravels discharge. In these valleys, there exist also late Pleistocene small terraces and alluvial deposits. Furthermore, in the south of Traun-Enns-Platte there are thick moraines, which overlay or intersect with the early Pleistocene gravels.

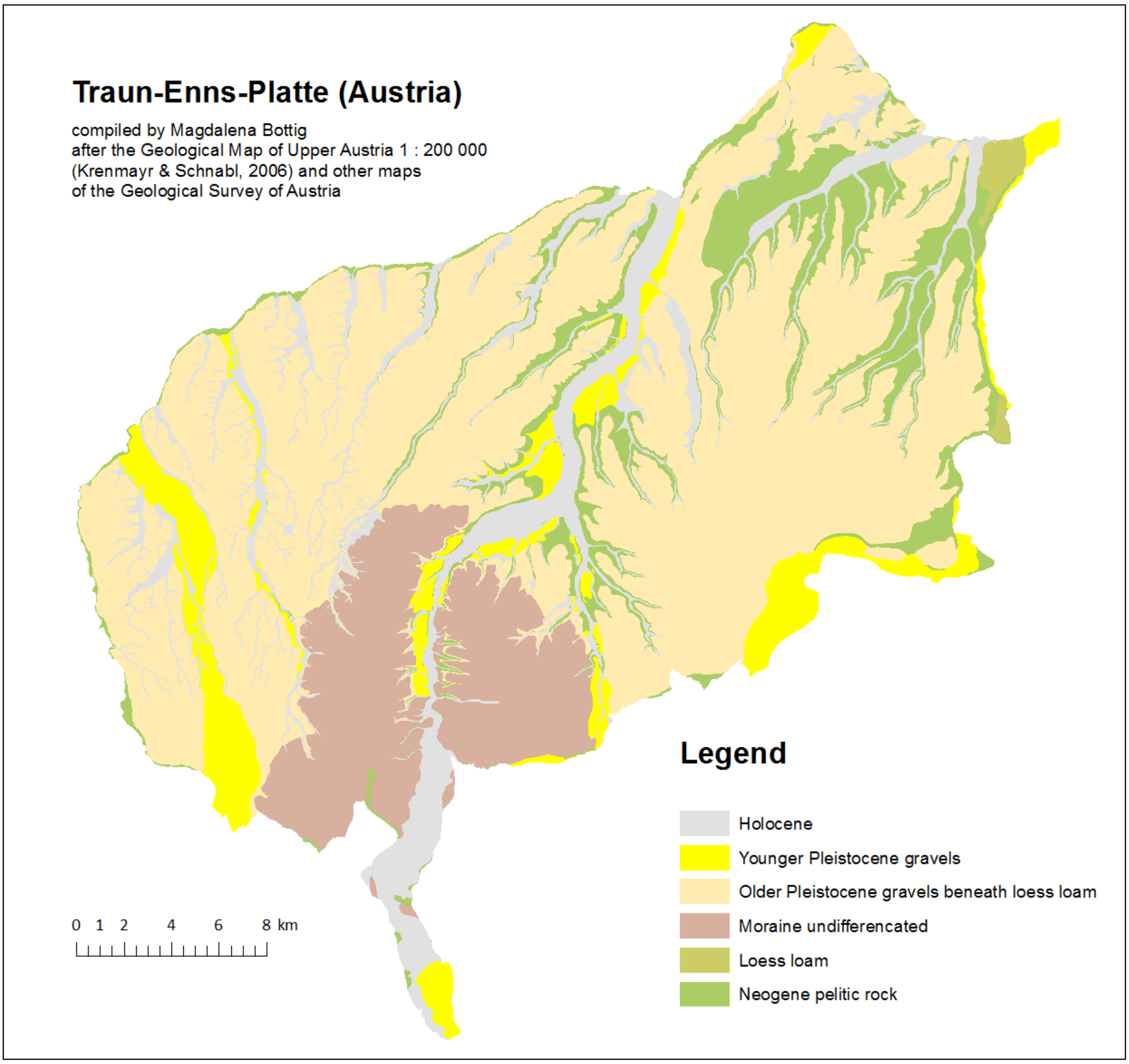


Figure 12: Geological map of the Trauns-Enns-Platte.

The input data used for the calculation of the DRASTIC parameters were collected in the project "Prozesse der Grundwasserneubildung in der Traun-Enns-Platte" ("Processes of Groundwater Recharge in Traun-Enns-Platte"). The federal government of Upper Austria financed this project. The results of the projects were summarised in the report Schubert & Kupfersberger (2014). Details concerning the calculation of the DRASTIC parameters in Traun-Enns-Platte are documented in Appendix B1.

3.1.11 Upper Guadiana (Spain) – IGME

The case study is the Upper Guadiana Basin, which is located in the central part of Spain, in the Mediterranean region of EU (Figure 13). It is composed of eight unconfined groundwater bodies where the DRASTIC method has been applied.

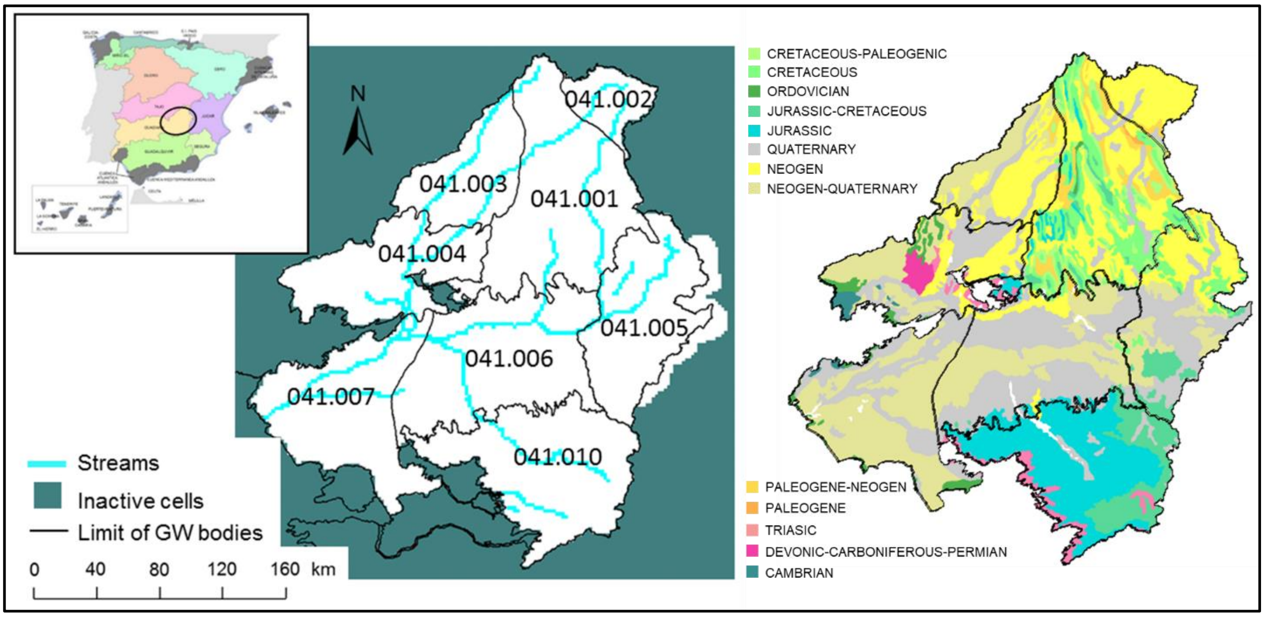


Figure 13: Location of the Upper Guadiana Basin (Spain) (left) and geology of the basin (right).

The basin shows strong natural interaction between groundwater and surface water and gives rise to over one hundred wetlands that make up UNESCO's "Mancha Húmeda Biosphere Reserve". The most part of them are groundwater-dependent wetlands. Intensive groundwater withdrawal depleted the water table by more than 20 m between the mid-1970s and the first decade of the new century, although an important and unexpected recovery of the Mancha Occidental aquifer has occurred recently. In general, depth to water table is higher than 15 meters in most of the area, so the most area of the Upper Guadiana Basin has lower values of 'D'-parameter.

Rainfall is the main source of aquifers recharge. The mean annual recharge estimated varies between 45 and 70 mm/a, although there is not an agreement in these values.

The geology is complex, including detrital and carbonated aquifers and the groundwater connectivity between the Upper Guadiana's aquifer is also structurally complex. In the southern half of the Upper Guadiana Basin the aquifers are predominantly composed by limestones, with many karstified zones. Many areas in the central aquifer are formed by tertiary detrital materials. The northern aquifers are more heterogeneous. There are no large karstified areas and other formations of metamorphic materials can be found in these aquifers. The unsaturated zone is formed by poorly permeable lithologies in the northern area and higher permeability values can be found in the southern part.

The soils in the basin mainly belong to the cambisol group according to the FAO classification. It can also be found regosol and others such as luvisol and podzol in the southeast area. The soil texture in the northern area is predominantly silty-loam, whereas the soil in the southern area is composed by peat.

The area is predominantly flat, sloping gently over 150 km, from the northeast (elevation 730 m a.s.l.) to the southwest (600 m a.s.l.).

The hydraulic conductivity in the Upper Guadiana Basin takes values in all the ranges proposed for the classification of this parameter in DRASTIC. The northern area has low conductivity (below 1.5×10^{-4} m/s although there exists a small area with conductivity higher than 10^{-3}. The central area takes values between 1.5×10^{-4} and 10^{-3} m/s and the conductivity in the southern area is mainly in the range of 3.5×10^{-4} - 5×10^{-4} m/s.

3.2 Input data of COP pilot areas

3.2.1 Catalonia (Spain) – ICGC

Nearly 30 % of the Catalan territory is covered by carbonated hydrogeological systems where karst has been developed at different levels. In those systems, recognised by the Catalan Water Agency (ACA), the COP method (Vías et al., 2006) has been also applied. They correspond to limestones, dolomites, and some detrital consolidated media with carbonated matrix. They are located mainly in the Pyrenees, Pre-Pyrenees and the Catalan Coastal Ranges (see Appendix B2).

The groundwater level in these areas has a high variability from very shallow values and up to 1600 m a.s.l. The lithology and the depth to groundwater level are considered in the 'O'-factor assessment, which determines the level of protection of the overlying layers. In addition to this hydrogeological context, the soil formation is another important protection parameter and is characterized by values of 2 in 84 % of the studied areas surface. As a result, the 'O'-factor concludes that the protection of the overlying layers is moderate in 37 % and high in 62 % of the area.

Related to the flow concentration factor 'C', it has to be mentioned that there is a high range of values. Despite this, more than a half of the surface considered is defined by a low – very low reduction of protection. This essentially is due to the endorheic areas detected and the intersection of swallow holes with streams or rivers. In addition to this, there are two more facts that mainly affect in the reduction of the protection factor: the slopes are higher than the 31 % in mainly the 60 % of the calculated territory and almost the 18 % of the territory has been defined as "developed karst" without surface layers (value of protection reduction equal to 0.25).

The precipitation parameter 'P' has been obtained from the data provided by the Meteorological Service of Catalonia (SMC). The average rainfall for the wet years is between 560 and 1660 mm/a and the temporal distribution average is about 8 mm/d. According to this, 93 % of the studied areas are affected by a reduction of protection from low to very low.

For more details, see the geographic distribution in Appendix B1.

3.2.2 Cobadin-Manga (Romania) – IGR

The study area is represented by the South Dobrogea, a region situated between the Black Sea and the Danube River, at the border with Bulgaria. The karstic aquifer of Sarmatian (corresponding to Serravallian – Tortonian) age consists of biogenic calcareous rocks with thicknesses up to 150 m, which are covered by Quaternary loessoid deposits that provide a satisfactory natural protection of the karstic aquifer against contamination.

An important role in the protection of the karst aquifer has the hydrophysical characteristics of the soil and rocks in the unsaturated area and their thickness. Soils and cover formations that are permeable, or have low thicknesses, especially in areas with wide valleys, offer low protection, facilitating the percolation of possibly contaminated waters in the Neogene karst aquifer.

In the studied area, the predominant soil types have a loamy texture and low thicknesses, and the unsaturated area consists of loess deposits, sands, silts, clays, calcareous sandstones, and oolitic limestones with thicknesses between 2-60 m.

The karst evolution of the area has led to the individualization of some depressions that do not present punctual losses of the waters coming from precipitations and of the surface waters.

The karstic system of Sarmatian age in the studied area is characterized by diffuse infiltration of water from precipitation and by water loss from irrigation systems. The karst aquifer discharges into the Black Sea and into the system of littoral lakes.

The studied area is characterized by a dry climate with rain in showers. The average amount of rainfall is 450 mm/year. From a morphological point of view, the studied perimeter is characterized by gentle slopes that normally facilitate the infiltration of waters from precipitations and by valleys, most of which are without water, with drainage occurring temporarily after the precipitation events.

3.2.3 Rockingham Spring Catchment (Ireland) – GSI

The hydrogeological characteristics of the Rockingham pilot area have been described in 3.1.7. The ‘C’-factor is described by the concentration of flow, and is related to influent karst features. The pilot area contains 125 mapped landforms, 94 % of which are enclosed depressions (sinkholes) and sinking streams.

Most of the rest of the area is considered as ‘developed karst’, some areas with surface layers and some without.

The slope values also affect the rate of runoff and infiltration, with a higher slope values in areas with karst features considered to increase the reduction in protection under the COP vulnerability technique, and lower slope values considered to increase the reduction in protection in the areas without karst features but with developed karst. The values in the pilot area were mixed with 31 % of the area with slopes of less than 8 %, 22 % of the area has a slope of between 8 % and 31 %, 20 % has a slope value between 31 % and 75 % and 27 % of the area has a slope of greater than 75 %. Due to all these factors the ‘C’-factor is mostly considered to ‘moderately’ reduce the protection with some areas of very high reduction of protection around the karst landforms.

The ‘O’-factor describes the overlying layers. The aquifer is unconfined with low permeability glacial material overlying karstic bedrock. The subsoil varies in thickness, and is covered in a thin layer of soil. In over 70 % of the pilot area, bedrock is within 3 m of the surface, and 16 % has bedrock at the surface or within 1 m of the surface. Due to the combination of thin overlying layers and low permeability of the subsoil, most of the pilot area, is considered to have a moderate and high protection value for the ‘O’-factor.

Lastly, the ‘P’-factor describes both the amount of precipitation and the intensity of this precipitation. The Rockingham pilot area receives a moderate amount of rainfall, with the annual 30 year average value being just over 1000 mm/a. However, this is fairly evenly distributed throughout the year with the rainfall intensity value being < 10 mm/d. This results in a ‘P’-factor reduction of protection of 0.8, which is classified as low.

For more details, see the geographic distribution in Appendix B1.

3.2.4 Slovenia (Slovenia) – GeoZS

In regions of the Slovenian territory (9,400 km^2), which were not assessed by the DRASTIC method, the COP method has been applied. This area is covered by karstic rocks where 35 % is on limestone and 8 % on dolomite, which was determined using the Hydrogeological Map (LAWA) of Slovenia (1:250.000). Limestone aquifers with high karst porosity are located in large continuous areas in the western and southern parts of Slovenia, from the Julian Alps to the Dinaric Karst. Fissure porosity is the dominant characteristic of the dolomite layers. The aquifers with karst and fissure porosity can reach thicknesses of several hundreds of meters, sometimes even more than one thousand. Hydraulic conductivity ranges from 10^{-1} m/s for karstified and fissured rocks to up to 10^{-11} m/s for massive limestone and dolomites. In aquifers with karstic porosity swallow holes and sink holes are present with the density up to 35 per km^2. In areas with fissured porosity, karstic formations like caves and abyss are developed.

The 'd_h'- and 's_f'-parameters are estimated based on the Digital Elevation Model at 12.5 x 12.5 m, Cave Inventory of Slovenia and Swallow Holes Inventory (1:5,000) using automatic calculation of the distance to the swallow holes and sinking streams, recharge areas and assignment of values.

For the 's_v'-factor, the vegetation cover is considered high when more than 30 % of the surface is covered. Slope values varies between 8 % on karst aquifers in southern part of the area and more than 31 % on mountain areas.

The reduction of protection of the concentration of the flow estimated by 'C'-factor is high on central part of the study area, while the low to moderate reduction of protection value is significant mainly for northwestern and southern parts of the area.

The protection of the overlying layers estimated by 'O'-factor is moderate to high on central and southern part of the study area, while the low protection value is significant mainly for the north-western part of the area.

Precipitation series from ARSO between 1980 and 2010 have been used to extract the mean annual precipitation in wet years. For the estimation of the rainy days, meteorological historical series for 2010 have been used. The mean precipitation in the study area for 'P_Q'-factor is about 2,060 mm/a and the mean 'P_I'-factor is about 14.8 mm/d. The precipitation factor of COP represents mainly very low to low reduction of protection in the study area.

3.2.5 Upper Guadiana (Spain) – IGME

About 70 % of the Upper Guadiana Basin is composed by carbonated and mixed (detrital and carbonated) aquifers. The COP method has been applied in those five groundwater bodies (Figure 13).

In the southern half of the Upper Guadiana Basin, the aquifers are predominantly composed by limestones, with many karstified zones. Many areas in the central aquifers (mixed aquifers) are formed by tertiary detrital materials. The northern aquifers are more heterogeneous. There are no large karstified areas and other formations of metamorphic materials can be found in these aquifers. There are no catchment areas to swallow holes in these aquifers. In general, karst is not very developed. The ‘s_f‘-parameter is estimated from the lithostratigraphic map of Spain (1:200,000).

Carbonate lithologies with low karstification are considered as fissured formations. Limestones and dolomites with high or very high permeability are considered as scarcely developed karst. For ‘s_v‘-factor, the vegetation cover is considered high when more than 30 % of the surface is covered. Other variables such as the period without crops or the continuity of the crops were considered to determine this factor. The ‘C’-factor shows higher reduction of protection in Campo de Montiel aquifer (in the southern) whereas in the rest of the area it shows low reduction (78 %).

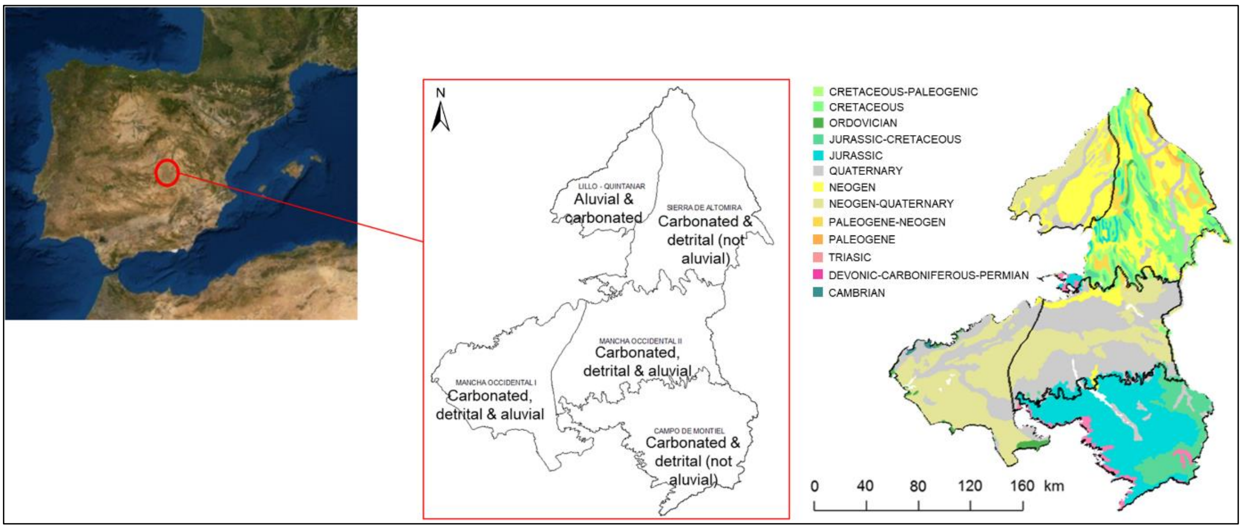


Figure 14: Groundwater bodies where COP methodology has been applied (left) and geology (right).

The groundwater level has high variability varying from less than 1 m to more than 250 m. The lithology in the northern area is poorly permeable and higher permeability values can be found in the south. The soil texture in the northern area is predominantly silty-loam. The protection of the overlying layers estimated by ‘O’-factor is high in 43 % of the area, moderate in 29 % of the area and very low in 13 % of the area.

Precipitation series from SPAIN02 between 1974 and 2015 have been used to extract the mean annual precipitation in the wet years. The mean precipitation for ‘P_Q’- factor is between 465 and 800 mm/a and the mean ‘P_I‘-factor is about 6 mm/d. For the estimation of the rainy days per year, meteorological historical series between 1974 and 2015 from SPAIN02 has been analysed. The precipitation factor of COP represents very low reduction of protection in the entire area.

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APPENDIX A1

List of DRASTIC parameters and rating

D – Depth to Water

Agreed classes (m)	Agreed ratings
< 1.5	10
1.5 - 5	9
> 5 - 10	7
> 10 - 15	5
> 15 - 25	3
> 25 - 50	2
> 50	1

R – Recharge

Agreed classes (mm)	Agreed rating
< 50	1
50 - 100	3
> 100 - 175	6
> 175 - 250	8
> 250 - 500	9
> 500	10

A – Aquifer media*

Aquifer media	Massive shale	Metamorphic / igneous	Weatherd metam / igneous	Glacial till	Bedded sandstone, limestone and shale sequences	Massive sandstone	Massive limestone	Sand and gravel	Basalt	Karst limestone
Typical Rating	2	3	4	5	6	6	6	8	9	10

S – Soil media*

Soil media	Clay	Muck	Clay loam	Silty loam	Loam	Sandy loam	Shrinking / aggregated clay	Peat	Sand	Thin or absent, gravel
Rating	1	2	3	4	5	6	7	8	9	10

T – Topography *

Topography (slope, %)	> 18	12 - 18	6 - 12	2 - 6	0 - 2
Rating	1	3	5	9	10

I – Impact of vadose zone *

Impact of the vadose zone	Confining layer	Silt/clay, shale	Metamorphic / igneous	Bedded sedimentary rocks, sandstone, limestone, sand and gravel with fines	Sand and Gravel	Basalt	Karst limestone
Typical Rating	1	3	4	6	8	9	10

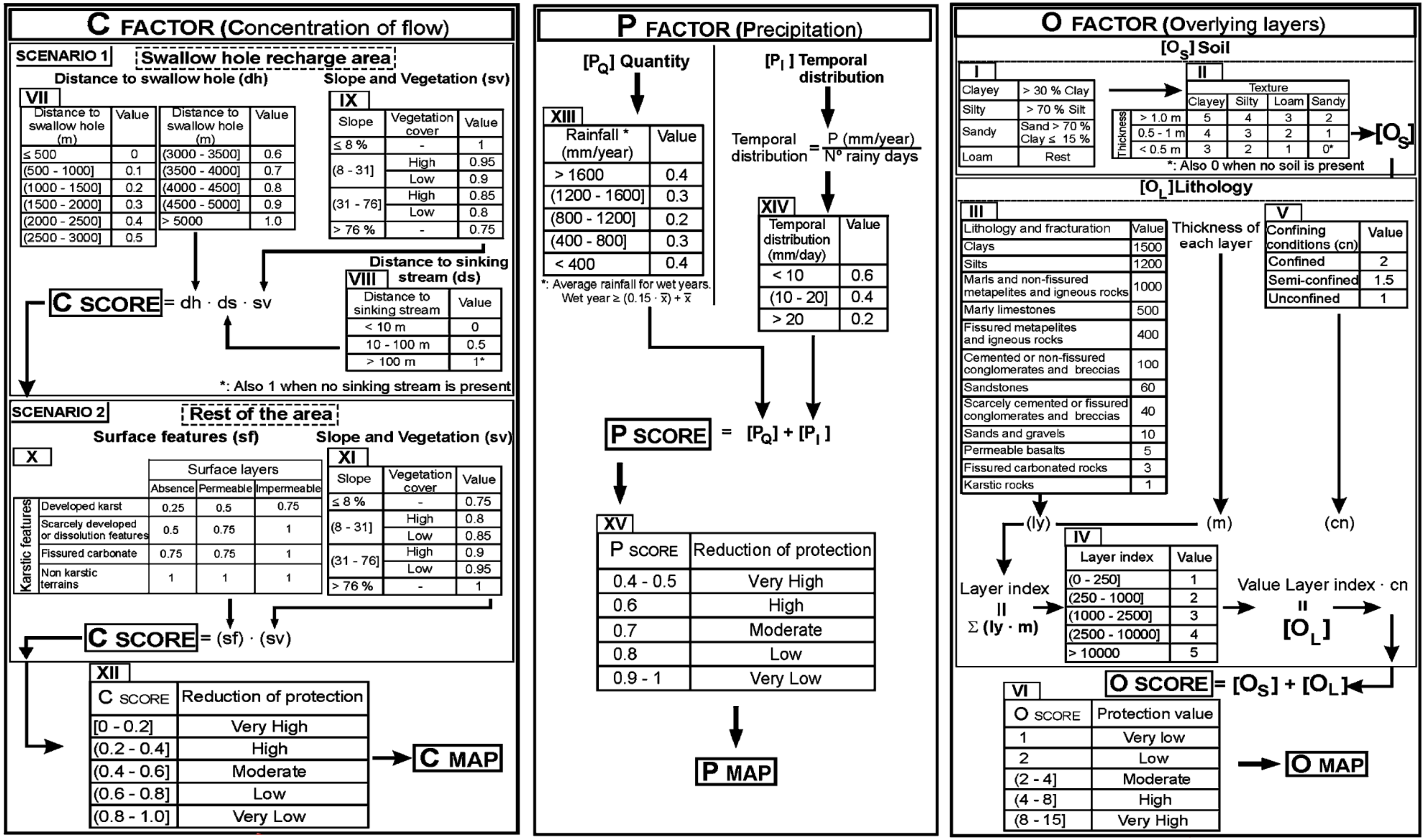
C – Hydraulic conductivity

Agreed classes (m/s)	Agreed ratings
$< 5.0 \times 10^{-7}$	1
5.0×10^{-7} - 5.0×10^{-5}	2
$> 5.0 \times 10^{-5}$ - 1.5×10^{-4}	3
$> 1.5 \times 10^{-4}$ - 3.5×10^{-4}	4
$> 3.5 \times 10^{-4}$ - 5.0×10^{-4}	6
$> 5.0 \times 10^{-4}$ - 1.0×10^{-3}	8
$> 1.0 \times 10^{-3}$ - 1.0×10^{-2}	9
$> 1.0 \times 10^{-2}$	10

* Rating for topography and non-numerical factors according to Aller et al. (1987). Rating of depth to water, recharge and hydraulic conductivity modified and agreed by all HOVER WP7 partners.

APPENDIX A2

Schema to determine the C, O and P factors of COP methodology (Vías et al, 2006).



Appendix B1

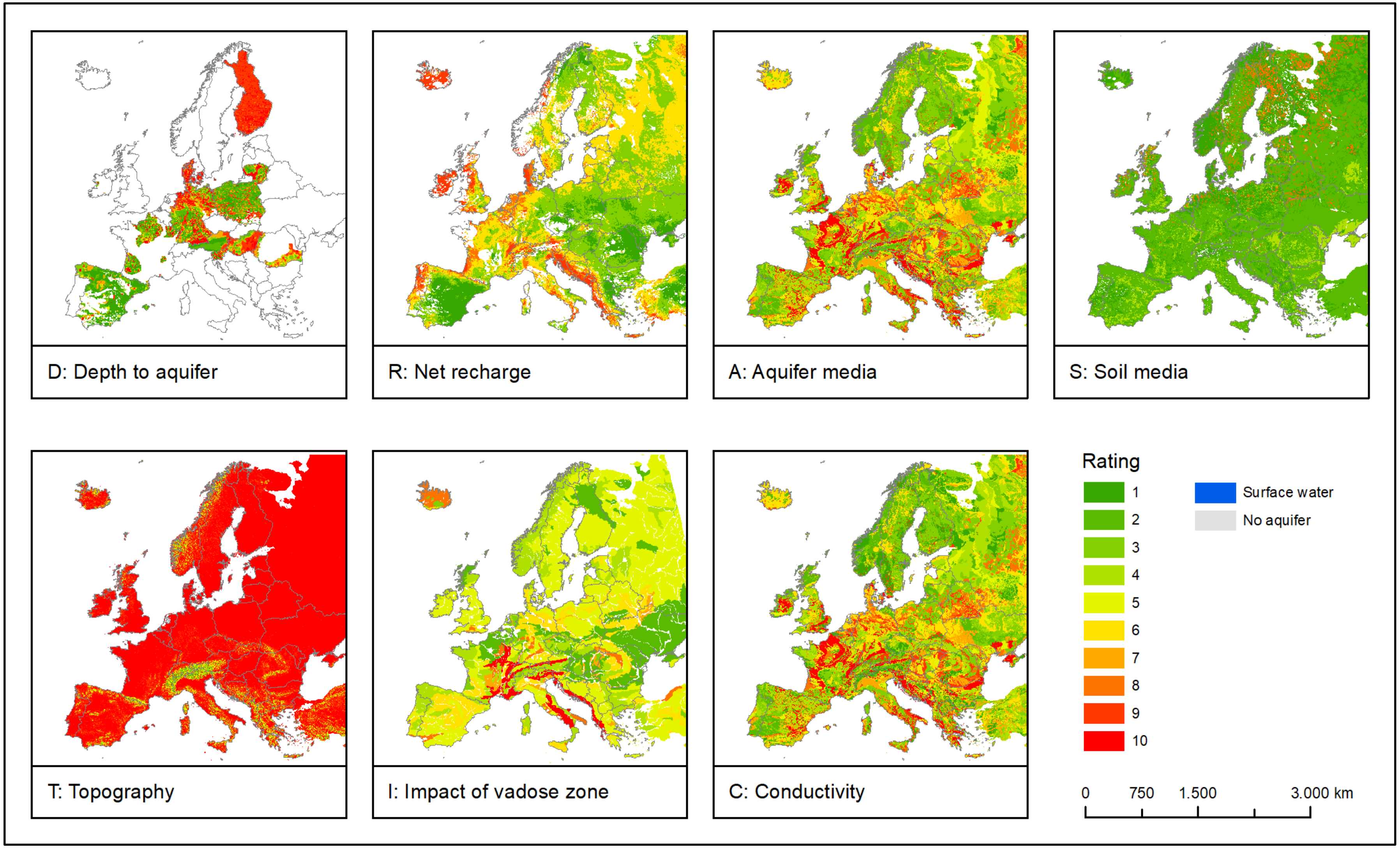
Pan-EU assessment (Cell size: 1,000 m, Total area: 10,911,893 km^2)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	D_panEU.tiff	Preliminary version	Water depth data from GeoERA RESOURCES project; contour lines from European Groundwater Resources Map 1:500,000 and IHME1500	TIN-generation for surface construction with the contour line information, raster conversion, smoothing	Preliminary data to be replaced by information of the GeoERA RESOURCES project. No complete coverage available Cell size: 10 000 m
R	Net recharge	R_panEU.tiff	Preliminary version	Average yearly diffuse net recharge for time period 1961 - 1990	Estimation of diffuse net recharge based on combination of several environmental data following Döll & Flörke (2005) and effective precipitation derived from WorldClim 1.0 data with employment of potential evaporation after Hargreaves & Samani (1985)	Net recharge calculated on an average monthly basis. Preliminary data to be replaced by information of the GeoERA TACTIC project.
A	Aquifer media	A_panEU.tiff	Preliminary version	IHME1500	Rating of lithology level 2 information according to proposal of Aller et al. (1985)	
S	Soil media	S_panEU.tiff	Preliminary version	SGDBE	Rating of SMU-based soil type information according to proposal of Aller et al. (1985)	
T	Topography/slope	T_panEU.tiff	Preliminary version	GTOPO30	Derivation of slope angle according to Zwengenbergen & Thorne (1969) and classification according to proposal by Aller et al. (1985)	
I	Impact of vadose zone media	I_panEU.tiff	Preliminary version	SGDBE	Rating of SGDBE parent material classes as aggregated by Günther et al. (2013) according to proposal of Aller et al. (1985)	
C	Hydraulic conductivity	C_panEU.tiff	Preliminary version	IHME1500	Assignment of averaged hydraulic conductivity information to IHME 1500 lithology classes and classification according to Aller et al. (1985)	Hydraulic conductivity information solely deduced from literature values on typical lithotypes

Pan-EU assessment (Cell size: 1,000 m, Total area: 10,911,893 km²)

Spatial distribution of DRASTIC input data ratings



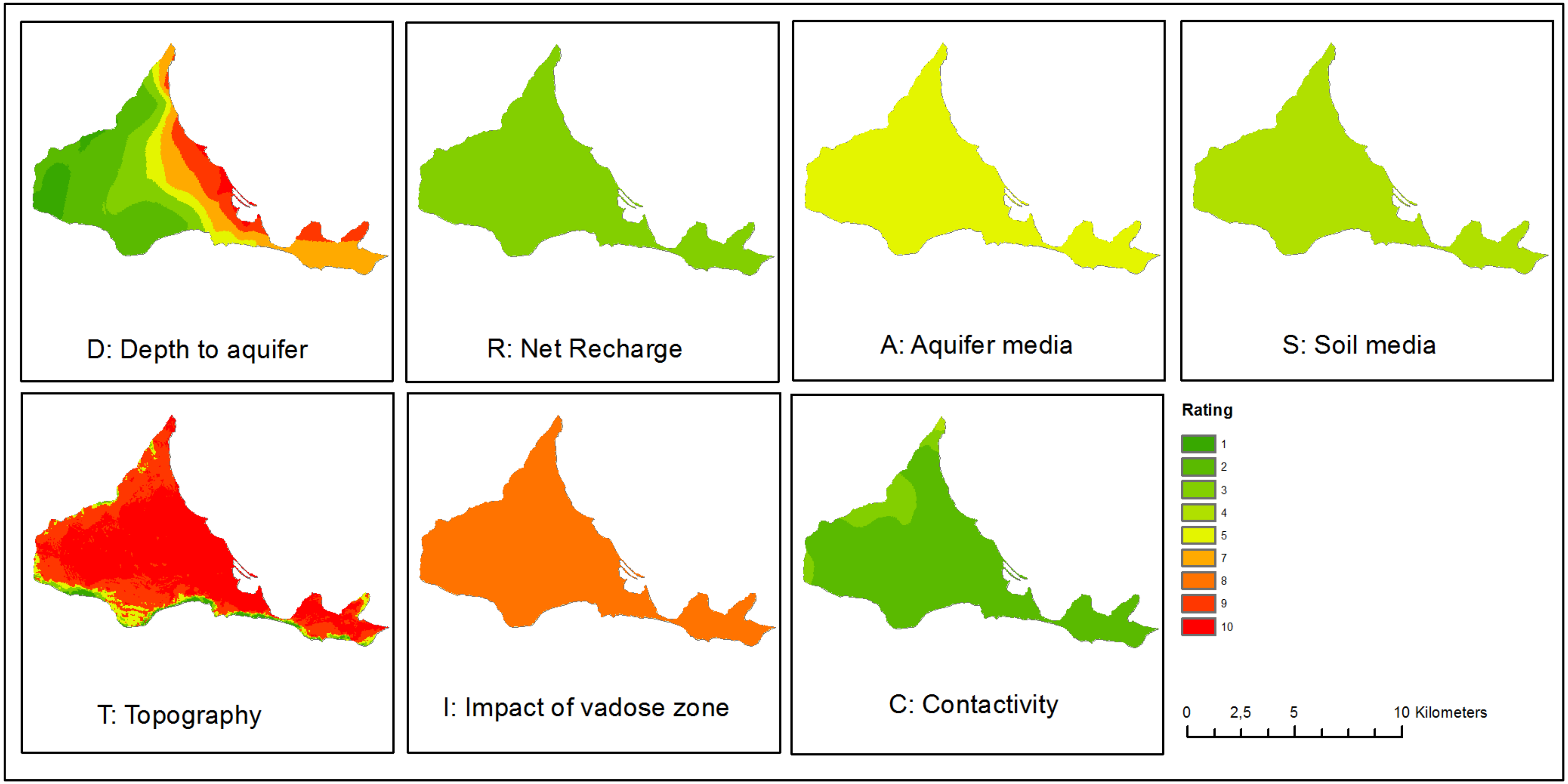
Pilot area Atalanti alluvial aquifer (Greece) - HSGME (Cell size: 50 m, Total area: 54.2 km²)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_ATA1_D.tif	Final version	Historical depth to water table data from HSGME data complemented with local in situ measurements and data from various studies	Spatial interpolation using Ordinary Kriging of groundwater level data and reclassification into D index values.	
R	Net recharge	GEWP7_ATA2_R.tif	Final version	GWV (Ground Water Vistas v.6) hydrogeology distributed model	Estimation of the mean net recharge taking into account the different hydrology circle variables in the period 1980-2018.	
A	Aquifer media	GEWP7_ATA3_A.tif	Final version	Aquifer Map of Atalanti at 1:50,000 (HSGME)	Direct assignment of A index value for the only aquifer delimitated	
S	Soil media	GEWP7_ATA4_S.tif	Final version	Soil Map of Greece at 1:500,000 (Agricultural University of Athens)	Direct assignment of S index value for the only soil type	
T	Topography/slope	GEWP7_ATA5_T.tif	Final version	Digital Terrain Model at 25 x 25 m cell size (DTM Greece)	Calculation of the slope raster file and reclassification of values into T index values	
I	Impact of vadose zone media	GEWP7_ATA6_I.tif	Final version	Geological Map of Atalanti at 1:50,000 (HSGME)	Direct assignment of I index values for the only hydrolithological unit	
C	Hydraulic conductivity	GEWP7_ATA7_C.tif	Final version	Hydrogeological Map of Atalanti at 1:50,000 (HSGME)	Direct assignment of C index values for each aquifer, hydrogeological units or water masses delimitation	

Pilot area Atalanti alluvial aquifer (Greece) - HSGME (Cell size: 50 m, Total area: 54.2 km²)

Spatial distribution of DRASTIC input data ratings

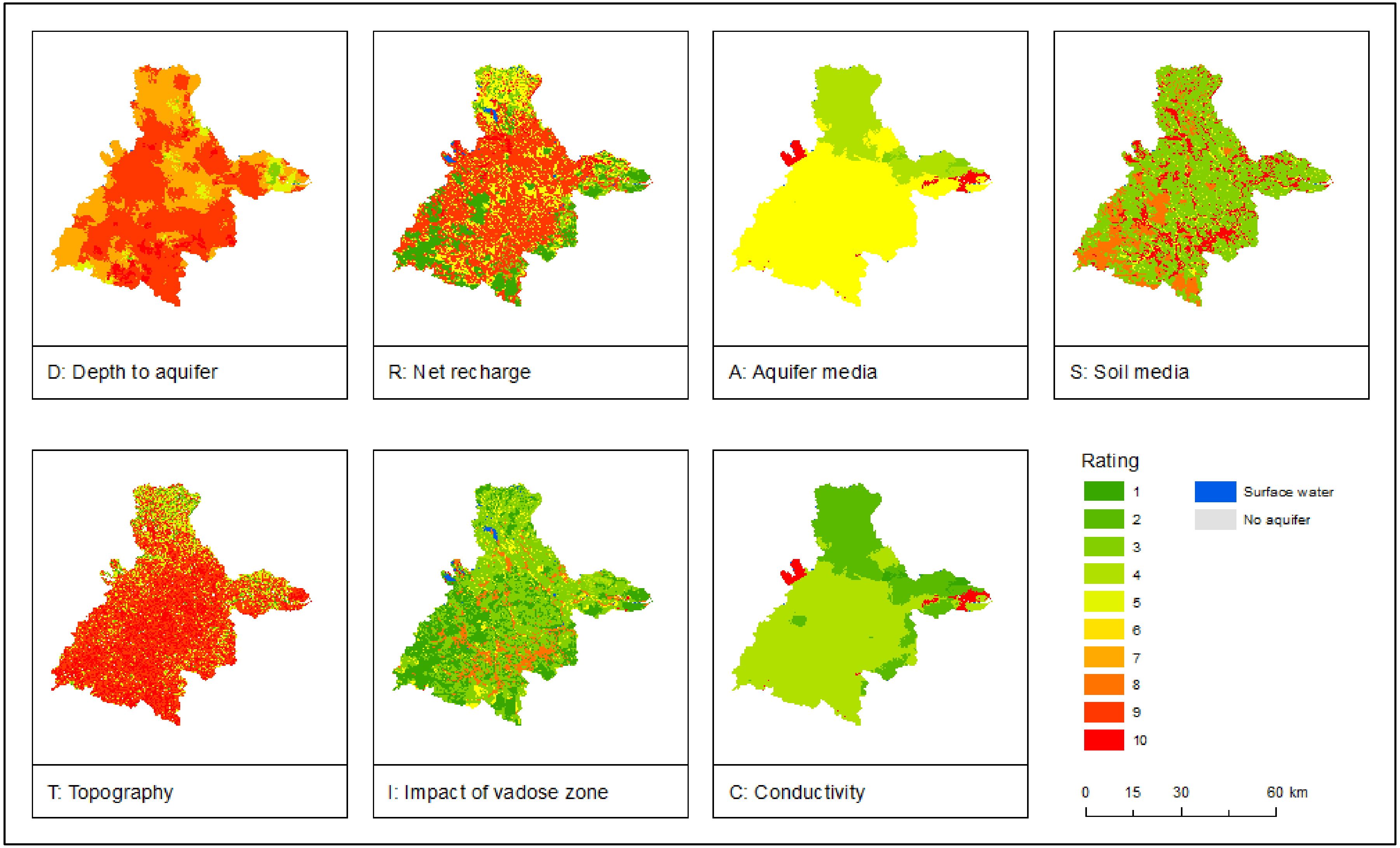


Pilot area Boyne (Ireland) - GSI (Cell size: 50 m, Total area: 2,693 km²)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (October 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_BOY1_D.tif	Final version	401 historical water level data points, along with karst spring data and data from groundwater surface water interactions	Spatial interpolation using Kriging of groundwater level data and reclassification into D index values.	The depth to water table ranges from 1.4 m to 26 m with the mean value being 6.5 m. The highest D values correspond with the shallowest water table and is generally found in the lower areas in the catchment, where the water table is close to the surface. The lower D values are generally found in the elevated areas in the catchment.
R	Net recharge	GEWP7_BOY2_R.tif	Final version	GSI National Groundwater Recharge Map, 1:50,000 scale	Aquifer recharge is effective rainfall multiplied by a recharge coefficient based on the permeability and thickness of superficial deposits and the ability of the underlying aquifer to accept recharge	High values correspond to areas where the overlying till is absent or thin or at karst features, low values correspond to areas where the glacial till is thickest and peat.
A	Aquifer media	GEWP7_BOY3_A.tif	Final version	GSI National Aquifer Map, 1:50,000 scale	Direct assignment of A index values for each aquifer delimitated	As most of the aquifers are fractured and bedded sedimentary rocks most of the catchment is assigned an A value of 6. The karst aquifers were assigned the highest value of 10 based on their high degree of karstification, weathered and igneous rock were given a value of 4, metamorphic rocks given a 3 and basalts given a value of 9.
S	Soil media	GEWP7_BOY4_S.tif	Final version	GSI National Vulnerability Map 1:50,000 scale FIPS-IFS Teasgasc Soil Map FIPS-IFS Teagasc Subsoil Map	Direct assignment of S index values for each soil and subsoil type based on BS9530 subsoil classifications and permeability assessments	The soils and subsoils were assigned a value based on what their primary constituent (or matrix) is. For example, a low permeability glacial till was assigned a S value of 3. The lowest value of recharge is under the peat but according to DRASTIC classification this was assigned a high S value of 8.
T	Topography/slope	GEWP7_BOY5_T.tif	Final version	Digital Terrain Model at 10 m x 10 m resolution (EPA / GSI)	The 10 m x 10 m file is interpolated to create a 5 m x 5 m DTM. This was then created into a slope raster file and reclassified into T index values	Due the generally flat topography the majority of the catchment is assigned the higher 'T' values with the average value being 7 and 8. The lowest T values are in the north of the catchment in areas of higher ground. .
I	Impact of vadose zone media	GEWP7_BOY6_I.tif	Final version	GSI National Aquifer Map, 1:50,000 scale	Direct assignment of I index values for each hydrological unit. If there were greater than 10 m of low permeability then the aquifer was considered confined. If there was > 3 meters of subsoil then the subsoil I value was used and if there was less than 3 m then the aquifer I value was used	Areas underlain by thick deposits (> 10 m) of low permeability subsoils were considered confined and given an I value of 1. The remaining areas with subsoil greater than 3 m were given a I value of 3 and areas where the subsoil was less than 3 m thick the subsoils were not considered to have a major impact. The characteristics of the vadose zone was taken from the aquifer characteristics, with karst aquifers being assigned a value of 10 and bedded sedimentary given a value of 6.
C	Hydraulic conductivity	GEWP7_BOY7_C.tif	Final version	GSI National Aquifer Map, 1:50,000 scale GSI National Aquifer Parameters database GSI National Water Tracing database	Direct assignment of C index values for each aquifer based on hydraulic properties of the aquifer and groundwater velocities from water tracing	The aquifers were assigned a C value based on their hydraulic conductivity values. As the majority of the aquifers are fractured sedimentary rocks, the majority of the study area has 'C' values of 4. Karst aquifers were given a value of 10 due to high groundwater velocities from tracer tests.

Pilot area Boyne (Ireland) (Cell size: 50 m, Total area: 2,693 km²)
DRASTIC input data specification



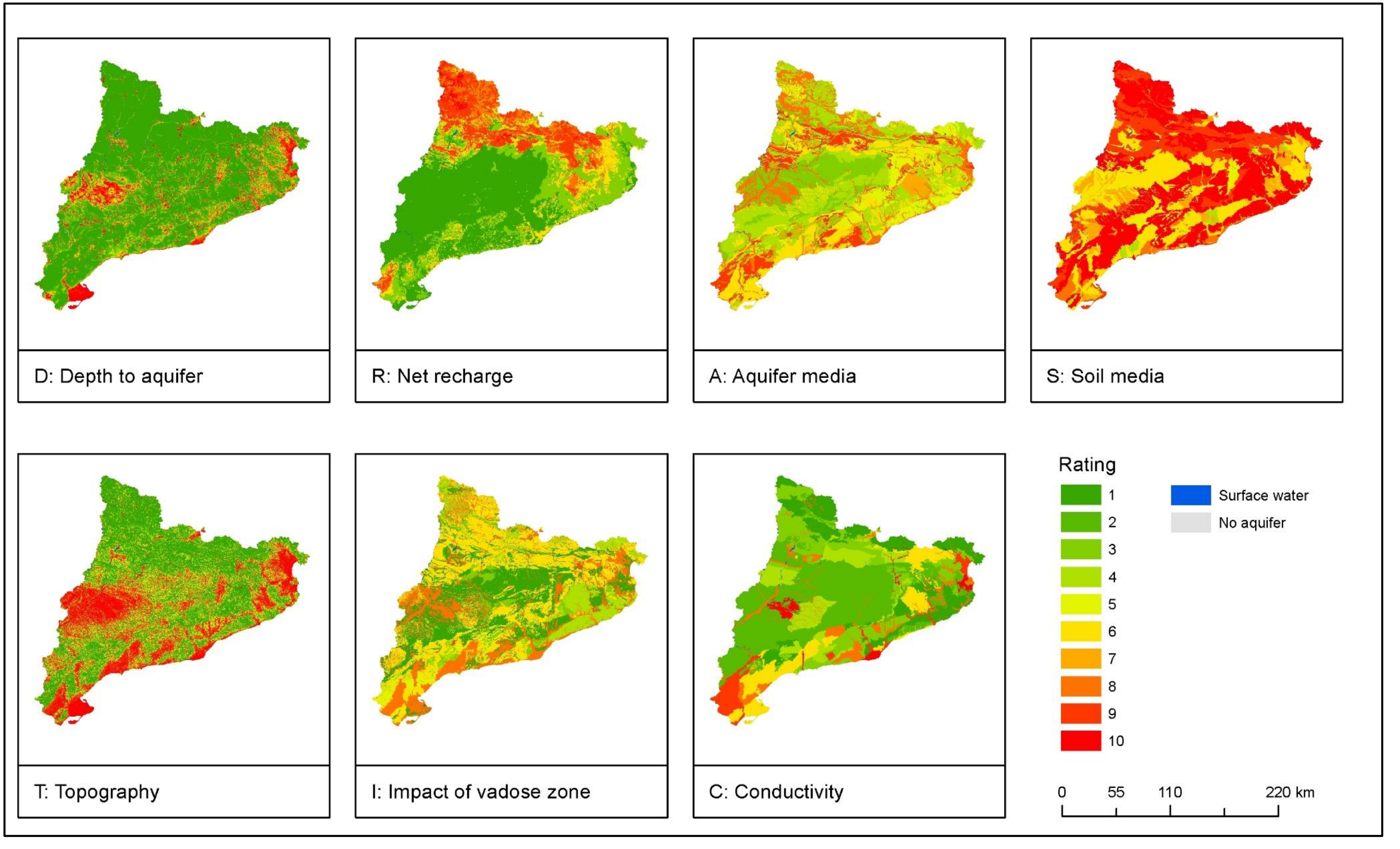
Pilot area Catalonia (Spain) - ICGC (Cell size: 50 m, Total area: 32,105 km²)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_CAT1_D.tif	Final version	16,534 of historical depth to water table data complemented with main river streams, piezometric lines and superficial water masses connected with groundwater	Spatial interpolation using Kriging of groundwater level data and reclassification into D index values.	High values of "D" correspond mainly with alluvial and delta plain areas. Low values correspond mainly with steepest and mountainous areas and karstic aquifers. For confined aquifers, "D" corresponds to the distance between the surface and the top of the confined aquifer.
R	Net recharge	GEWP7_CAT2_R.tif	Final version	Both SIMPA hydrogeology distributed model (Agriculture Ministry of Spain) and Pan-EU recharge map (approach borrowed from Döll & Flörke, 2005)	For SIMPA data, estimation of the mean net recharge taking into account the different hydrology cycle variables in the period 1940-2017. For pan-Eu approach assignment of R index values.	High values correspond to areas where the difference between precipitation and surface runoff is highest; areas with lower values correspond to areas where the difference between precipitation and runoff is low or very low.
A	Aquifer media	GEWP7_CAT3_A.tif	Final version	Hydrogeological Areas Map of Catalonia at 1:250,000 (ICGC)	Direct assignment of A index values for each hydrogeological formation delimitated in the map.	A value of 9 was assigned to the aquifers with high permeability / vulnerability, which correspond to limestone and unonslidated sedimentary formations (sands and gravels). A value of 3 was assigned to the aquifers with low permeability / vulnerability.
S	Soil media	GEWP7_CAT4_S.tif	Final version	Soil Map of Catalonia at 1:250,000 (ICGC)	Direct assignment of S index values for each soil type	The values range from 4 to 10. The highest values correspond to lithologies that don't become soils or at least very shallow ones (metamorphic or igneous rocks for instance). The lowest values correspond to lithologies that can generate a much deeper soil layers (basically detrital sediments).
T	Topography/slope	GEWP7_CAT5_T.tif	Final version	Digital Terrain Model at 15 x 15 m cell size (ICGC)	Calculation of the slope rasterfile and reclassification of the slope values into T index values	The highest values correspond to low slope areas that facilitate infiltration such as deltas or depression and the highest values correspond to steepest areas which facilitate runoff.
I	Impact of vadose zone media	GEWP7_CAT6_I.tif	Final version	Geological Map of Catalonia at 1:50,000 (ICGC)	Direct assignment of I index values for each hydrological unit	The lowest values correspond to areas where the unsaturated zone is formed by very poorly permeable lithologies and the highest values have been assigned to lithologies with higher permeability (such as gravel and sands).
C	Hydraulic conductivity	GEWP7_CAT7_C.tif	Final version	Aquifers Map of Catalonia at 1:50,000 (ACA)	Direct assignment of C index values for each aquifer, hydrogeological units or water masses delimitation	Lithology of the aquifers and the data collected from pumping tests (where available) have been taken into account to make the assignment. Generally, the highest values correspond to high permeability porous media like alluvial formations and low values correspond to fracture porosity media with local aquifers such as metamorphic formations among others.

Pilot area Catalonia (Spain) - ICGC (Cell size: 50 m, Total area: 32,105 km^2)

Spatial distribution of DRASTIC input data ratings



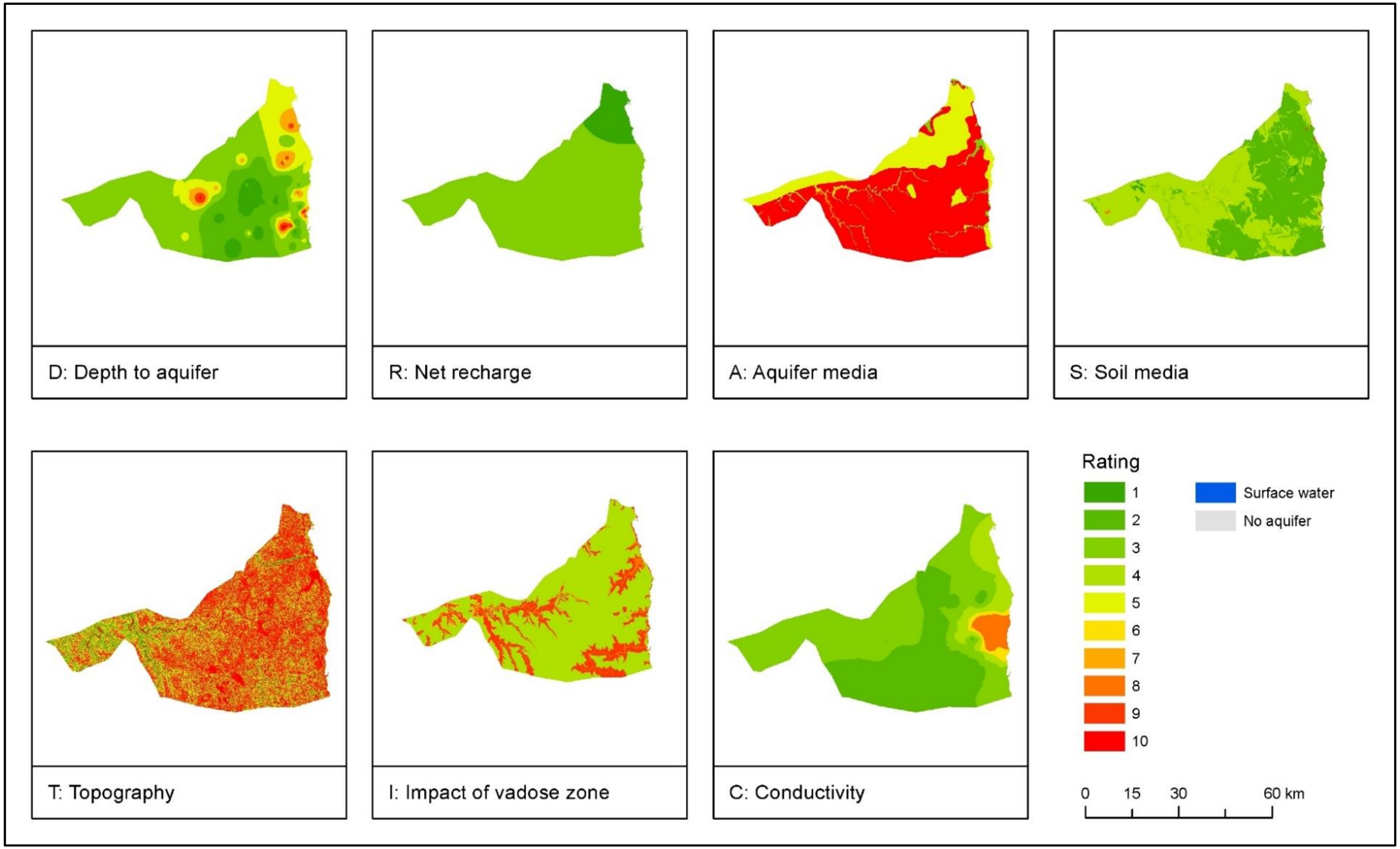
Pilot area Cobadin-Mangalia (Romania) - IGR (Cell size: 50 m, Total area: 2,192 km^2)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_COB1_D.tif	Final version	Historical groundwater depth data from hydrogeological map at 1:100,000 (IGR) updated based on piezometric maps and wells data published by different studies (Moldoveanu, 1998 and Zamfirescu et al, 2006, etc).	The method of interpolation applied for data on *depth to water table* is the IDW method. The data have been reclassified resulting "D" index values.	The high values of "D" correspond to those areas where the recharge is high. Outcropping, or being situated at shallow depths, the Sarmatian aquifer is covered by permeable porous Quaternary deposits.
R	Net recharge	GEWP7_COB2_R.tif	Final version	Precipitation and temperature data provided by the Romanian National Institute of Meteorology. They a provided by the Romanian network of meteorological data.	By applying the groundwater balance method, the recharge resulted. The method takes into account precipitation and temperature data from period 2006-2011. By using Turc formula, the evapotranspiration has been calculated.	The high values of the recharge correspond to those areas where the effective infiltration is higher than the water losses generated by evapotranspiration, runoff, and by the hydraulic connection between aquifers.
A	Aquifer media	GEWP7_COB3_A.tif	Final version	Hydrogeological Map of Romania at 1:100,000 (IGR), data from wells provided by the publications of Institute of Meteorology and Hydrology and by other studies.	The vector data resulting from digitization of the printed maps were processed. Each type of rock was analysed in terms of effective porosity, permeability and horizontal hydraulic conductivity. The data were reclassified resulting "A" index value.	The "A" index values range from 3 to 10. The highest values of 10, 9 and 8 were assigned to the aquifers with high permeability/vulnerability, which correspond to fractured and karstified limestone and sedimentary formations with high effective porosity and permeability (sands and gravels).
S	Soil media	GEWP7_COB4_S.tif	Final version	Soil Map of Romania at 1:200,000 (IGR).	The vector data resulting from digitization of the printed maps were processed. Vector data that resulted were processed. Each type soil was analysed in terms of texture and permeability and reclassified into "S" index value	For the "S' factor, the soil texture was takes into account. The values range from 1 to 9. The highest values correspond to sandy soil and the lowest values correspond to clayey loam soil.
T	Topography/slope	GEWP7_COB5_T.tif	Final version	ASTER Global Digital Elevation Model(GDEM)at 30 x 30 m cell size	Calculation of the slope and reclassification of values into "T" index values.	The highest values correspond to those areas with a low slope where the effective infiltration is high.
I	Impact of vadose zone media	GEWP7_COB6_I.tif	Final version	Geological Map of Romania at 1:200,000 (IGR) and lithological data from wells published by different studies (Moldoveanu, 1998 and Zamfirescu et al, 2006, etc).	The vector data resulting from digitization of the printed maps were processed. Each type of rock was analysed in terms of effective porosity and permeability and reclassified into "I" index value.	The highest values correspond to those areas with high permeability (limestone, gravel, sand).
C	Hydraulic conductivity	GEWP7_COB7_C.tif	Final version	Transmissivity Map, thickness data of karst-aquifer from wells and pumping tests data provided by articles published by Moldoveanu, (1998), Zamfirescu et al, (2006), etc.	Transmissivity and thickness data from wells have been interpolated using the IDW method. The conductivity was calculated by multiplying the transmissivity values with thickness of the Sarmatian limestone deposits and then reclassified into "C" index values.	The highest values of conductivity correspond to intensely karstified areas.

Pilot area Cobadin-Manga (Romania) – IGR (Cell size: 50 m, Total area: 2,192 km²)

Spatial distribution of DRASTIC input data ratings

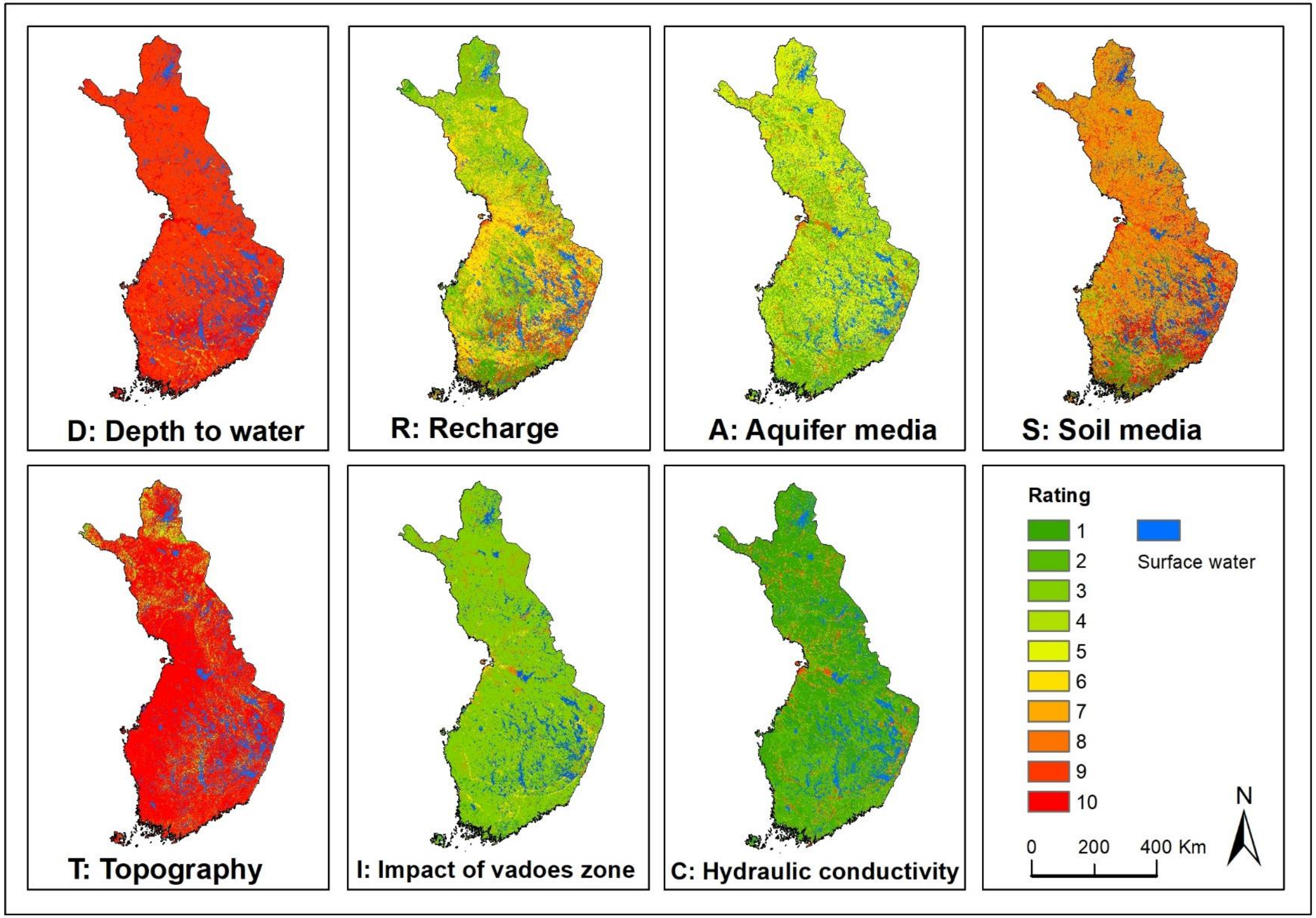


Pilot area Finland (Finland) – GTK (Cell size: 200 m, Total area: 338,440 km²)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_FIN1_D.tif	Final version	13,057 of the mean groundwater level data points during 1971-2020 were obtained from SYKE-POVET and GTK-Lähde database.	Spatial interpolation using inverse distance weighted (IDW) technique of groundwater level data. Depth to water grid map was produced by subtracting the topographic (DEM) and groundwater level grid maps and reclassification into D index values.	The main shallow groundwater areas in Finland are accumulated in the porous gravelly and sandy sediments in the end moraine complexes, eskers, outwash plains or littoral beach ridges and terraces, deposited during or immediately after the deglaciation of the last Weichselian (Wisconsin) glaciation. However, glacial till is the most common sediment in Finland. Mean groundwater level is quite shallow at approx. 4 m below ground surface on average.
R	Net recharge	GEWP7_FIN2_R.tif	Final version	Weather data (temperature and precipitation) obtained from FMI, land use map from SYKE and superficial deposit map of Finland at 1:20K and in some areas 1:200K from GTK.	Recharge estimation used the water balance approach from the annual mean 30 years of temperature and precipitation data (1981-2010) and the infiltration coefficient of different soil types.	Annual mean precipitation in Finland varies between 400-750 mm. High recharge could be around 40-60 % of precipitation in sandy and gravelly soils and 5-15 % in clay soils.
A	Aquifer media	GEWP7_FIN3_A.tif	Final version	Base sediment deposit map of Finland at 1:20K and in some areas 1:200K (GTK).	Direct assignment of A index values for each aquifer media types.	High values of "A" correspond to the porous gravelly and sandy superficial sediments, which deposited during or immediately after the deglaciation of the last Weichselian (Wisconsin) glaciation. Low values correspond to the areas of bedrock, glacial till and fine-grain sediments (silt and clay).
S	Soil media	GEWP7_FIN4_S.tif	Final version	Surface sediment deposit map of Finland at 1:20K and in some areas 1:200K (GTK).	Direct assignment of S index values for each soil type	Similar to the Aquifer media. The majority of the soil media is glacial till and thin or absent in the bedrock area. High values of "S" correspond to the porous gravelly and sandy surface sediments of the superficial deposit.
T	Topography/slope	GEWP7_FIN5_T.tif GEWP7_FIN6_I.tif	Final version	Digital Elevation Model at 10m cell size from the Natural Land Survey of Finland (NLS).	Calculation of the slope raster file (%) and reclassification of values into T index values.	The topography in Finland is relatively quite flat. High topography are found in the Lapland and some areas in the east.
I	Impact of vadose zone media	GEWP7_FIN7_C.tif	Final version	Base sediment deposit map of Finland at 1:20K and in some areas 1:200K (GTK).	Direct assignment of I index values for each soil unit.	Similar to the Aquifer media.
C	Hydraulic conductivity	GEWP7_FIN1_D.tif	Final version	Soil analysis from drilled boreholes data from GTK-Lähde database integrated with the base sediment deposit map of Finland at 1:20K and in some areas 1:200K (GTK).	K-values from soil analysis and a direct assignment of C index values for each soil type/aquifer media.	Due to the limitation of measured data, the mean K-values that represent for each aquifer media were assigned directly to the base sediment deposit map.

Pilot area Finland (Finland) – GTK (Cell size: 200 m, Total area: 338,440 km²)
Spatial distribution of DRASTIC input data ratings



Pilot area Middle and Lower Oder/Odra river (Poland/Germany) – PGI/LBGR/BGR (Cell size: 200 m, Total area: 7,374 km²)

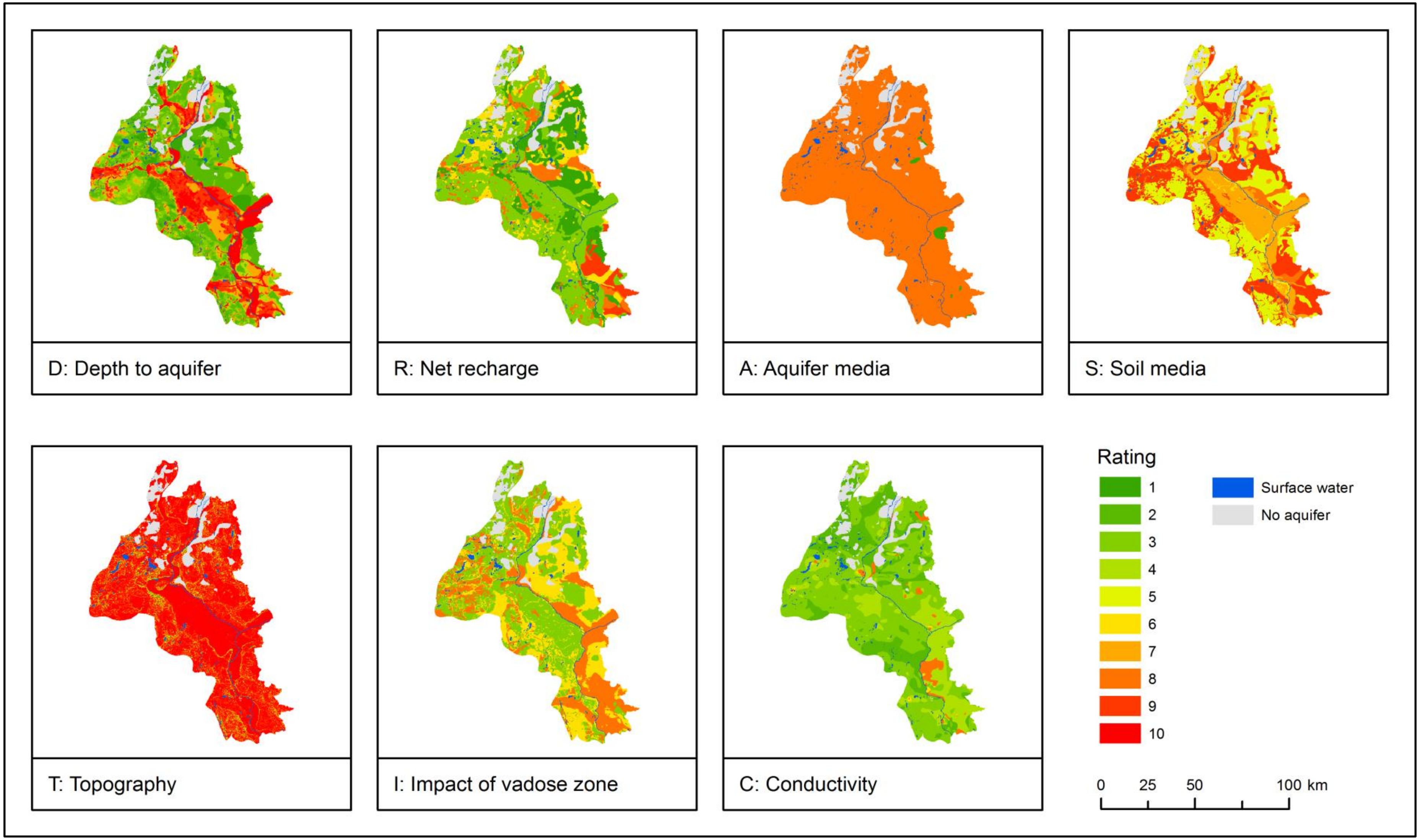
DRASTIC input data specification

Factor	Title of dataset	Country	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark(optional)
D	Depth to water table	Poland	GEWP7_ODR1_D.tif	Final version	Hydrogeological Map of Poland scale 1:50,000 (Main Useful Aquifer and First Aquifer), hydrogeological cross-sections [source: PIG-PIB]	Data analysis, adjustment of depth intervals, changes in areas extent, reclassification into D index values.	
		Germany			Depth to groundwater table for the upper used aquifer (source: LfU Brandenburg 2015)	Spatial interpolation of groundwater level data using Kriging techniques and reclassification into D index values	
R	Net recharge	Poland	GEWP7_ODR2_R.tif	Final version	Hydrogeological Map of Poland scale 1:50,000 (1994-2004) Recharging infiltration (efficient infiltration) (mm/year) [source: PIG-PIB]	Efficient infiltration (mm/year) was calculated using : resource renewal indicator (mm/year) and efficient infiltration indicator (-)	
		Germany			Precipitation-outflow model (1976-2005) water balance model ABIMO (source: LfU Brandenburg 2009)	Calculation of multi-annual mean net recharge by use of the water balance model ABIMO in the period 1976-2005	For all areas where the main aquifers is covered by clays, tills or silts, the net recharge was additionally corrected by introducing an reduction factor of 0.75.
A	Aquifer media	Poland	GEWP7_ODR3_A.tif	Final version	Hydrogeological Map of Poland scale 1:50,000 [source: PIG-PIB; data prepared for the RESOURCE project]	Data analysis within the Main Useful Aquifer's hydrogeological units and assignment of the A index values	
		Germany			Hydrogeological Map of the GDR in the scale: 1:50,000 (source: ZGI 1987)	Direct assignment of A index values for the distribution of the aquifers consisting of sand and gravel	
S	Soil media	Poland	GEWP7_ODR4_S.tif	Final version	Geological map of Poland 1:500,000 [source: PIG-PIB]	Assignment of S index values for each geological formation, comparison of results and correction of input data	
		Germany			Soil map of the Federal State of Brandenburg scale: 1:300,000 (source: LBGR 2019)	Direct assignment of S index values for each soil type and subsequent comparison of results and improvement of input data	
T	Topography/slope	Poland	GEWP7_ODR5_T.tif	Final version	SRTM 1 (source: NASA 2015)	Calculation of the slope raster file and reclassification of values into T index values	Gaps/voids in the dataset were filled applying a standard GIS routine
		Germany					

Factor	Title of dataset	Country	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark(optional)
I	Impact of vadose zone media	Poland	GEWP7_ODR6_I.tif	Final version	Hydrogeological Map of Poland 1:50,000 and Geological Map of Poland 1:500,000 [source: PIG-PIB; data prepared for the RESOURCE project]	Assignment of I index values for each geological formation within the Main Useful Aquifer's hydrogeological units.	
		Germany			Geological Map of Brandenburg scale: 1:100,000 (source: LBGR 2019)	Direct assignment of I index values for each hydrological unit	
C	Hydraulic conductivity	Poland	GEWP7_ODR7_C.tif	Final version	Hydrogeological Map of Poland 1:50,000 [source: PIG-PIB; data prepared for the RESOURCE project]	Assignment of C index values for each Main Useful Aquifer's hydrogeological unit.	
		Germany			Well data (source: LBGR 2020)	Spatial interpolation of hydraulic conductivity map using Kriging techniques and reclassification into D index values	The spatial interpolation of the hydraulic conductivity map based on drilling data (most of data represent lithological information about aquifer media (main aquifer), a smaller part of the data are results from sieve samples and pumping tests related to the main aquifer). All calculated hydraulic conductivities shown in the information layer C represent thickness-weighted harmonic mean values.

Pilot area Middle and Lower Oder/Odra river (Poland/Germany) – PGI/LBGR/BGR (Cell size: 200 m, Total area: 7,374 km²)

Spatial distribution of DRASTIC input data ratings



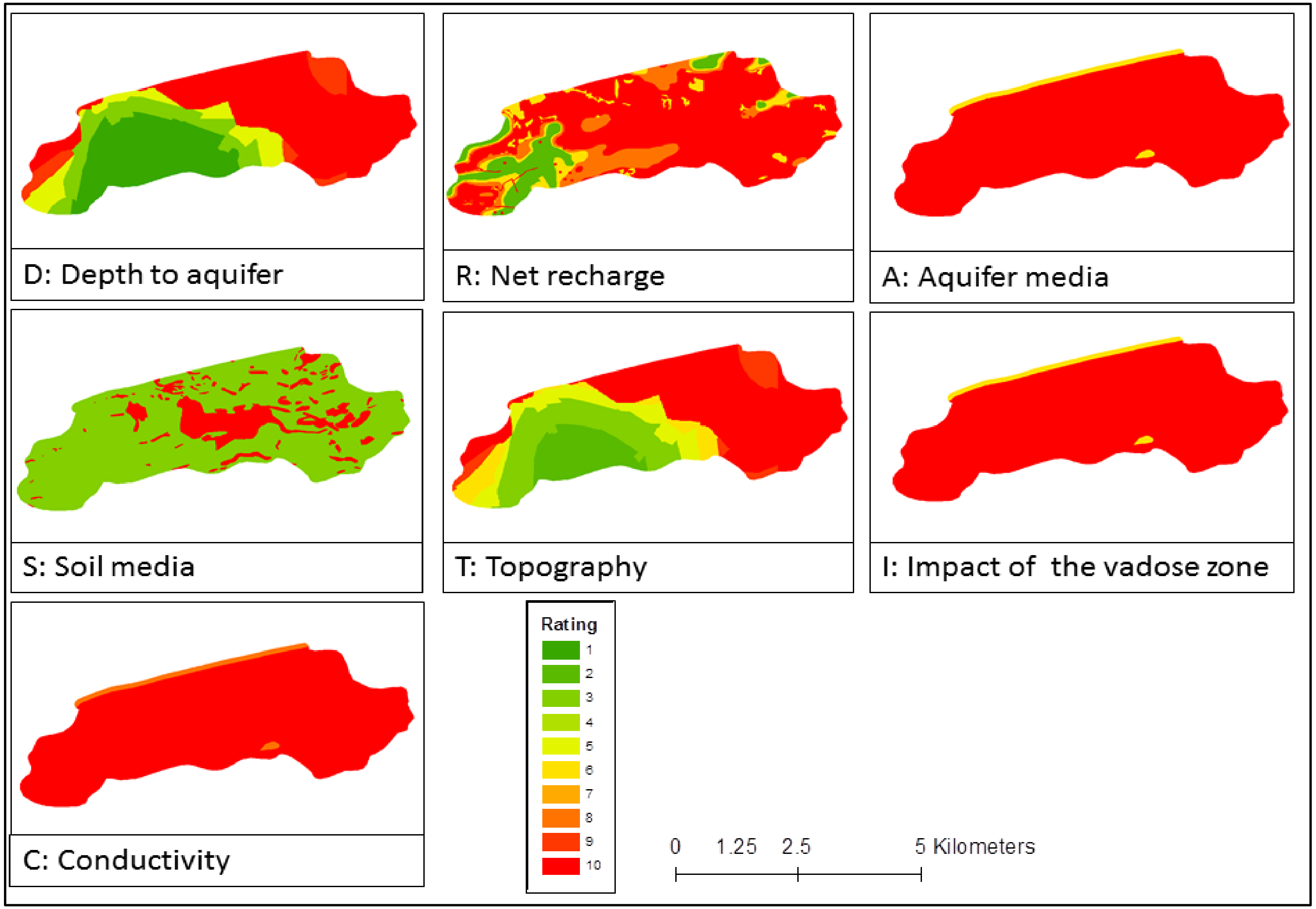
Pilot area Rockingham (Ireland) (Cell size: 10 m, Total area: 15 km²)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_ROC1_D.tif	Final version	120 historical water level data points, along with karst spring data and data from groundwater surface water interactions	Spatial interpolation using Kriging of groundwater level data and reclassification into D index values.	High values of "D" correspond mainly with the higher areas to the south of the pilot area. These areas are characterised by groundwater recharge and recharge karst landforms and the water table is generally greater than 30 m bgl. The areas to the north and northeast are characterised by groundwater discharge, including large karst springs. The water table is within 3 metres of the surface over more than half the study area.
R	Net recharge	GEWP7_ROC2_R.tif	Final version	GSI National Groundwater Recharge Map, 1:50,000 scale	Aquifer recharge is effective rainfall multiplied by a recharge coefficient based on the permeability and thickness of superficial deposits and the ability of the underlying aquifer to accept recharge	High values correspond to areas where the overlying till is absent or thin or at karst features, low values correspond to areas where the glacial till is thickest such as at low permeability drumlin landforms
A	Aquifer media	GEWP7_ROC3_A.tif	Final version	GSI National Aquifer Map, 1:50,000 scale	Direct assignment of A index values for each aquifer delimitated	The karst aquifers were assigned the highest value of 10 based on their high degree of karstification and the impure limestone was assigned a value of 6 due to its fractured nature
S	Soil media	GEWP7_ROC4_S.tif	Final version	GSI National Vulnerability Map 1:50,000 scale FIPS-IFS Teagasc Soil Map FIPS-IFS Teagasc Subsoil Map	Direct assignment of S index values for each soil and subsoil type based on BS9530 subsoil classifications and permeability assessments	Areas overlain by glacial till were given a value of 3 due to its low permeability and high clay content. Areas where soil and subsoil is absent was assigned a value of 10
T	Topography/slope	GEWP7_ROC5_T.tif	Final version	Digital Terrain Model at 10 m x 10 m resolution (EPA / GSI)	The 10 m x 10 m file is interpolated to create a 5 m x 5 m DTM. This was then created into a slope raster file and reclassified into T index values	The highest values correspond to the flat low-lying areas near the rivers and lakes. The lowest values correspond to the greatest slopes and are found in the steeper areas up to the plateau and the drumlins areas.
I	Impact of vadose zone media	GEWP7_ROC6_I.tif	Final version	GSI National Aquifer Map, 1:50,000 scale	Direct assignment of I index values for each hydrological unit	As much of the area has very little thickness of glacial material (>70 % has subsoil thickness of 3 m or less) and as the areas of thicker till is only found in small drumlin features (meaning runoff enters the aquifer at the base of these features) the subsoils were not considered to have a major impact. The characteristics of the vadose zone was taken from the aquifer characteristics, with karst aquifers being assigned a value of 10
C	Hydraulic conductivity	GEWP7_ROC7_C.tif	Final version	GSI National Aquifer Map, 1:50,000 scale GSI National Aquifer Parameters database GSI National Water Tracing database	Direct assignment of C index values for each aquifer based on hydraulic properties of the aquifer and groundwater velocities from water tracing	Due the highly karstic nature of the bedrock, the extremely rapid groundwater velocities from water tracing and high aquifer conductivity values from borehole data, the karst aquifers were assigned a value of 10. The fractured limestone aquifers were assigned a value of 4 due to the average k value

Pilot area Rockingham (Ireland) (Cell size: 10 m, Total area: 15 km²)

DRASTIC input data specification



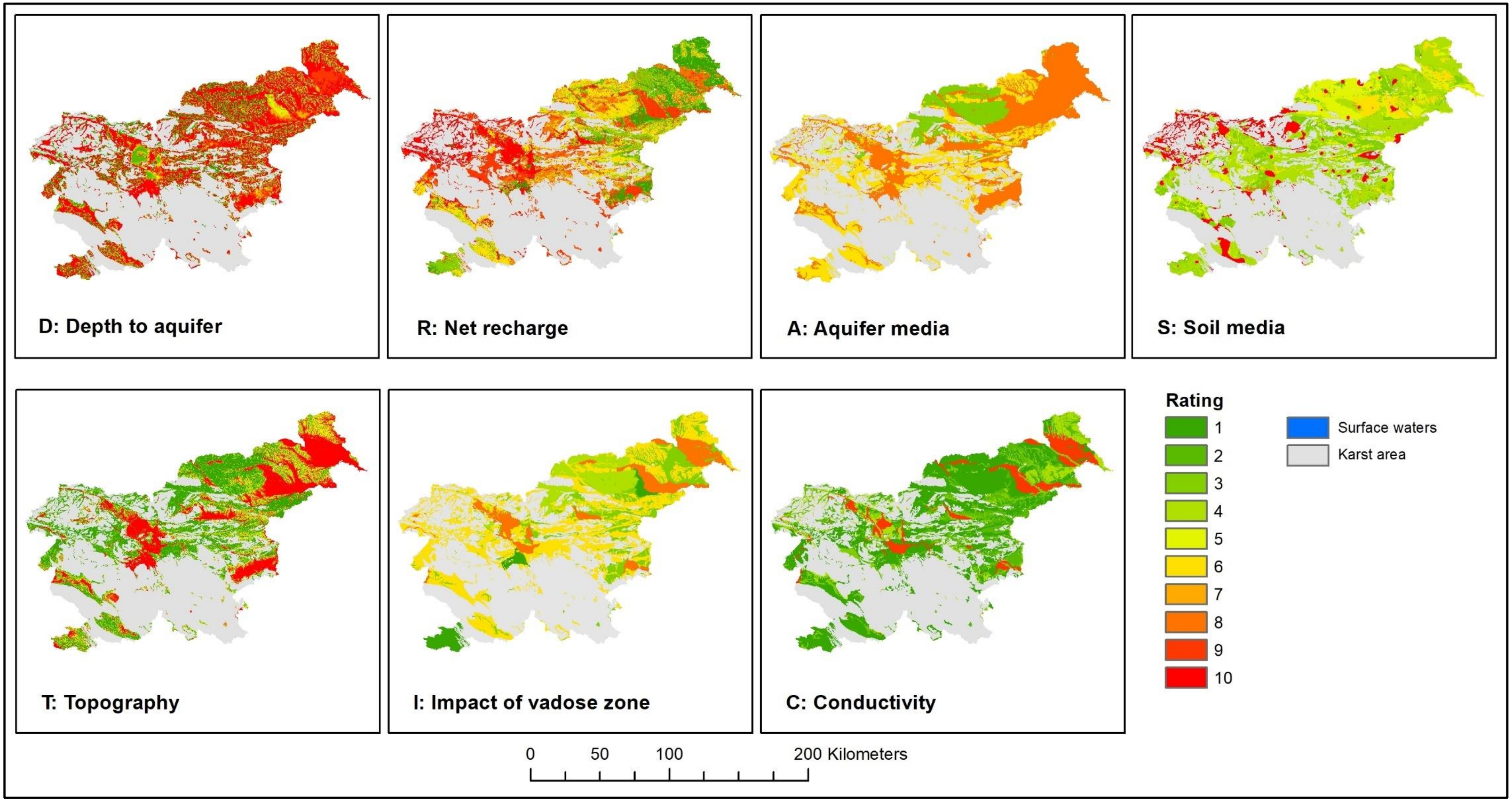
Pilot area Slovenia (Slovenia) – GeoZS (Cell size: 100 m, Total area: 10,876 km^2)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_SLO1_D.tif	Final version	Groundwater level isolines on alluvial aquifers. Springs inventory in Slovenia. Surface water network (1:25,000). Digital elevation model DEM (cell size 25 x 25 m)	Spatial interpolation using "topo to raster" function of groundwater level data and reclassification into D index values.	High values of "D" factor correspond mostly with alluvial aquifers in NE part of the area where shallow groundwater prevails. Low values correspond mainly with steepest mountainous areas and deeper aquifers.
R	Net recharge	GEWP7_SLO2_R.tif	Final version	GROWA "qn" groundwater recharge for the period 1981-2010 (ARSO)	Estimation of the mean net recharge in GROWA in the period 1981-2010.	Lower values correspond to NE part of the area, where amount of precipitation is small.
A	Aquifer media	GEWP7_SLO3_A.tif	Final version	Hydrogeological map (IAH) of Slovenia at 1:250,000 (GeoZS) Hydrogeological map (LAWA) of Slovenia at 1:250,000 (GeoZS) Litho-geochemical map of Slovenia at 1:250,000 (GeoZS)	Direct assignment of A index values for each aquifer delimitated	Higher values of "A" factor correspond to alluvial quaternary aquifers and Miocene sedimentary formations (sands and gravels). Smaller values represent areas with metamorphic and igneous rocks.
S	Soil media	GEWP7_SLO4_S.tif	Final version	Pedological Map of Slovenia at 1:250,000 (MKGP) Pedological profiles in Slovenia (MKGP) Litho-geochemical map of Slovenia at 1:250,000 (GeoZS)	Direct assignment of S index values for each pedological unit with information from pedological profiles and litho-geochemical map (where no profiles were available)	The highest values correspond to lithologies that don't constitute soils or at least very shallow ones (< 30 cm). The lowest values are significant for areas with deeper soil layers (sedimentary rocks).
T	Topography/slope	GEWP7_SLO5_T.tif	Final version	Digital Elevation Model (DEM) at 12.5 x 12.5 m cell size (GURS)	Calculation of the slope rasterfile and reclassification of values into T index values	The highest values correspond to low slope areas (alluvial aquifers) and the highest values correspond to steepest areas in mountains.
I	Impact of vadose zone media	GEWP7_SLO6_I.tif	Final version	Geological map of Slovenia at 1:250,000 (GeoZS) Litho-geochemical map of Slovenia at 1:250,000 (GeoZS)	Direct assignment of I index values for each hydrological unit	Higher values of "I" factor correspond to areas with unsaturated zone formed by gravel and sand, smaller values represent areas with unsaturated zone formed by metamorphic and igneous rocks.
C	Hydraulic conductivity	GEWP7_SLO7_C.tif	Final version	Cp map (Kennesey) at 1:250,000 (GeoZS)	Direct assignment of C index values for each aquifer from cp map	Higher values of C correspond to alluvial aquifers, and smaller values to metamorphic and igneous rocks.

Pilot area Slovenia (Slovenia) – GeoZS (Cell size: 100 m, Total area: 10,876 km²)

Spatial distribution of DRASTIC input data ratings



Pilot area Tønder (Denmark) – GEUS (Cell size: 100 m, Total area: 293 km^2)

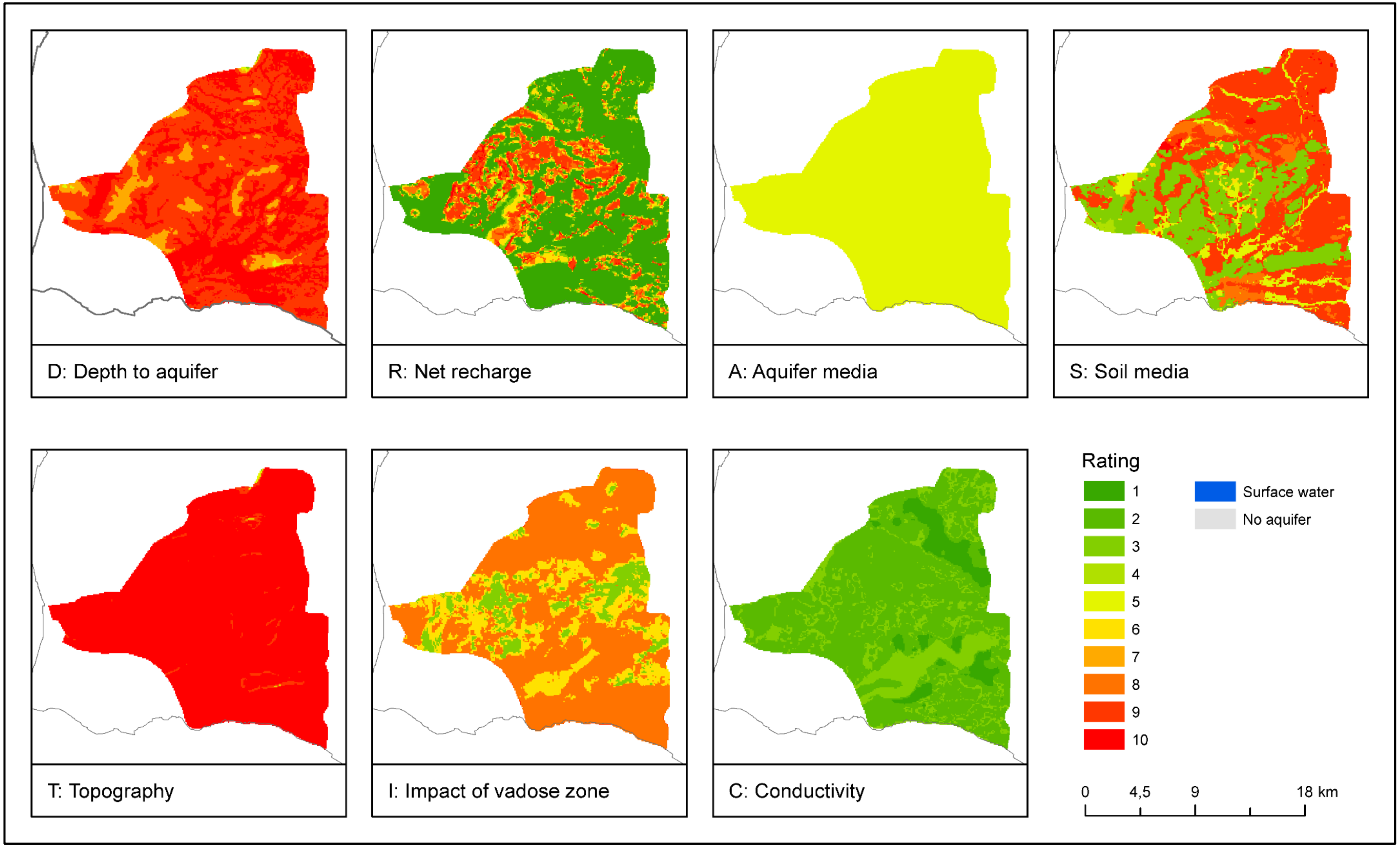
DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology[1]	Remark (optional)
D	Depth to water table	GEWP7_TON1_D.tif	Final version	Hydraulic head simulated with MODFLOW2000/GroundwaterVistas6 model for the study area (Rasmussen and Sonnenborg, 2015)	Unit conversion (m a.s.l. to m b.g.l.), and reclassification into D index value	The simulated hydraulic head is for the actual abstraction volumes for 2012. It corresponds to model layer at -29 m a.s.l. This level is chosen to represent the aquifer, because it is the average abstraction depth of the waterworks wells in the study area.
R	Net recharge	GEWP7_TON2_R.tif	Final version	Vertical flow simulated with MODFLOW2000/GroundwaterVistas6 model for the study area (Rasmussen and Sonnenborg, 2015)	Rasterization, unit conversion (mm/day to mm/y), and reclassification into R index value	The vertical flow to the representative model layer at -29 m a.s.l. approximating the recharge to the top of the aquifer. Rasterization was used to convert the model grid centroids (100m x 100m)
A	Aquifer media	GEWP7_TON3_A.tif	Final version	Conceptual geological model of the area. The 3D geological model (Jørgensen et al., 2015) was not used for this simplified version of the A-parameter.	The aquifer we assess is a glacial till aquifer, so we assigned the original typical rating for this class (5) over the entire area.	Initially we used information from the 3D geologic model (Jørgensen et al., 2015) to redefine this parameter, so it reflects the vertical heterogeneity of the aquifer, expressed in percent sandy vs clayey voxels in depth. (Voutchkova et al,2020). However, for comparability with the rest of the pilot areas, we have revised our submission, so the entire area is classified as "Glacial till".
S	Soil media	GEWP7_TON4_S.tif	Final version	Denmark's digital surface geology map v.4 at 1:25,000 (GEUS) (Jakobsen et al., 2015)	Conversion of surface geology classes and rasterization. Filling of raster gaps through interpolation with a maximum search radius of raster-cells.	The sediment type at 1m depth is used. The class modification concerned only the loam-classes, which are not used as a textural description in the Danish surface geology map. The glacial tills, the gyttja, and some of the classes with alternating small layers were distributed in the range of the loamy classes. More details are provided in (Voutchkova et al., 2020ep).
T	Topography/slope	GEWP7_TON5_T.tif	Final version	Digital terrain model of Denmark at 0.4 x 0.4 m resolution (Spec_DHM/T_V2.0, Danish Agency for Data Supply and Efficiency)	Merging of 1km tiles. Resampled from 0.4 x 0.4 m to 100 x 100 m with upscaling option "Mean Value (cell area weighted)". Slope calculation and reclassification to T index value.	Derived from LiDAR data collected in the period 2014-2015 with an average density of 4-5 points/m^2. The DTM has a horizontal accuracy 0.15 m and vertical accuracy 0.05 m. More details are provided in (Voutchkova et al, 2020).
I	Impact of vadose zone media	GEWP7_TON6_I.tif	Final version	Cumulative thickness of the protective clay layer (above the aquifer) from the 3D geological model of the study area 100 x 100 x 5 m resolution (Jørgensen et al., 2015; Hansen et al., 2016)	Reclassified into the typical ratings for the classes "Sand and gravel" (8), "Sand and Gravel with significant silt and clay" (6), and "Silt/clay" (3).	Originally, the this parameter was defined so the ranges of possible ratings for each class were used (Voutchkova et al, 2020). In this revision we use the typical ratings, such as if the thickness of the protective clay layer is ≤ 5m we assigned rating 8, for 5-15 m we assigned rating 6, and for > 15 m thickness of the protective clay layer, we assigned rating 3.
C	Hydraulic conductivity	GEWP7_TON7_C.tif	Final version	Calibrated horizontal hydraulic conductivity from the MODFLOW2000/GroundwaterVistas6 model for the study area (Rasmussen and Sonnenborg, 2015)	Reclassification into C index value	The hydraulic conductivity is also for the representative model layer at -29 m a.s.l.

[1] All rasters were reprojected (QGIS Warp, nearest neighbour) to the common HOVER WP7 projection: ETRS89 / LAEA Europe EPSG:3035 (the original projection for the DK pilot is ETRS89 / UTM zone 32N EPSG:25832)

Pilot area Tønder (Denmark) – GEUS (Cell size: 100 m, Total area: 293 km²)

Spatial distribution of DRASTIC input data ratings



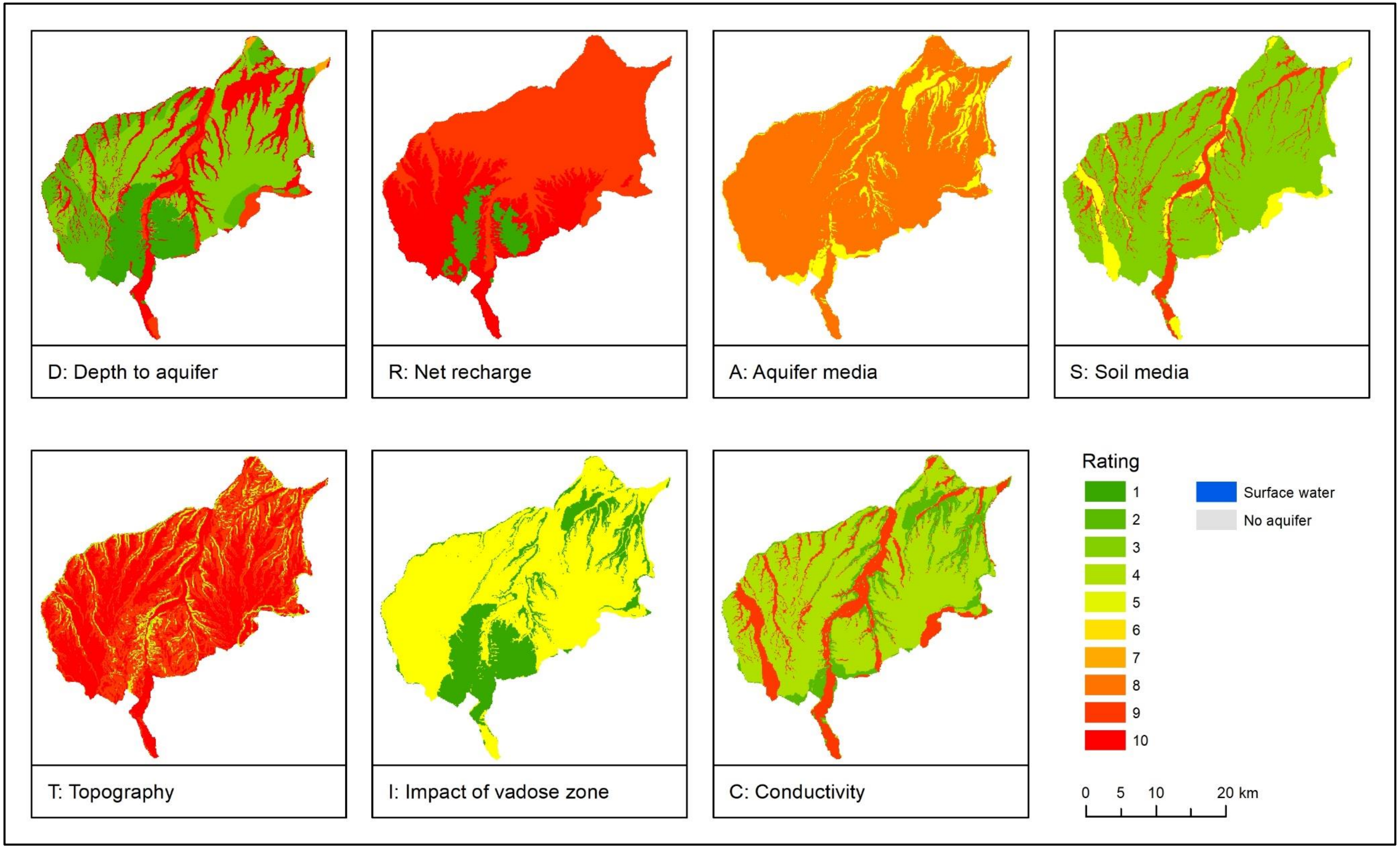
Pilot area Traun-Enns-Platte (Austria) – GBA (Cell size: 100 m, Total area: 810 km²)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_TEP1_D.tif	Final version	Factor D bases upon the “digital terrain model of Austria, based on airborne lasers canning” (www.geoland.at) and upon the water table contour lines in Schubert & Kupersberger (2014), fig. 14, which came from the regional study of Flögl & Flögl (1984), but also from several local measurements.	Factor D was derived from the difference between the digital terrain model and the water table contour line.	In fig. D, it can be seen that where the valleys cut into the gravel plain the shallow depth of water table causes the lowest D-Factors.
R	Net recharge	GEWP7_TEP2_R.tif	Final version	Factor R was derived from the recharge data shown in Schubert & Kupersberger (2014), fig. 6, which bases upon the data of https://ehyd.gv.at/.	As the Quaternary gravels have no surface runoff, the recharge could be calculated by the difference of precipitation minus evapotranspiration after Turc. For the calculation, long term mean values (several decades) were used.	In the south, where the moraines are several dozens of meters thick locally the recharge is very low and a local surface runoff happens (green colour in the fig. R).
A	Aquifer media	GEWP7_TEP3_A.tif	Final version	Factor A is an interpretation of the geological model in Bottig & Schubert (2012) and Bottig et al. (2013). The geological model bases upon Flögl & Flögl (1984), Kohl & Letouzé-Zezula (1990) and the geological maps of the Survey (https://www.geologie.ac.at/onlineshop/karten) as well as upon an airborne-geoelectromagnetic survey (Moser, G. & Reitner, J., 1998).	Direct assignment of A index values for each geological units	The yellow colour in fig. A is the Neogene marl in the valleys. Furthermore, beneath the moraines where the gravels are missing the yellow colour appears.
S	Soil media	GEWP7_TEP4_S.tif	Final version	Factor S bases upon the interpretation of the geological model (see factor A)	Direct assignment of S index values for each geological unit.	The thick and loamy loess on the top of the gravels causes most of the green colour in fig. F. Within them, the infiltration needs one year per meter.
T	Topography/slope	GEWP7_TEP5_T.tif	Final version	Factor T bases upon “digital terrain model of Austria, based on airborne laser scanning” (www.geoland.at)	Calculation of the slope rasterfile and reclassification of values into T index values	Traun-Enns-Platte is mostly flat. In fig. T also the streamless valleys on the top of the gravel plain can be seen.
I	Impact of vadose zone media	GEWP7_TEP6_I.tif	Final version	Factor I bases upon the interpretation of the geological model (see factor A)	Direct assignment of I index values for each geological units	In picture I the green colour is in the distribution area of the mighty moraines in the south and where the Neogene crops out.
C	Hydraulic conductivity	GEWP7_TEP7_C.tif	Final version	For the calculation of Factor C, the data from Lohberger (1997), cited in Schubert, G., Elster, D. & Berka, R (2013) Lohberger (1997), were used.	The different gravels of the geological model were attributed with the kf-values.	The highest conductivities appears in the younger gravels in the valleys.

Pilot area Traun-Enns-Platte (Austria) – GBA (Cell size: 100 m, Total area: 810 km^2)

Spatial distribution of DRASTIC input data ratings



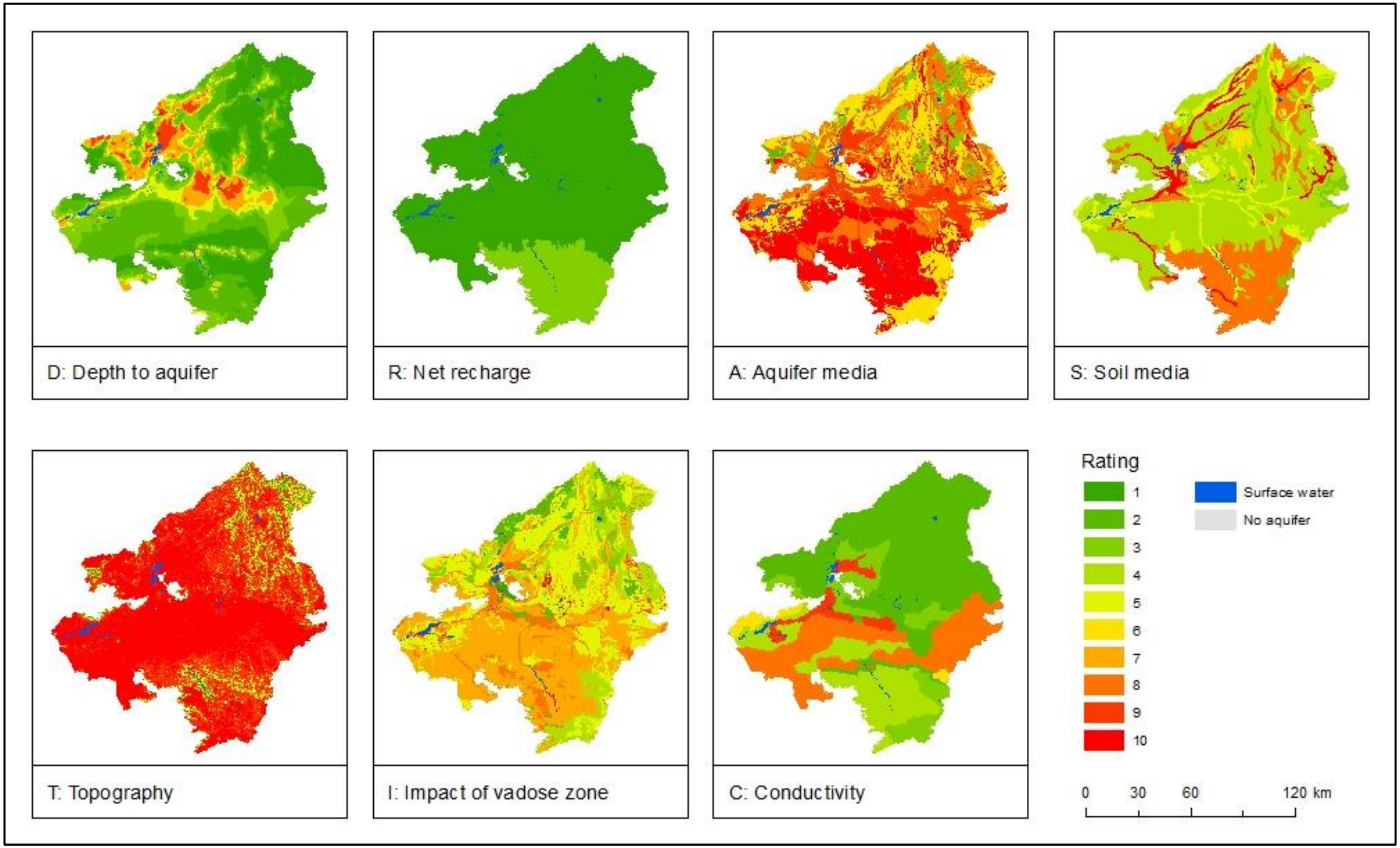
Pilot area Upper Guadiana Basin (Spain) – IGME (Cell size: 100 m, Total area: 14,093 km^2)

DRASTIC input data specification

Factor	Title of dataset	Name of the input dataset file	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
D	Depth to water table	GEWP7_UGB1_D.tif	Final version	Data from simulation flow model (CHG) (mean of the simulated data for each grid point from 1974 to 2015)	Spatial interpolation using IDW of groundwater level data and reclassification into D index values.	-
R	Net recharge	GEWP7_UGB2_R.tif	Final version	Recharge time series calculated from SACRAMENTO model. Mean recharge value in the period 1974-2015.	Estimation of the mean net recharge taking into account the different hydrology cycle variables in the period 1974-2015.	-
A	Aquifer media	GEWP7_UGB3_A.tif	Final version	Hydrogeological map of Spain 1:200,000 (IGME)	Direct assignment of A index values for each hydrogeological unit delimitated	-
S	Soil media	GEWP7_UGB4_S.tif	Final version	Soil Map of Spain at 1:1,000,000 (IGN)	Direct assignment of S index values for each soil type	-
T	Topography/slope	GEWP7_UGB5_T.tif	Final version	Digital Terrain Model at 100 x 100 m cell size (IGN)	Calculation of the slope rasterfile and reclassification of values into T index values	-
I	Impact of vadose zone media	GEWP7_UGB6_I.tif	Final version	Lithostratigraphic map of Spain at 1:200,000 (IGME)	Direct assignment of I index values for each lithostratigraphic unit	-
C	Hydraulic conductivity	GEWP7_UGB7_C.tif	Final version	Flow model at 1000 x 1000 m cell size (CHG)	Spatial interpolation using IDW of conductivity data and reclassification into C index values.	-

Pilot area Upper Guadiana Basin (Spain) – IGME (Cell size: 100 m, Total area: 14,093 km²)

Spatial distribution of DRASTIC input data ratings



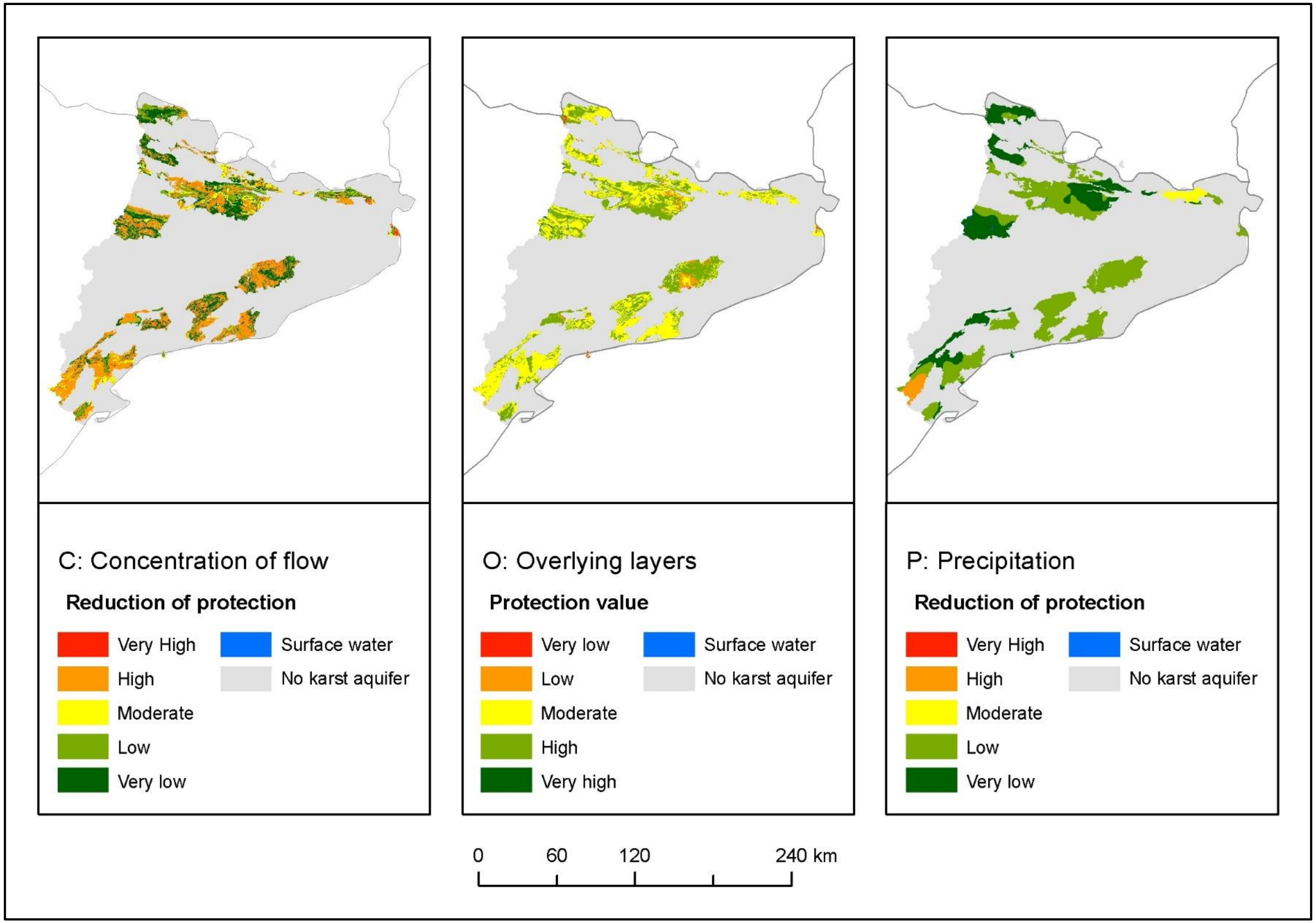
APPENDIX B2

Pilots karst areas in Catalonia (Spain) – ICGC (Cell size: 50 m, Total area: 10,947 km²)

COP input data specification

Factor	Title of dataset	Input factor dataset file	Subfactor	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
C	Concentration on flow	GEWP7_CAT_C.tif	Scenario 1	Final version	Swallow holes inventory and vegetation map of Catalonia at 1:50,000. Karstic morphologies defined in the Geomorphological map 1:50,000 (IGME) and in Geological Maps of Catalonia at 1:50,000 and 1:25,000 scales (ICGC). Digital Terrain Model (DTM) at 5 x 5 m cell size (ICGC)	Automatic calculation of the distance to the swallow holes and sinking streams, recharge areas and assignment of values. Slope calculation, classification of the vegetation distribution map and assignment of the corresponding COP method values taking into account both parameters	The lowest values correspond to endorheic areas, detected with the automatic calculation and a subsequent review, and to streams or rivers affected by swallow holes. The highest are concentrated in the areas furthest from the charging points.
			Scenario 2	Final version	Vegetation distribution map of Catalonia at 1:50,000 scale. DTM at 5 x 5 m cell size (ICGC). Geological Map of Catalonia at 1:50,000 (ICGC)	Assignment of the values for the karstified areas taking into account the presence and intensity of karst features. Assignment of inverted values for vegetation and slope	The values are determined mainly by the SF factor, this is the reason why the lowest values correspond largely to the karstified areas without surface layers.
O	Overlying layers	GEWP7_CAT_O.tif	O_S - Soil	Final version	Soil Map of Catalonia at 1:250,000 (ICGC)	Assignment of the Os values after classifying the different types of soil depending on the proportion of clay and sand	The highest values correspond to lithologies that don't constitute soils or at least very shallow ones (metamorphic, igneous, etc.). The lowest values correspond to lithologies that can generate a much deeper soil layer (basically detrital sediments).
			O_L - Lithology	Final version	Geological Map of Catalonia at 1:50,000 (ICGC) and groundwater level data	Distribution analyse of the geological layers between the surface and the groundwater level. simplification of the 3D conceptual model into two main layers and assignment of the O_L corresponding values	The lowest values correspond to areas where the unsaturated zone is formed by lithologies with high permeability and the distance to groundwater table is low. The highest values are defined in areas with poorly permeable lithologies and high thickness.
P	Precipitation	GEWP7_CAT_P.tif	P_Q - Precipitation quantity	Final version	Annual precipitation map of Catalonia. Meteorological stations data for precipitation number of rainy days. SMC - Meteorological Service of Catalonia	Reclassification of the precipitation values into the P_Q subfactor values, taking into account the average rainfall in the wet years.	Meteorological historical series between 1950 and 2018 have been used to extract the mean annual precipitation taking into account the wet years.
			P_I - Temporal distribution	Final version	Meteorological stations data (number of rainy days in Catalonia). SMC - Meteorological Service of Catalonia	Identification of the nearest meteorological station with data regarding the number of rainy days above 1 mm. In case of having more than one station, it has been calculated the mean value. Interpolation of these data and the average rainfall in the wet years.	For the estimation of the rainy days per year, meteorological historical series between 1990 and 2019 has been analysed.

Pilots karst areas in Catalonia (Spain) – ICGC (Cell size: 50 m, Total area: 10,947 km²)
Spatial distribution of COP input data

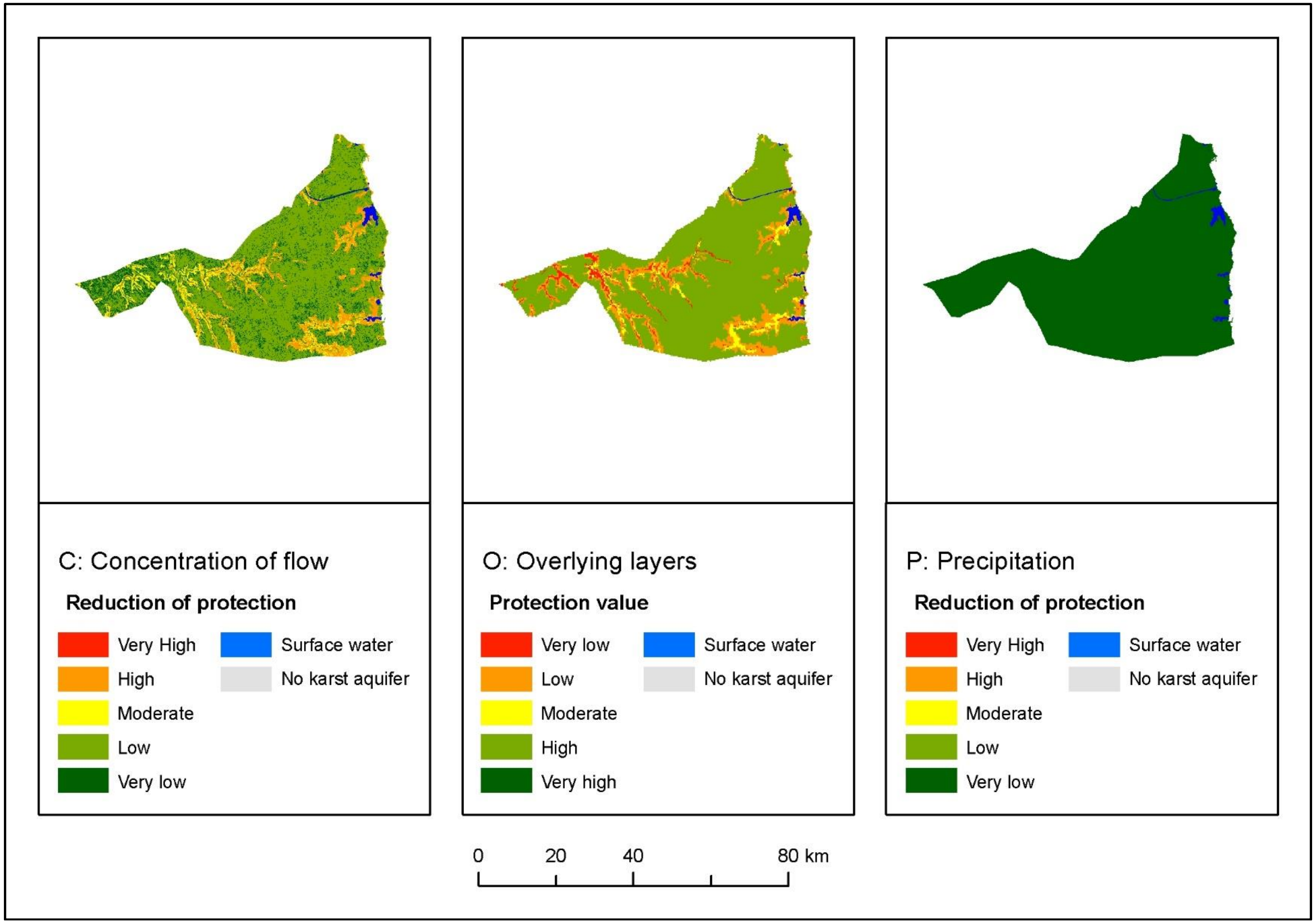


Pilots karst areas in Cobadin-Mangalia (Romania) – IGR (Cell size: 50 m, Total area: 2,192 km²)

COP input data specification

Factor	Title of dataset	Input factor dataset file	Subfactor	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
C	Concentration on flow	GEWP7_COB_C.tif					
			Scenario 2	Final version	Geological Map of Romania at 1:200,000 (IGR). Landuse map at 1:100,000 scale.(Corine LandCover) ASTER Global Digital Elevation Model (GDEM)at 30x30m cell	The *C* score was evaluated by the combination of three variables: surface features (*sf*), slope (*s*) and vegetation (*v*). To obtain the *C* score the slope vegetation (*sv*) parameter were weighted by the surface features (*sf*).	-
O	Overlying layers	GEWP7_COB_O.tif	O_S - Soil	Final version	Soil Map of Romania at 1:200,000(IGR)	The Os factor evaluation criteria are the texture and the thickness of the soil.	-
			O_L - Lithology	Final version	Geological Map of Romania at 1:200,000 (IGR) and lithological information from wells (previous reports).	O_L factor evaluation criteria are the type of rock (the main characteristics being efficient porosity and hydraulic conductivity), and the degree of fracturing (ly) , thickness of each layer (m) and any limiting condition (cn).	-
P	Precipitation	GEWP7_COB_P.tif	P_Q - Precipitation quantity	Final version	Meteorological data from Meteorological Services from Romania	Precipitation data were interpolated using IDW method and reclassified into the P_Q subfactor values.	Precipitation data between 2006-2011 have been used to extract the mean annual precipitation.
			P_I - Temporal distribution	Final version	Meteorological data from Meteorological Services Romania	Number of rainy days per station were interpolated and reclassified into the Pi subfactor value.	The number of rainy days from 2006-2011 was taken into account.

Pilot area Cobadin-Mangalia (Romania) – IGR (Cell size: 50 m, Total area: 2,192 km²)
Spatial distribution of COP input data

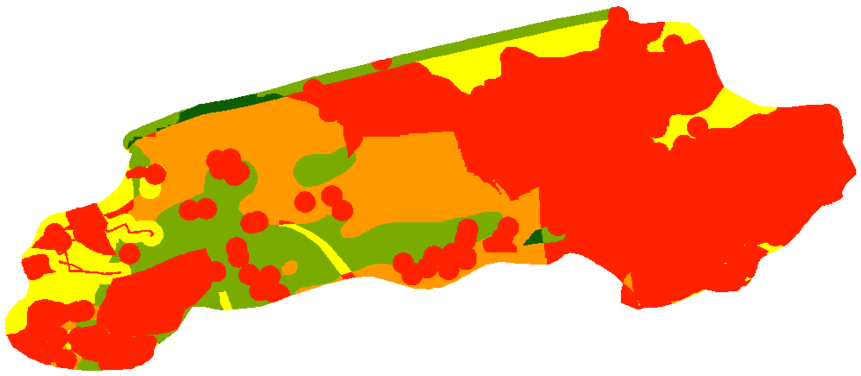


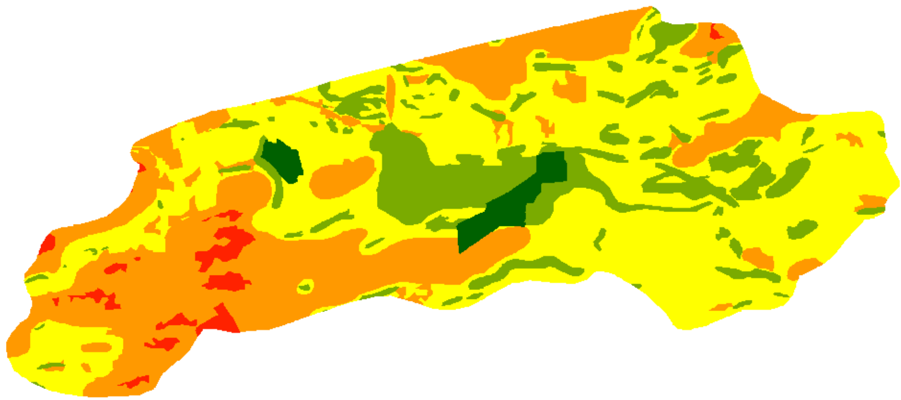
Pilots karst areas in Rockingham (Ireland) (Cell size: 10 m, Total area: 15 km²)

COP input data specification

Factor	Title of dataset	Input factor dataset file	Subfactor	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
C	Concentration of flow	GEWP7_ROC_C.tif	Scenario 1	Preliminary version	GSI National Karst database including sinking stream buffer Digital Terrain Model at 10 m x 10 m resolution (EPA / GSI) CORINE land cover data	Reclassified distances to swallow holes and sinking streams for Irish karst pilot and Irish situation. Buffering of same with new buffer classifications. The DTM was then created into a slope raster file and assigned appropriate values. Vegetation was classified based on forestry or grassland.	The lowest values are at the influent karst landforms and the values get progressively greater with greater distance from the landform. The higher the slope value and the lower the vegetation cover within the catchment to the influent landforms the lower the number, also, due to increased runoff to landform
			Scenario 2	Final version	Digital Terrain Model at 10 m x 10 m resolution (EPA / GSI) CORINE land cover data GSI National Aquifer Map GSI National Vulnerability Map FIPS-IFS Teagasc Soil Map FIPS-IFS Teagasc Subsoil Map	Classified aquifer based on the presence or absence of karst features, presence and permeability of overlying, vegetation cover type and slope values	In this case the lower the slope value and greater the vegetation cover the lower the number as more recharge is thought to be able to infiltrate. Aquifers with developed karst and no overlying layers are assigned the lowest value and aquifers with no karst and impermeable overlying layers get assigned the highest values
O	Overlying layers	GEWP7_ROC_O.tif	O_S - Soil	Final version	FIPS-IFS Teagasc Soil Map	Classification of Os values was based on soil texture, permeability and whether that soil is wet or dry. Thickness of each layer was assigned based on actual values	The soils are generally very thin (or absent) in the pilot area and are mainly composed of loams. Areas of heavier soil were classified as clayey
			O_L - Lithology	Final version	GSI National Vulnerability Map (National DTB map and National subsoil permeability map) FIPS-IFS Teagasc Subsoil Map GSI National Aquifer Map Rockingham depth to water table map	This was divided into two lithologies; the thickness and lithology of the subsoil and the thickness and lithology of the unsaturated bedrock aquifer and values were calculated for each layer	The lowest values correspond to areas of karst aquifer with no overlying subsoil and the water table is at or near the surface. The highest values are for non-karst rocks overlain by thick impermeable subsoils with a deep water table. The biggest influencing factor here was the presence and thickness of clay subsoil
P	Precipitation	GEWP7_ROC_P.tif	P_Q - Precipitation quantity	Final version	Met Éireann's 1971-2000 rainfall dataset	Annual average precipitation values used across the study area were classified into Pq values	Annual average precipitation is fairly uniform across the pilot area and was assigned a value of 0.2
			P_I - Temporal distribution	Final version	Met Éireann's 1971-2000 rainfall dataset, Annual average no of rainy days value	The annual average number of rainy days was calculated from the adjacent Met Eireann station and the precipitation quantity was divided by this number.	The average number of rainy days for this pilot is 225, which results in a low intensity value for precipitation and an overall low reduction of protection 'P' score overall

Pilot area Rockingham (Ireland) (Cell size: 10 m, Total area: 15 km²)
DRASTIC input data specification





C: Concentration of flow Reduction of protection	**O: Overlying layers** Protection value

Very High
High
Moderate
Low
Very low

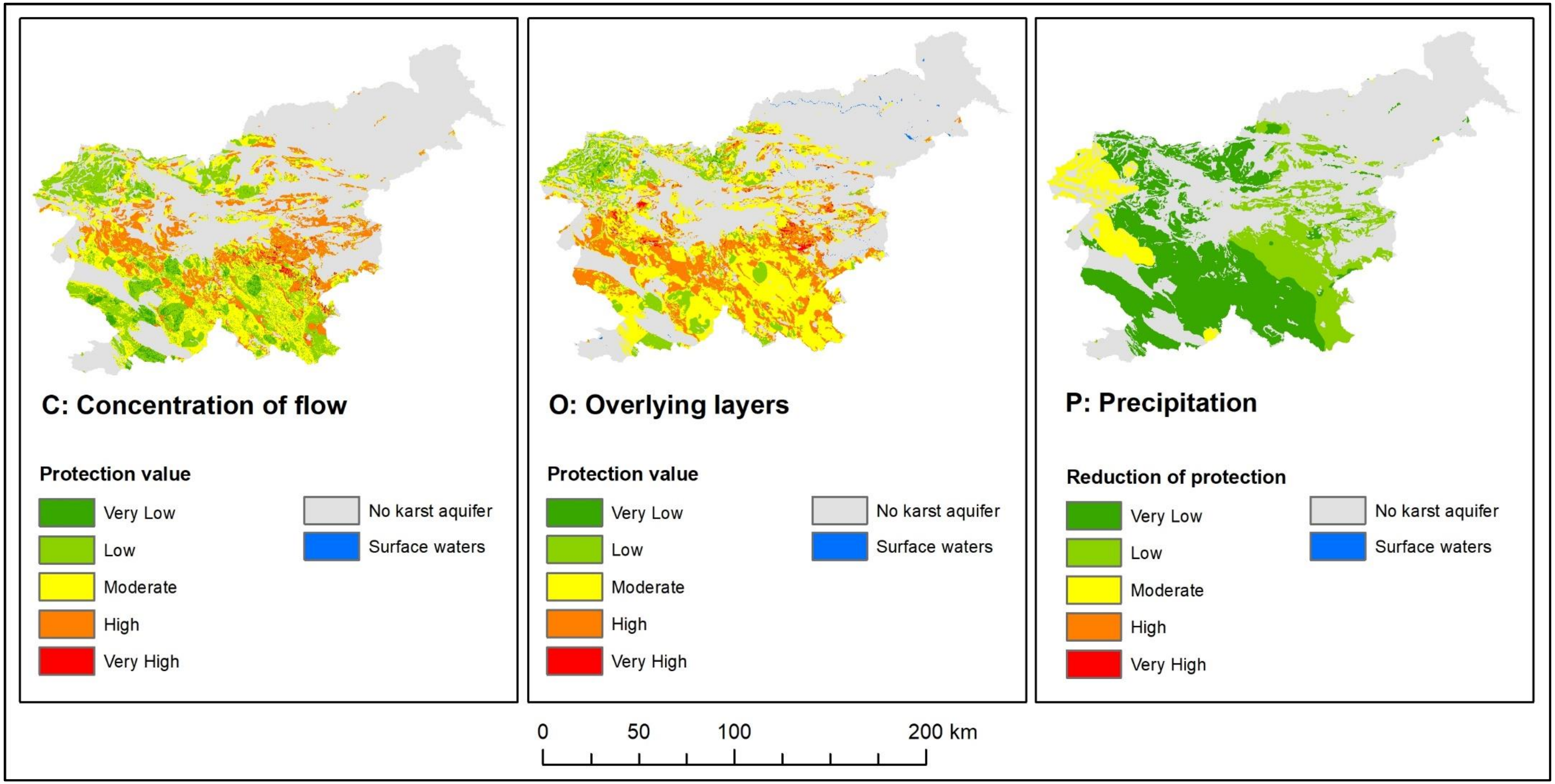
0 1 2 4 Kilometers
N

Pilots karst areas in Slovenia – GeoZS (Cell size: 100 m, Total area: 9,399 km²)

COP input data specification

Factor	Title of dataset	Input factor dataset file	Subfactor	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
C	Concentration on flow	GEWP7_SLO_C.tif	Scenario 1	Final version	Digital Elevation Model (DEM) at 12.5 x 12.5 m cell size. Corine Land Cover of Slovenia. Cave inventory of Slovenia (DZRJL). Swallow holes inventory (1:5,000) (DRSV, GeoZS).	Automatic calculation of the distance to the swallow holes and sinking streams, recharge areas and assignment of values. Slope calculation, classification of the vegetation distribution map and assignment of the corresponding COP method values taking into account both parameters.	-
			Scenario 2	Final version	Digital Elevation Model (DEM) at 12.5 x 12.5 m cell size (GURS). Corine Land Cover of Slovenia (ARSO). Hydrogeological map (IAH) of Slovenia and Hydrogeological map (LAWA) of Slovenia (1:250,000)	Assignment of the values for the karstified areas taking into account the presence and intensity of karst features. Assignment of inverted values for vegetation and slope.	The vegetation cover is considered high when more than 30% of the surface is covered.
O	Overlying layers	GEWP7_SLO_O.tif	O_S - Soil	Final version	Pedological Map of Slovenia at 1:250,000 (MKGP) Pedological profiles in Slovenia (MKGP) Litho-geochemical map of Slovenia at 1:250,000 (GeoZS)	Classification of different types of soil depending on the proportion of clay and sand. Interpolation of soil thickness from pedological profiles. From intersection of soil thickness and soil classification, Os values were assigned.	The values “High” correspond to classic karst with soil thickness between 50 and 100 cm, while the “moderate” values correspond to high mountains where soil layers are absent or at least very shallow ones.
			O_L - Lithology	Final version	Geological map of Slovenia at 1:250,000 (GeoZS) Litho-geochemical map of Slovenia at 1:250,000 (GeoZS)	Determination of Lithology and fracturation values of geological layers and thickness. In the intersection output O_L values were assigned.	-
P	Precipitation	GEWP7_SLO_P.tif	P_Q - Precipitation quantity	Final version	Annual precipitation map of Slovenia (ARSO).	Reclassification of the precipitation values into the P_Q subfactor values, taking into account the average rainfall in the wet years (2010).	Precipitation series between 1980 and 2010 have been used to extract the mean annual precipitation in the wet year (2010).
			P_I - Temporal distribution	Final version	Meteorological stations data (number of rainy days in Slovenia). Annual precipitation of Slovenia. (ARSO)	Interpolation of point data of number of rainy days above 1 mm for wet years. Calculation of temporal distribution from precipitation and rainy days for wet years (2010).	For the estimation of the rainy days, meteorological historical series for 2010 has been used.

Pilots karst areas in Slovenia – GeoZS (Cell size: 100 m, Total area: 9,399 km^2)
Spatial distribution of COP input data



Pilot karst areas in Upper Guadiana Basin (Spain) – IGME (Cell size: 100 m, Total area: 10,300 km^2)

COP input data specification

Factor	Title of dataset	Input factor dataset file	Subfactor	Status / version (Nov 2020)	Data source	Methodology	Remark (optional)
C	Concentration on flow	GEWP7_UGB _C.tif	-	-	-	-	There are no catchment areas to swallow holes in these aquifers.
			Scenario 2	Final version	Vegetation from CORINE LAND COVER and slope from Digital Terrain Model (100 x 100 m cell size (IGN)) Karstic features from previous research works & fieldwork (from a previous work for the Spanish Ministry) and Lithostratigraphic map 1:200,000.	Assignment of the values for the karstic features, vegetation and slope according to COP methodology.	The vegetation cover is considered high when more than 30 % of the surface is covered. Other variables such as the time period without crops or the continuity of the crops were considered to determine this factor.
O	Overlying layers	GEWP7_UGB _O.tif	O_S - Soil	Final version	Soil Map of Spain at 1:1,000,000 (IGN)	Assignment of the Os values after classify the different types of soil according to the COP methodology.	-
			O_L - Lithology	Final version	Lithostratigraphic map of Spain at 1:200,000 (IGME)	Classification of each lithology according to COP methodology and determination of thickness of vadose zone from 3D flow model.	-
P	Precipitation	GEWP7_UGB _P.tif	P_Q - Precipitation quantity	Final version	Precipitation data from SPAIN02 in the grid within the Upper Guadiana Basin (mean rainfall taking into account data above 0.5 mm/day).	Reclassification of the precipitation values into the P_Q subfactor values, taking into account the average rainfall in the wet years.	Precipitation series from SPAIN02 between 1974 and 2015 have been used to extract the mean annual precipitation in the wet years.
			P_I - Temporal distribution	Final version	Precipitation data from SPAIN02 (number of rainy days in the grid within the Upper Guadiana Basin).	Counting of the number of rainy days above 0.5 mm for each cell in the SPAIN02 grid.	For the estimation of the rainy days per year, meteorological historical series between 1974 and 2015 from SPAIN02 has been analysed.

Pilot karst areas in Upper Guadiana Basin (Spain) – IGME (Cell size: 100 m, Total area: 10,300 km^2)

Spatial distribution of COP input data