



Scuola Superiore
Sant'Anna



SMAQua
SMart ICT tools per l'utilizzo
efficiente dell'AcQua



2nd International LIFE REWAT Summer School

*Digital water management and water-related
agroecosystem services: geostatistics, hydroinformatics and
groundwater flow numerical modelling*

September 9th—20th, 2019
Scuola Superiore Sant'Anna
Pisa, Italy



2nd FREEWAT International Workshop

Free and open source tool for water quantity and quality management

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EIP Water Action Group
Pooling resources – Innovating water



FREEWAT
Free and Open Source Software Tools for Water Resource Management
EU HORIZON 2020 Project

 **ict4water.eu**



AkvaGIS

Free and open source tool for water quantity and quality management

Rotman Criollo

2nd International LIFE REWAT Summer School
2nd FREEWAT International Workshop

SEPTEMBER 17th 2019. Pisa



FREEWAT
Free and Open Source Software Tools for Water Resource Management
EU HORIZON 2020 Project

Greatest resource of water

Atmosphere	Vegetation	Surface water	Soil water
12,000 km ³	1,000 km ³	100,000 km ³	16,000 km ³

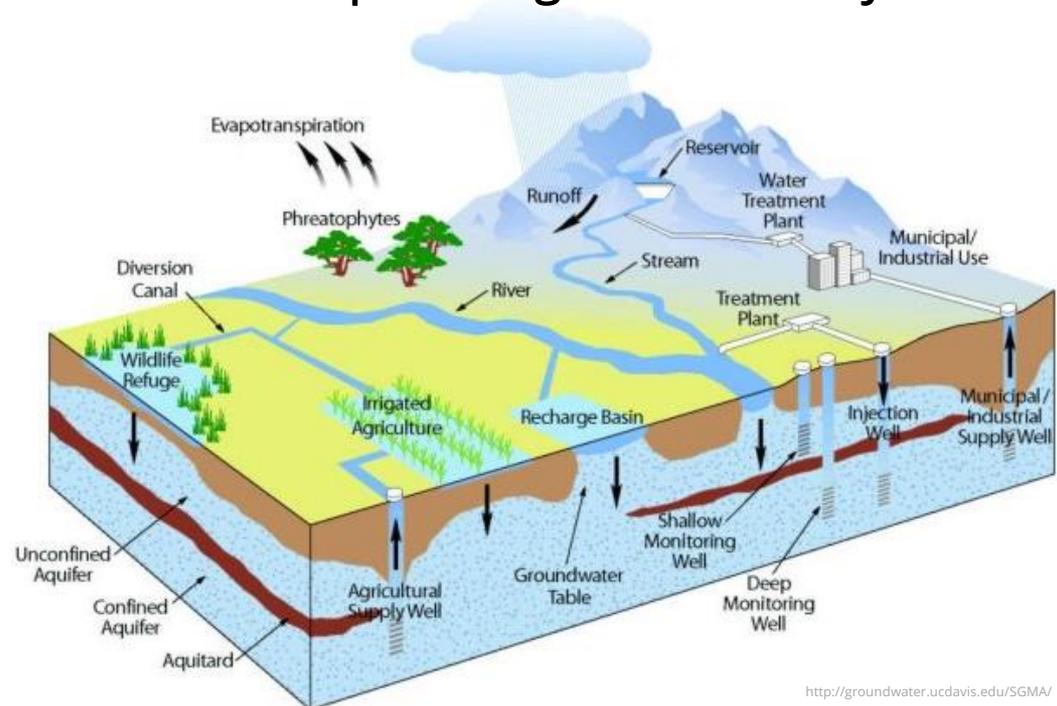


Modern groundwater
347,180 km³

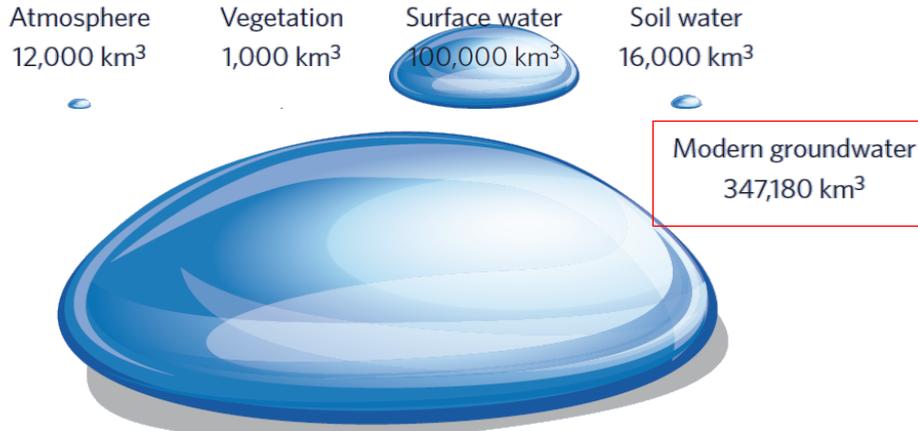
Gleeson et al., 2016. Nature Geosc.

Anthropic Actions →

→ Impacts in groundwater systems!!

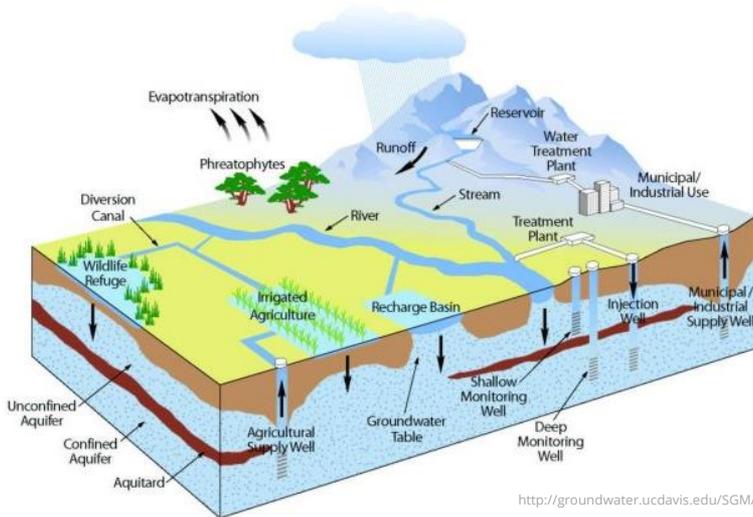


Greatest resource of water → Complex System



Gleeson et al., 2016. Nature Geosc.

+ Anthropogenic Actions → Complexity ↑



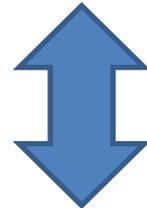
<http://groundwater.ucdavis.edu/SGMA/>



Ensure Groundwater Sustainability



Conceptual Model



Geology

Aquifer Geometry

Hydraulic Parameters

Heads

Concentrations

Time
&
Space
Dependant

Monitoring



<https://www.sontek.com>

Design Mon. Network

Instrumentation

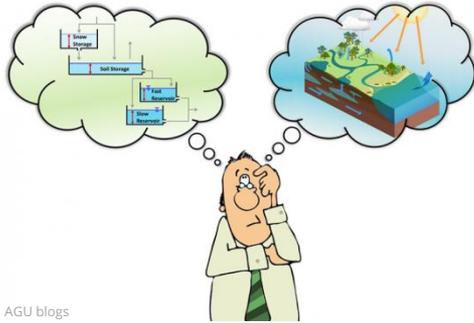
Measurements

Data Management

Data "Uses"

Monitoring
Process
Management

Conceptual Model



AGU blogs

Time
&
Space
Dependant



Monitoring



<https://www.sontek.com>

Monitoring
Process
Management



Control Devices



Handle Data



Share and Communicate Information



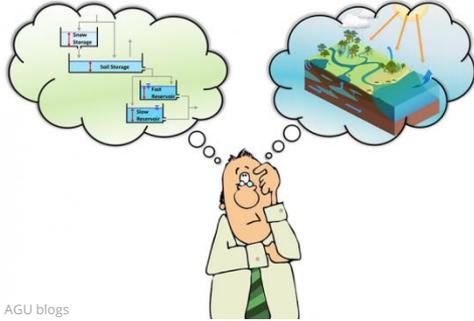
Find Smart Information



Simulate Events (App)



Conceptual Model



AGU blogs

Time & Space Dependant



Monitoring



<https://www.sontek.com>

Monitoring Process Management



Control Devices



Handle Data



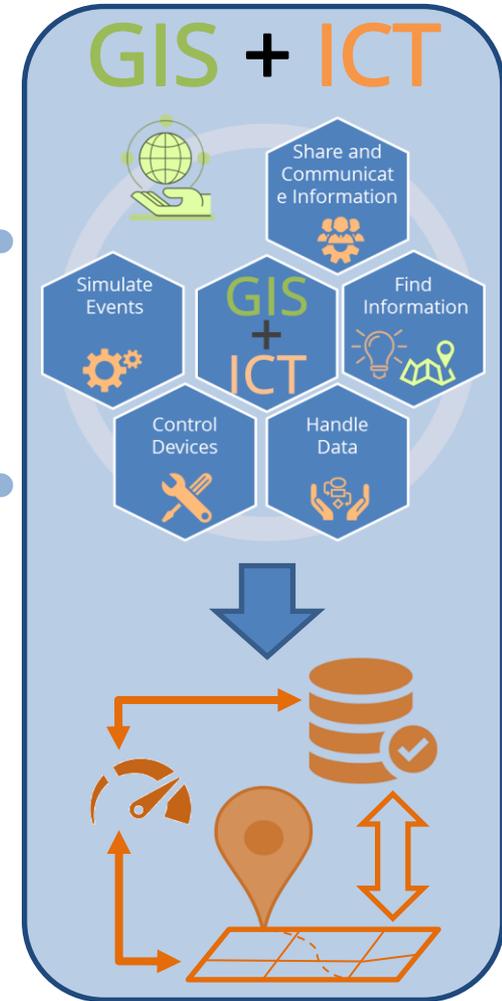
Share and Communicate Information



Find Smart Information



Simulate Events (App)



Introduction & Background

Reference	Spatial DataBase	ICT GIS-based tools (geology, hydrochemistry, head levels, ...)	ICT GIS-based tools for analysis of Hydraulic Parameters
Radu et al., 2001	✓	✓	-
Cabalska et al., 2005	✓	✓	-
Strassberg, 2005, 2011	✓	✓	ArchHydro
De Dreuzy et al., 2006	✓	-	-
Yang and Lin, 2010	-	✓	uWater-PA
Chesnaux et al., 2011	✓	-	-
Wodja et al., 2013	✓	-	-
Velasco, 2013	✓	✓	HEROS/QUIMET
Alcaraz, 2016	-	✓	MetroGeotherTools

(*) Only This method disregarding other aquifer characteristics (e.g., boundaries, anisotropy, well losses...)

Introduction & Background

Reference	ICT GIS-based tools	Numerical Model coupled in the same GIS platform	Open source
Radu et al., 2001	✓	-	-
Cabalska et al., 2005	✓	-	-
Strassberg, 2005	✓	-	-
De Dreuzy et al., 2006	-	-	-
Yang and Lin, 2010	✓	-	-
Chesnaux et al., 2011	-	-	-
Wodja et al., 2013	-	-	-
Velasco, 2013	✓	-	-
Alcaraz, 2016	✓	-	-
Wang et al., 2016	✓	✓ GIS-Groundwater (ESRI)	-





New developments required

To **ADAPT** ICT tools to specific institutions and / or third - party
databases

To ensure data **VALIDATION**

To **ANALYSE** further hydrogeological processes and obtain aquifer
parameters from field measurements

To **ENABLE** the groundwater community to use these platforms

AkvaGIS: An open source tool for water management

Motivation



- ICT GIS-based tools to **boost the application of Water related Directives;**



- **Share** free and open source tools, numerically based, GIS integrated to perform spatial and temporal analysis on water quantity and quality issues; use effectively data provided by the extensive monitoring required by the WD;



- Including **participatory approach** earlier than the results discussion;



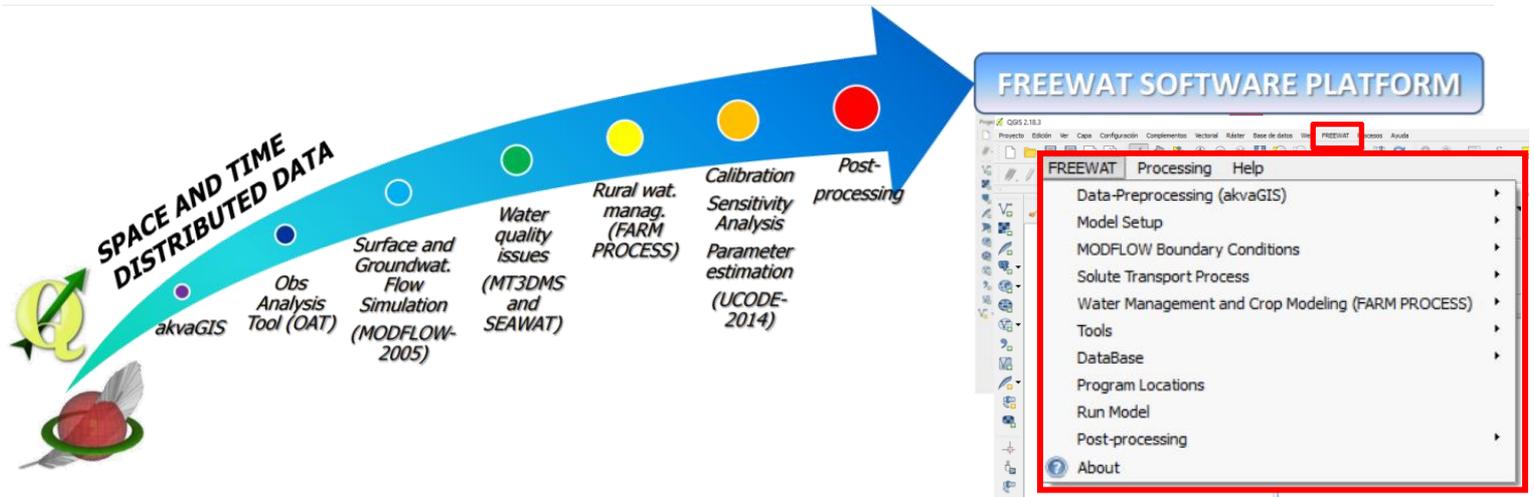
- **Training** technical staff at authorities and private companies on the use of state-of-the-art innovative software for water management; capacity building within the EU water sector

AkvaGIS: An open source tool for water management

Motivation. H2020 FREEWAT platform



FREEWAT
Free and Open Source Software Tools for Water Resource Management
EU HORIZON 2020 Project



AkvaGIS: An open source tool for water management

Objectives

- It is essential **open source** tools to fulfil the needs for:



- **Managing** and **visualizing** hydrogeological and hydrochemical **standardized data** with different temporal and spatial scales to facilitate development of the environmental conceptual model



- **Preparing** hydrogeological **input files** for any groundwater **numerical model** in all of the available formats in QGIS

- **Simplifying** the **application** of water directives

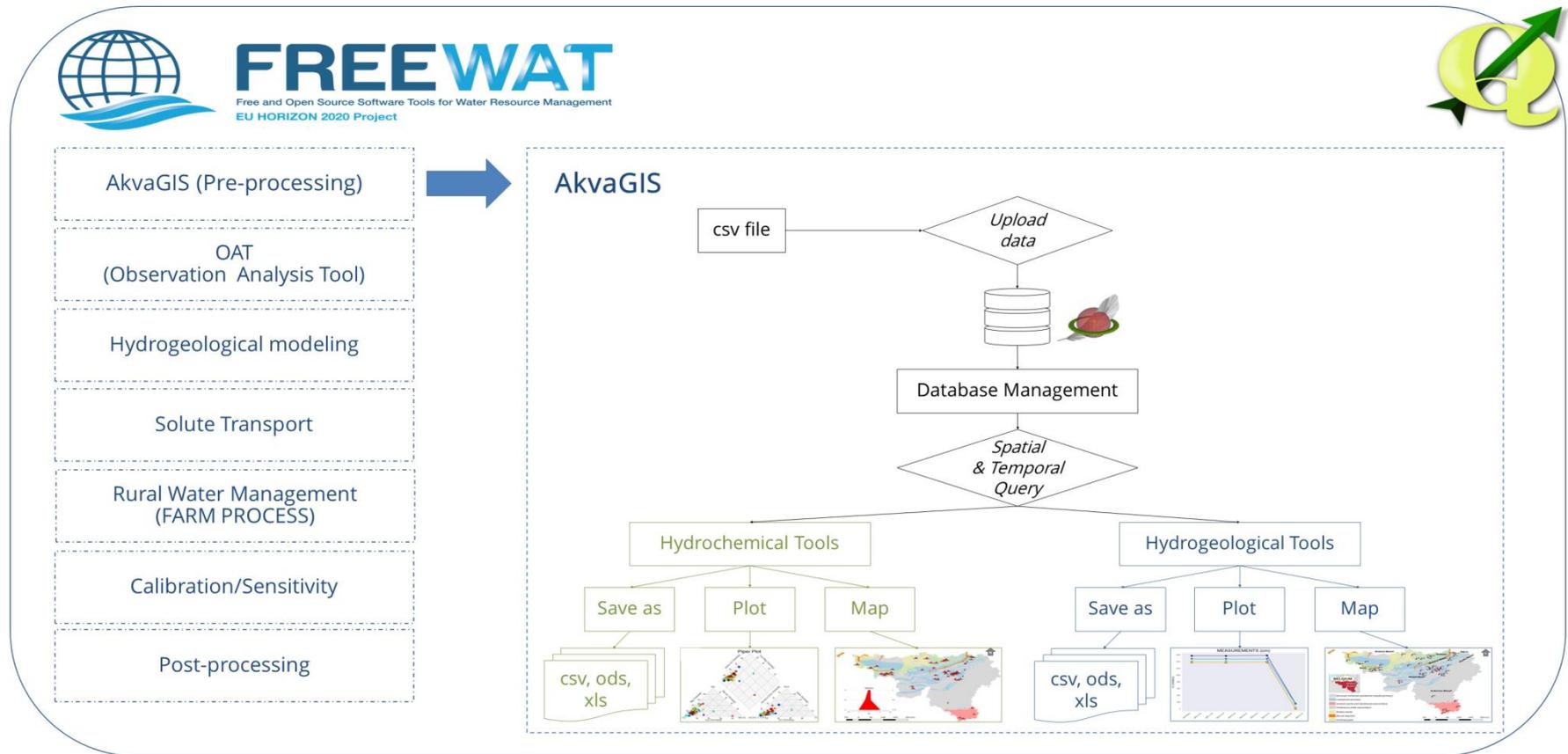


- **Capacity building** within the EU water sector (training technical staff at authorities and private companies) including **participatory approach** before starts discussion of results obtained (more than 1200 people)



AkvaGIS: An open source tool for water management

AkvaGIS is a novel, free and open source module included in the FREEWAT plugin for QGIS that supplies a standardised and easy-to-use workflow for the storage, management, visualisation and analysis of hydrochemical and hydrogeological data



AkvaGIS: An open source tool for water management

Commands developed cover a wide range of methodologies for querying, interpreting, and comparing groundwater quantity and quality data and facilitate the pre-processing analysis for being used in the realization of groundwater modelling

The screenshot displays the AkvaGIS software interface. The main menu is open, showing the following options:

- Database
- Web
- FREEWAT**
- Processing
- Help

The 'Data-Preprocessing (akvaGIS)' sub-menu is expanded, listing the following tools:

- Model Setup
- MODFLOW Boundary Conditions
- Solute Transport Process
- Water Management and Crop Modeling (FARM PROCESS)
- Calibration/Sensitivity
- Tools
- DataBase
- Program Locations
- Run Model
- Post-processing
- OAT
- About

The 'Data-Preprocessing (akvaGIS)' sub-menu is further expanded, showing the following tools:

- Create AkvaGIS Database
- Open AkvaGIS Database
- Close AkvaGIS Database
- Manage Hydrochemical Data
- Hydrochemical Spatial Query
- Piper Plot
- SAR Plot
- SBD Plot
- Stiff Plot
- Hydrochemical Parameters Time Plot
- Ionic Balance Report
- Chemical Parameter Map
- Parameter Normative Map
- Stiff Diagram Map
- EasyQuim Export
- ExcelMix Export
- StatQuimet Export
- Hydrogeological Spatial Query
- Hydrogeological Parameters Time Plot
- Hydrogeological Parameter Map
- Hydrogeological Units Map

The tools are categorized into three groups:

- DATABASE MANAGEMENT** (top group, black box): Create AkvaGIS Database, Open AkvaGIS Database, Close AkvaGIS Database.
- HYDROCHEMICAL ANALYSIS TOOLS** (middle group, blue box): Manage Hydrochemical Data, Hydrochemical Spatial Query, Piper Plot, SAR Plot, SBD Plot, Stiff Plot, Hydrochemical Parameters Time Plot, Ionic Balance Report, Chemical Parameter Map, Parameter Normative Map, Stiff Diagram Map, EasyQuim Export, ExcelMix Export, StatQuimet Export.
- HYDROGEOLOGICAL ANALYSIS TOOLS** (bottom group, green box): Hydrogeological Spatial Query, Hydrogeological Parameters Time Plot, Hydrogeological Parameter Map, Hydrogeological Units Map.

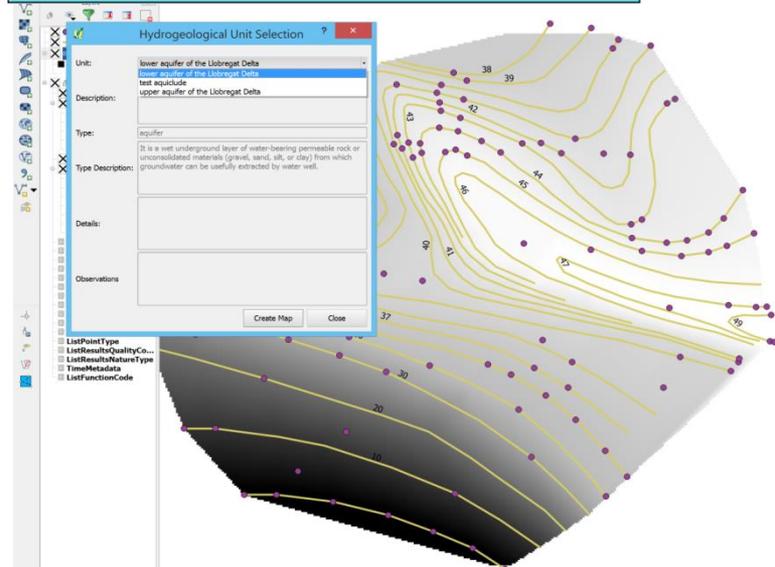
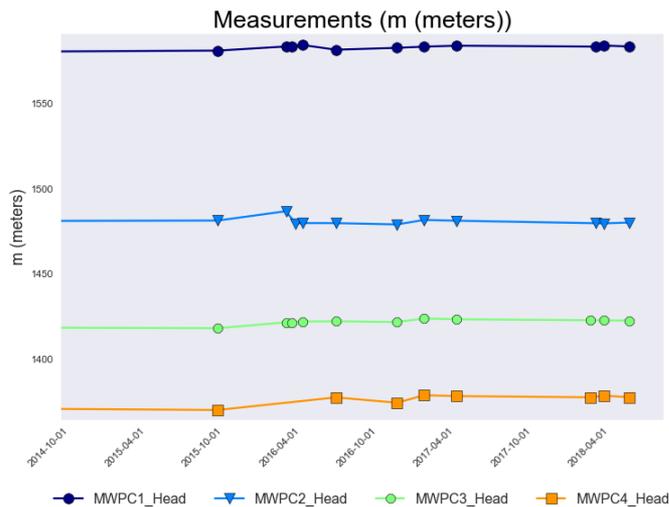
AkvaGIS: An open source tool for water management

Hydrogeological data management

Active	Point	Observation	Measurement Date	Parameter	Value	Unit	Is Calculated
<input checked="" type="checkbox"/>	P10	headObservation_P10	2003-08-03 00:00:00.000	Head	19.5	cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	headObservation_P10	2003-08-04 00:00:00.000	Head	18	cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	headObservation_P10	2009-07-29 03:38:33.000	Head	20	cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	headObservation_P10	2013-07-07 03:37:09.000	Head	7000	cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P11	headObservation_P11	2004-08-05 00:00:00.000	Head	10	cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P11	headObservation_P11	2005-08-02 00:00:00.000	Head	20	cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P11	headObservation_P11	2010-07-29 03:37:02.000	Head	23	cm	<input type="checkbox"/>

Unit: aquicludeTest
Description:
Type: aquiclude
Type Description: It is a HydrogeologicalUnit that due to its low permeability can act as a barrier to groundwater flow and as such often confines aquifers or aquifer systems.
Details:
Observations

Finished creating the requested map.
The following map has been generated:
- aquicludeTest
OK



AkvaGIS: An open source tool for water management

Hydrochemical data management

Active	Point	Sample	Sample Date	Campaign	Measurement Date	Parameter	Value	Unit	Is Calculated
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	Alkalinity (TAC)	329	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	EC	1388	uS/cm	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	bicarbonate	401.38	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	calcium	134.8	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	chloride	193	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	magnesium	28	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	nitrites	16.7	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	pH	7.21	°C	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	potassium	12.2	mg/l	<input type="checkbox"/>
<input checked="" type="checkbox"/>	P10	P10_CUP0610	2006-10-25 00:00:00.000	Campaign9	2006-10-25 00:00:00.000	sodium	143.8	mg/l	<input type="checkbox"/>

SAR Plot

Sodium Adsorption Ratio (SAR)

Electric Conductivity (uS/cm)

very high(1)
high(1)
medium(1)
low(1)

low(1) medium(2) high(2) very high(2)

● P10_CUP0610
● P11_CAG0110-005
● P12_CUP0612
● P2_CPR1011
● P2_CCL0301
● P3_CUP0610
● P4_CPR1011
● P5_CCL0301

TimePlot Results

ggis-bin

Borders: top, bottom, left, right

Spacings: hspace, vspace

TimePlot

Measurements (mg/l)

Plot configuration

General Plot Settings

Plot size: X (pixels): 860, Y (pixels): 720

Font type: Arial, Font color: Red, Font size: 24.0

Marker: filled set, Colorset: jet, Size: 10.5, Edge width: 0.5

Number of columns: 4, Marker scale: 1.0, Font size: 14.00

Normative Map Measurements

Measurements Query

Normative Selection

Normative to apply: EXDMA

Responsible: EXEWF

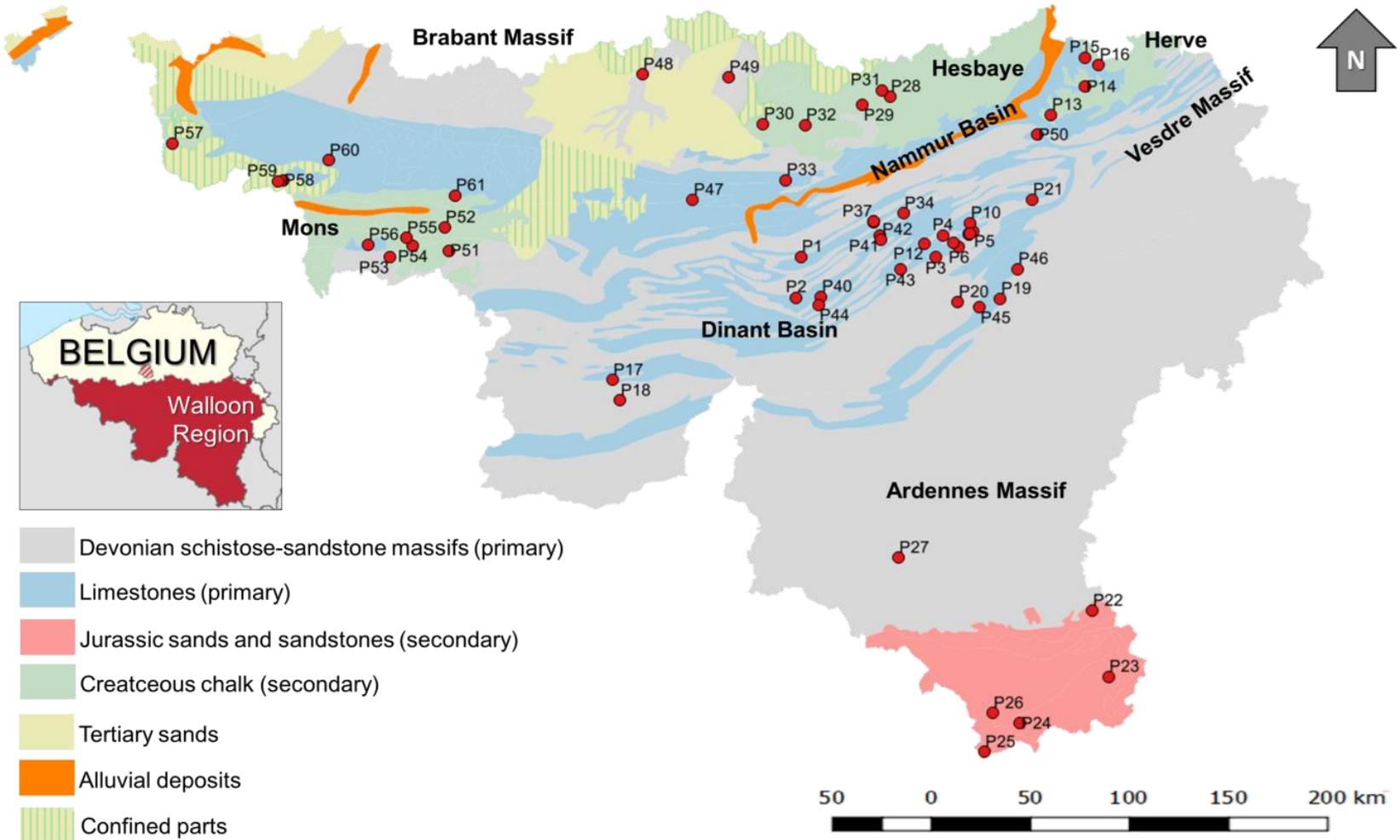
Date: 2003-2-21

Details: Examples data! Any similarities to a real data are pure, unintentional coincidence

Observations

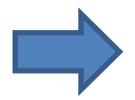
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Application. Walloon Region (Belgium)



Groundwater abstraction

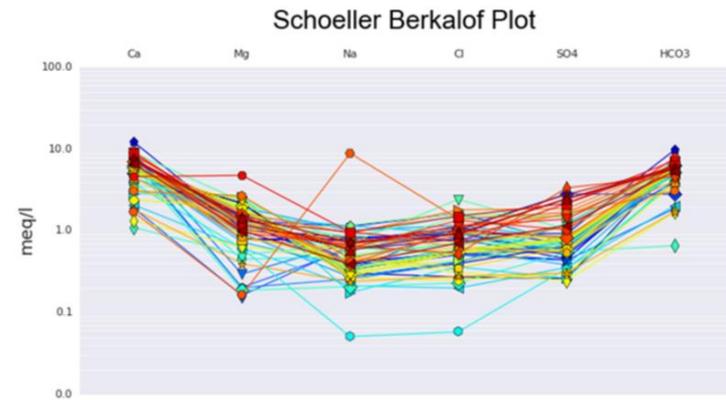
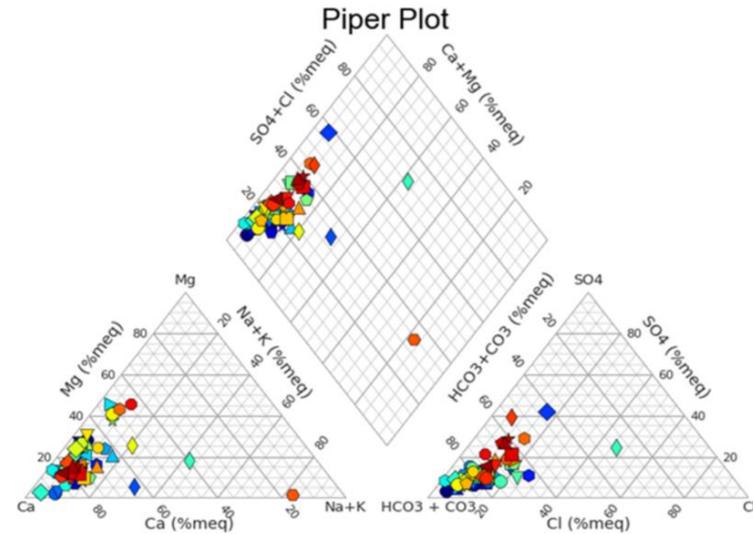
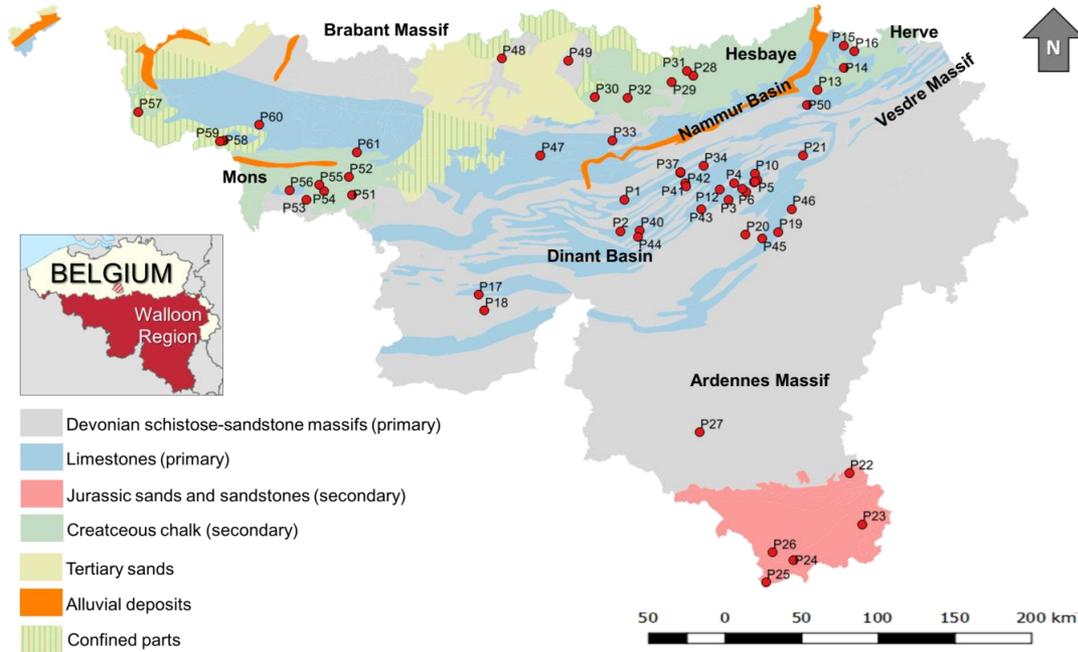
- Limestones (51%)
- Chalky formations (21%)



For water supply purposes (80% of the water volumes collected)

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Application. Walloon Region (Belgium)



Spring 2016.
64 groundwater points sampled
Ca-HCO₃ type mainly

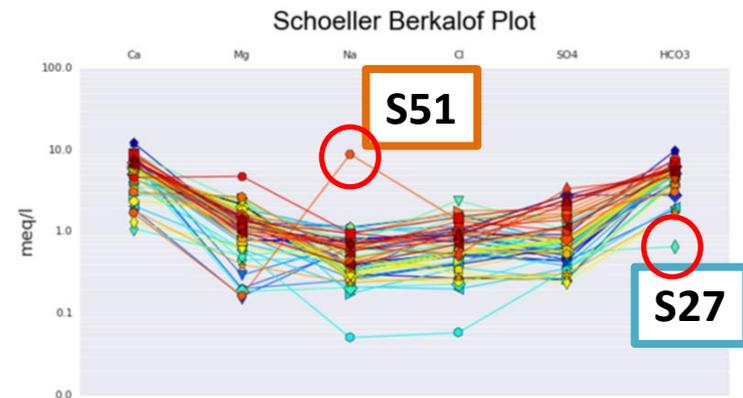
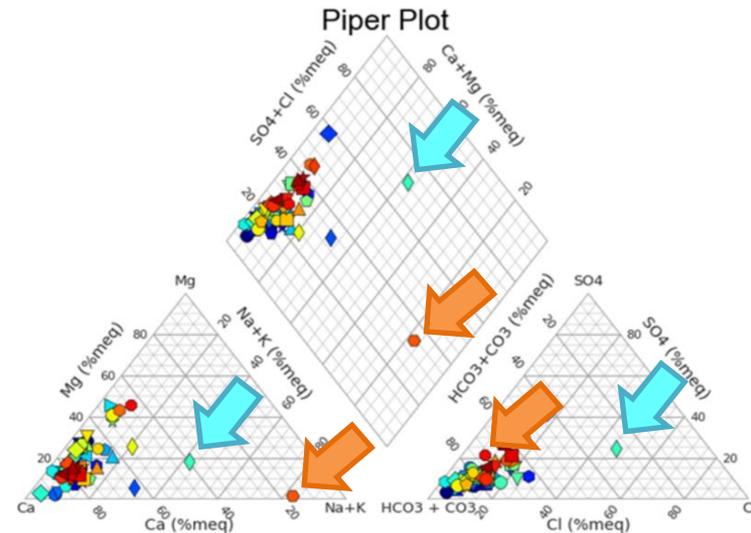
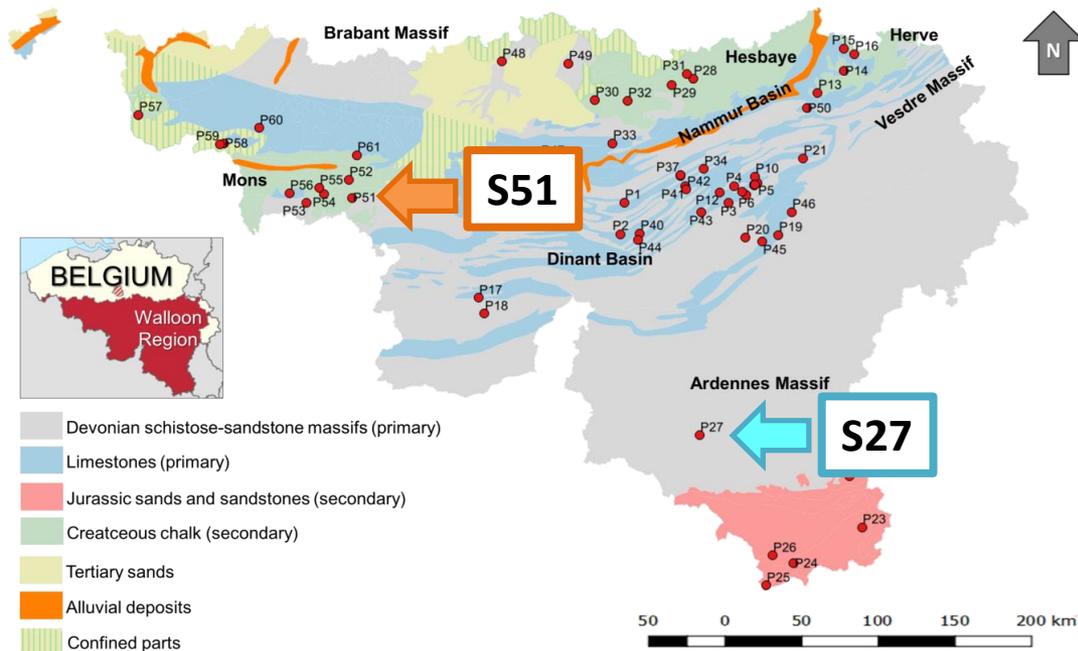
- ◆ S1
- ◆ S10
- ★ S19
- ▼ S29
- ◇ S38
- ★ S46
- ◆ S54
- ▼ S2
- ◆ S11
- ▲ S20
- S30
- ◇ S39
- ▲ S47
- ▼ S55
- ◆ S3
- ◆ S12
- ▲ S21
- S31
- ◇ S40
- ▲ S48
- ▼ S56
- ◆ S4
- ◆ S13
- ▲ S22
- S32
- ◇ S41
- ▲ S49
- S57
- ◆ S5
- ◆ S14
- ▲ S23
- ★ S33
- ▼ S42
- ◆ S50
- ◆ S58
- ★ S6
- ▼ S15
- ▲ S24
- ▲ S34
- ◇ S43
- ◆ S51
- ★ S59
- ◆ S7
- ◆ S16
- ◆ S26
- S35
- ◆ S44
- ◆ S52
- ★ S60
- ◆ S8
- ◆ S17
- ◆ S27
- ▼ S36
- ◆ S45
- ◆ S53
- ★ S61
- ◆ S9
- ◆ S18
- ◆ S28
- S37

Note.

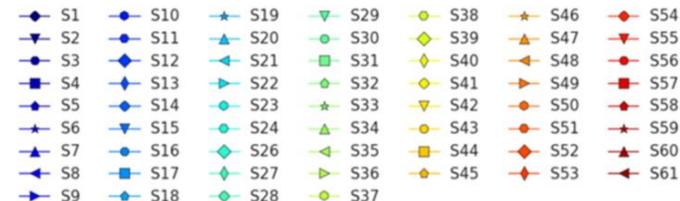
Database created for this study can be found in Criollo et al. (2019)

AkvaGIS: An open source tool for water management

Application. Walloon Region (Belgium)



Ca-HCO₃ type mainly
S51 Na-HCO₃
S27 Na-K-Cl

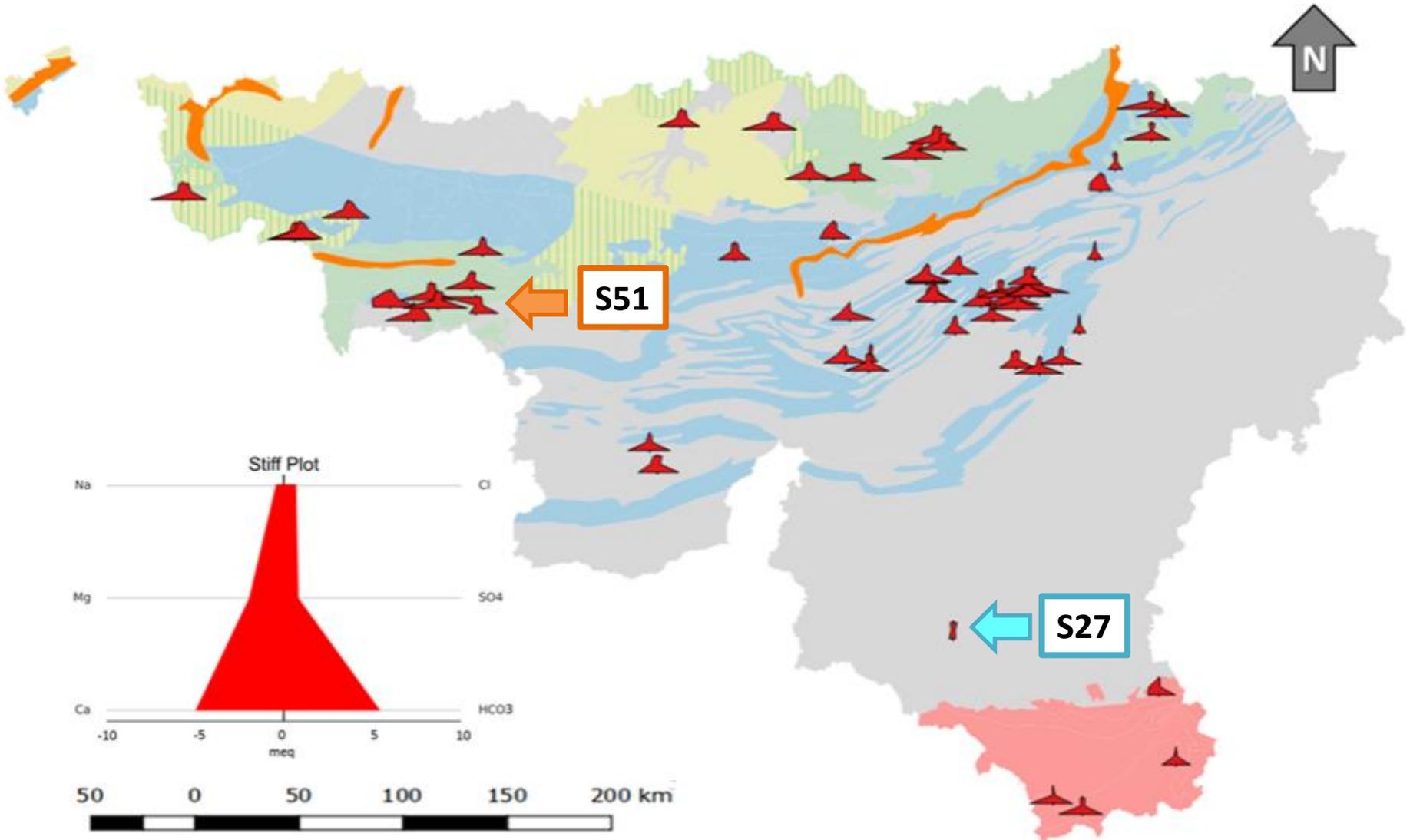


Note.

Database created for this study can be found in Criollo et al. (2019)

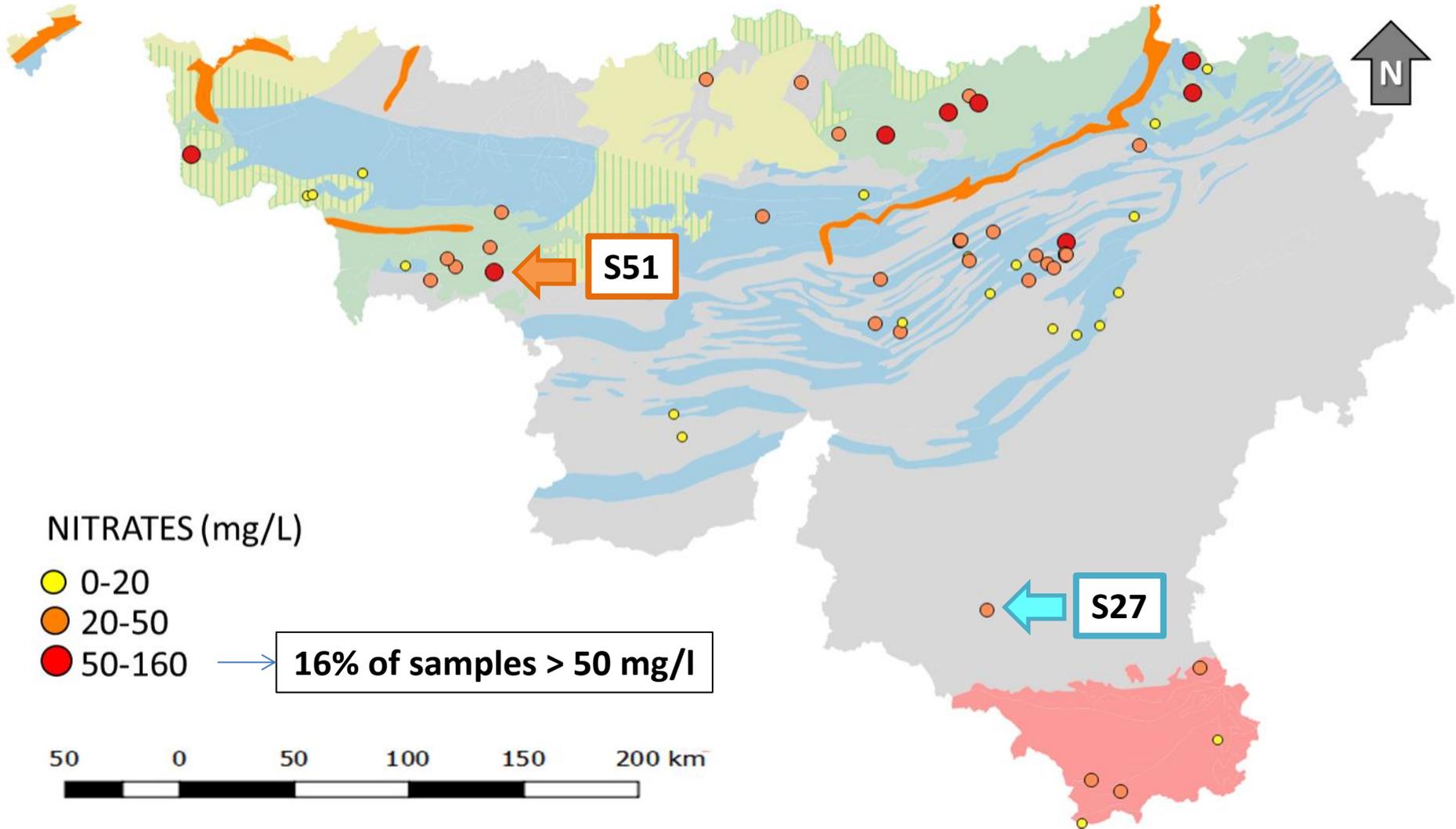
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Application. Walloon Region (Belgium)



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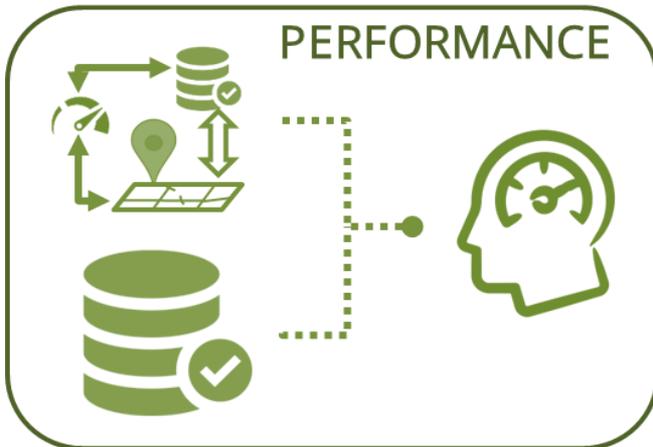
Application. Walloon Region (Belgium)



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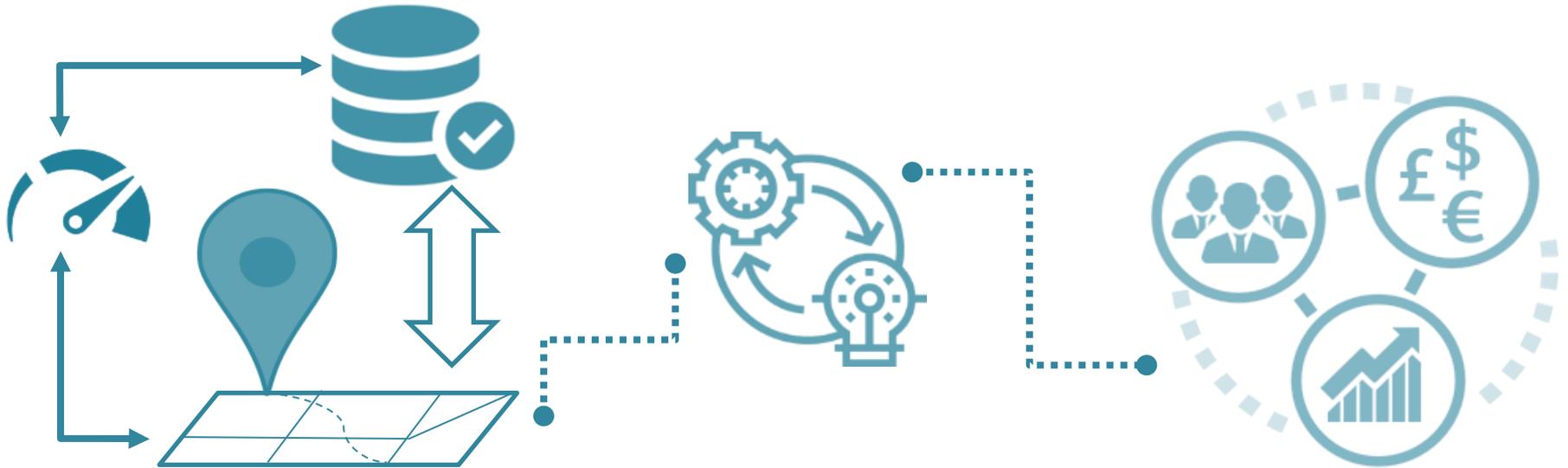
Conclusions

- **AkvaGIS** aims to endorse water management and planning by **simplifying** the **application** of **water-related directives**
- The scientific **community**, water resource authorities, and the private sector **might benefit** from using AkvaGIS
- Due to its **open-source architecture**, AkvaGIS can be **updated** and **extended** depending on the **tailored applications** by any advanced user



AkvaGIS: An open source tool for water management

- AkvaGIS is **free and open-source** → **reducing** the **costs** of commercial software and **improving** open sharing of hydrochemical and hydrogeological data and its interpretations in the **water governance process**





Thank you for your attention!

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www.idaea.csic.es

LIFE REWAT project partners



LIFE REWAT project co-financers



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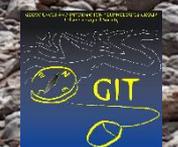


University of Applied Sciences and Arts of Southern Switzerland

SUPSI



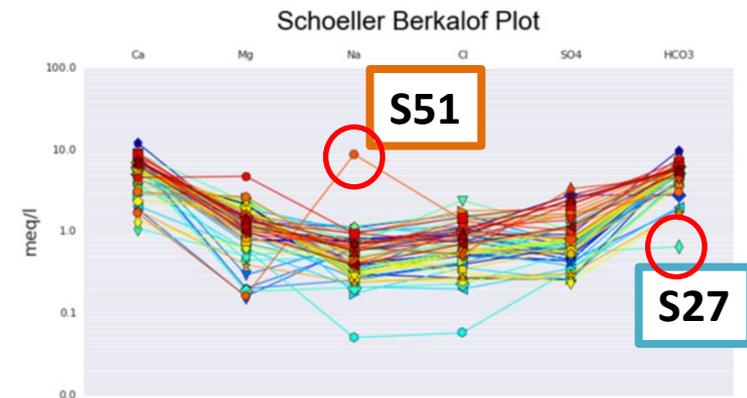
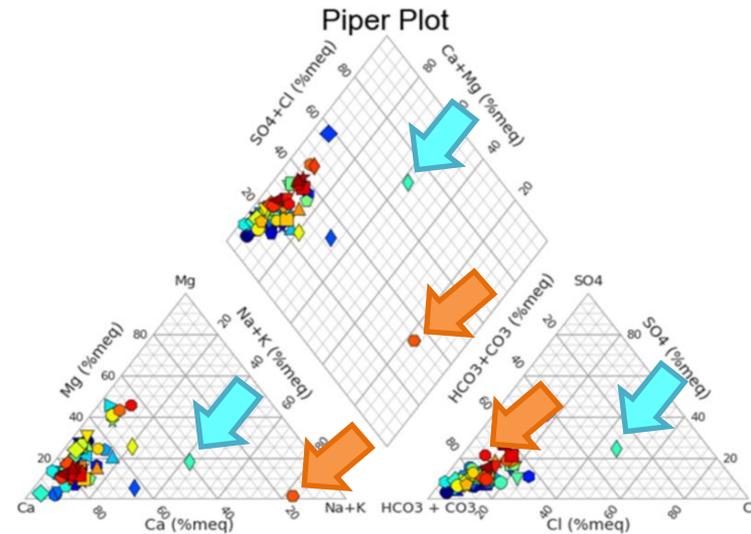
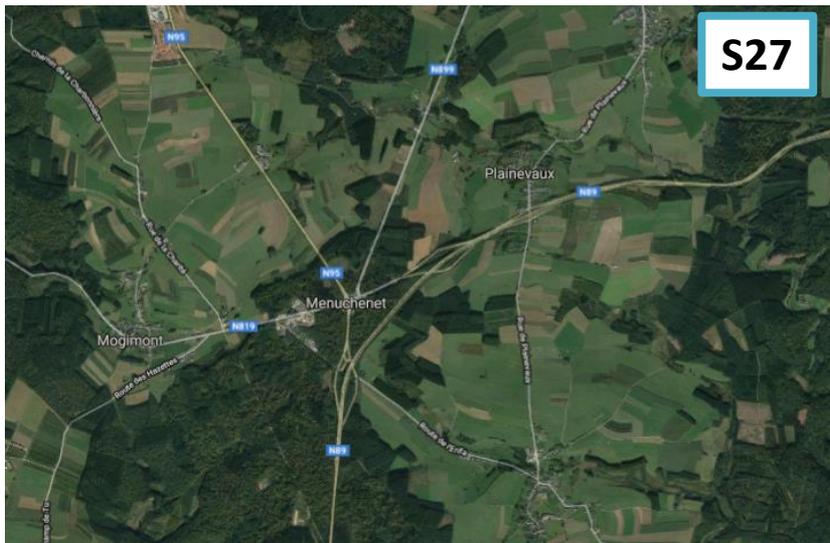
Patronage



This presentation is given within the framework of the EU LIFE REWAT project. The REWAT project has received funding from the European Union's Life Programme LIFE 14 ENV/IT/001290. This presentation reflects only the authors' views and the European Union is not liable for any use that may be made of the information contained therein.

AkvaGIS: An open source tool for water management

Application. Walloon Region (Belgium)



- | | | | | | | |
|------|-------|-------|-------|-------|-------|-------|
| ◆ S1 | ◆ S10 | ◆ S19 | ◆ S29 | ◆ S38 | ◆ S46 | ◆ S54 |
| ◆ S2 | ◆ S11 | ◆ S20 | ◆ S30 | ◆ S39 | ◆ S47 | ◆ S55 |
| ◆ S3 | ◆ S12 | ◆ S21 | ◆ S31 | ◆ S40 | ◆ S48 | ◆ S56 |
| ◆ S4 | ◆ S13 | ◆ S22 | ◆ S32 | ◆ S41 | ◆ S49 | ◆ S57 |
| ◆ S5 | ◆ S14 | ◆ S23 | ◆ S33 | ◆ S42 | ◆ S50 | ◆ S58 |
| ◆ S6 | ◆ S15 | ◆ S24 | ◆ S34 | ◆ S43 | ◆ S51 | ◆ S59 |
| ◆ S7 | ◆ S16 | ◆ S26 | ◆ S35 | ◆ S44 | ◆ S52 | ◆ S60 |
| ◆ S8 | ◆ S17 | ◆ S27 | ◆ S36 | ◆ S45 | ◆ S53 | ◆ S61 |
| ◆ S9 | ◆ S18 | ◆ S28 | ◆ S37 | | | |

Note. Database created for this study can be found in Criollo et al. (2019)