flowpath Malta 2023

14th – 16th June
National Meeting on Hydrogeology

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JUNE 14-16, 2023

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Radar precipitation data as functional input for deriving the potential volume of water available for infiltration: the pilot case of Lombardy Region.

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UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI SCIENZE DELLA TERRA "ARDITO DESIO"

Aims and research goals

The study aims to understand the **water availability** and **its distribution** in the study area as accurately as possible.

- To **correct the radar signal** in the study area using data recorded from **rain gauges**.
- To **define** the **mean annual** Potential GroundWater Recharge (**PGWR**) in the study area in the **2011-2020 period**.
- To **prove that** the use of **radar** in combination with data retrieved from rain gauges could be **a useful tool** to estimate the water resource entering the system.

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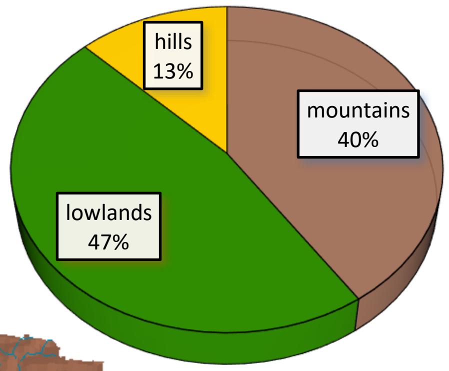
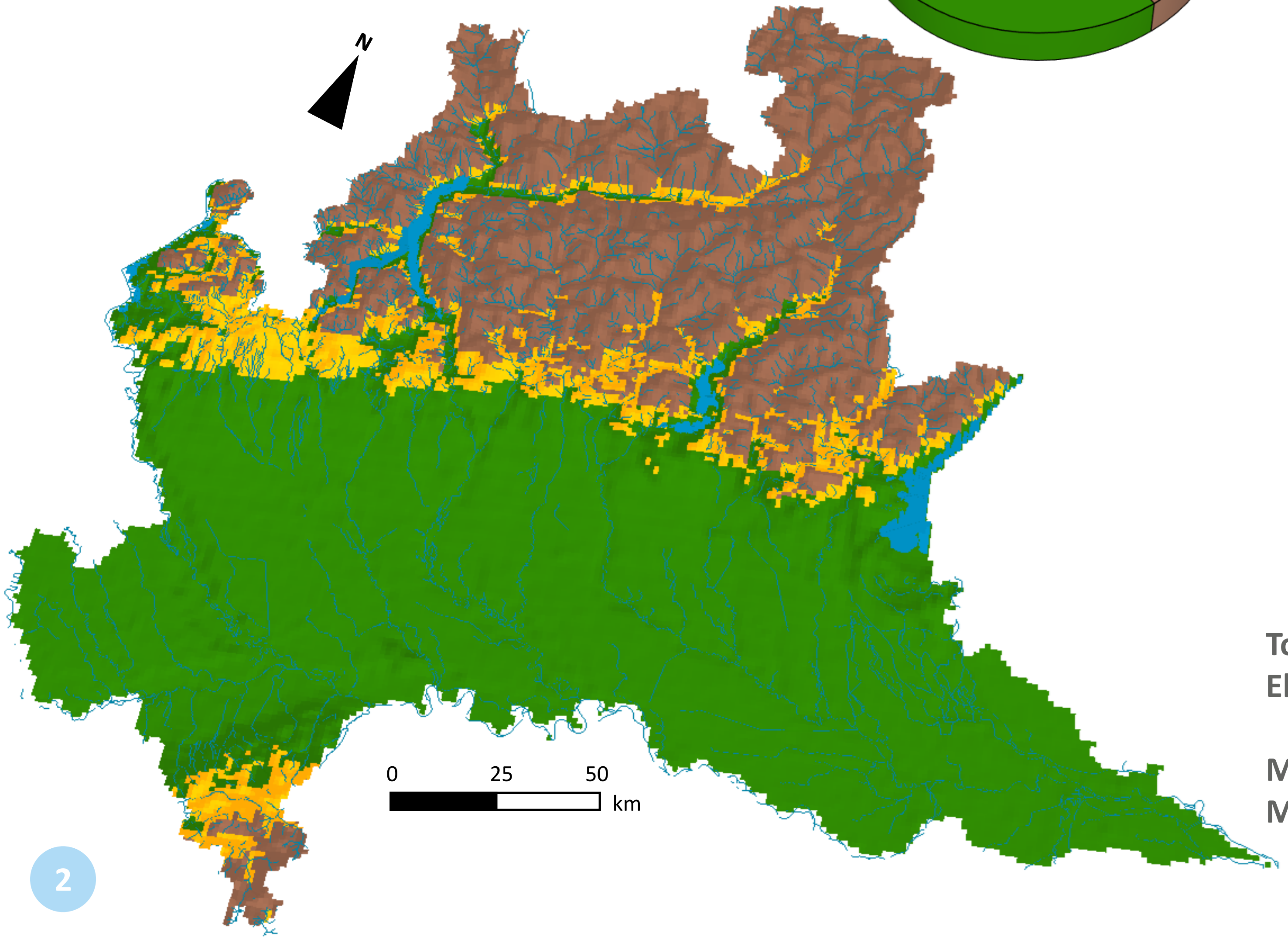
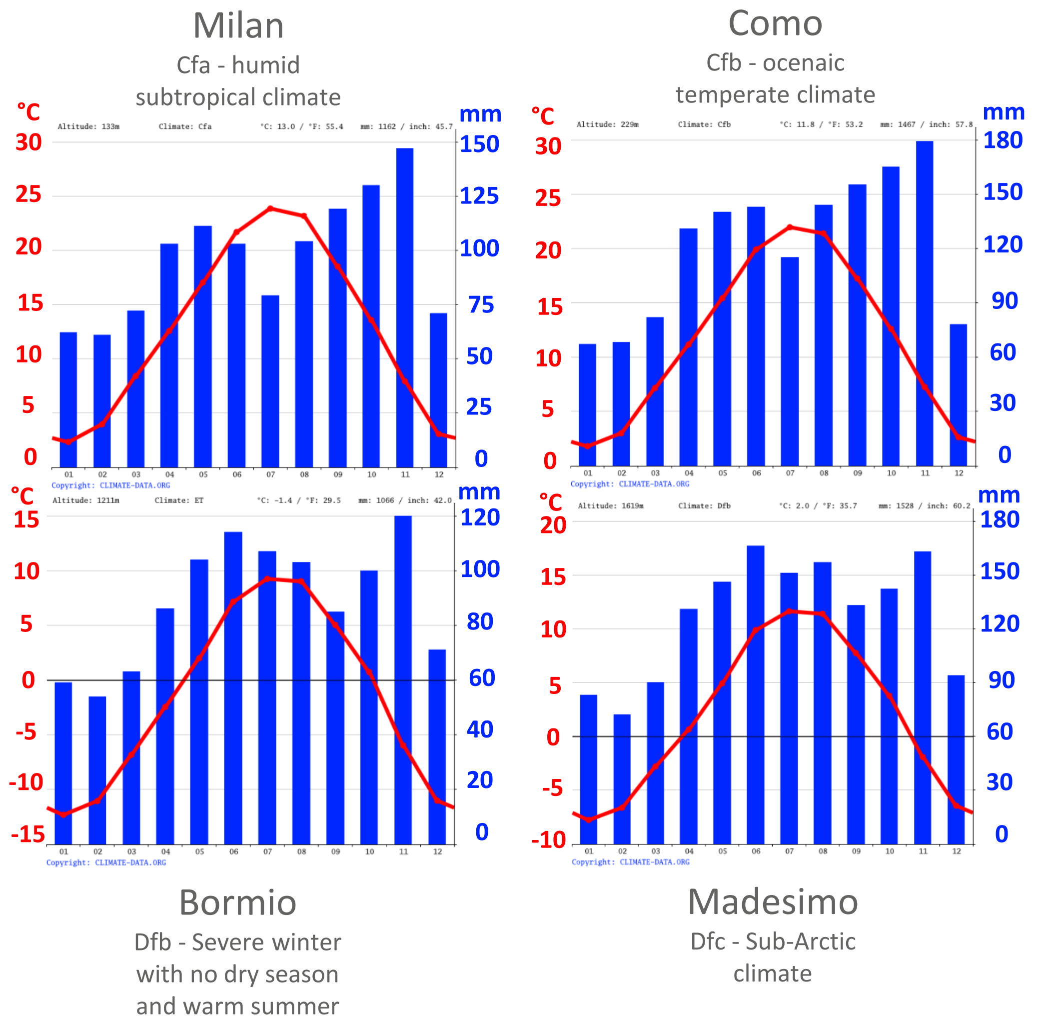
Study area







Total area: 23864 km^2
Elevation: 6 – 3786 m a.s.l.

Mean temperature: 17°C/y
Mean precipitation: 947 mm/y

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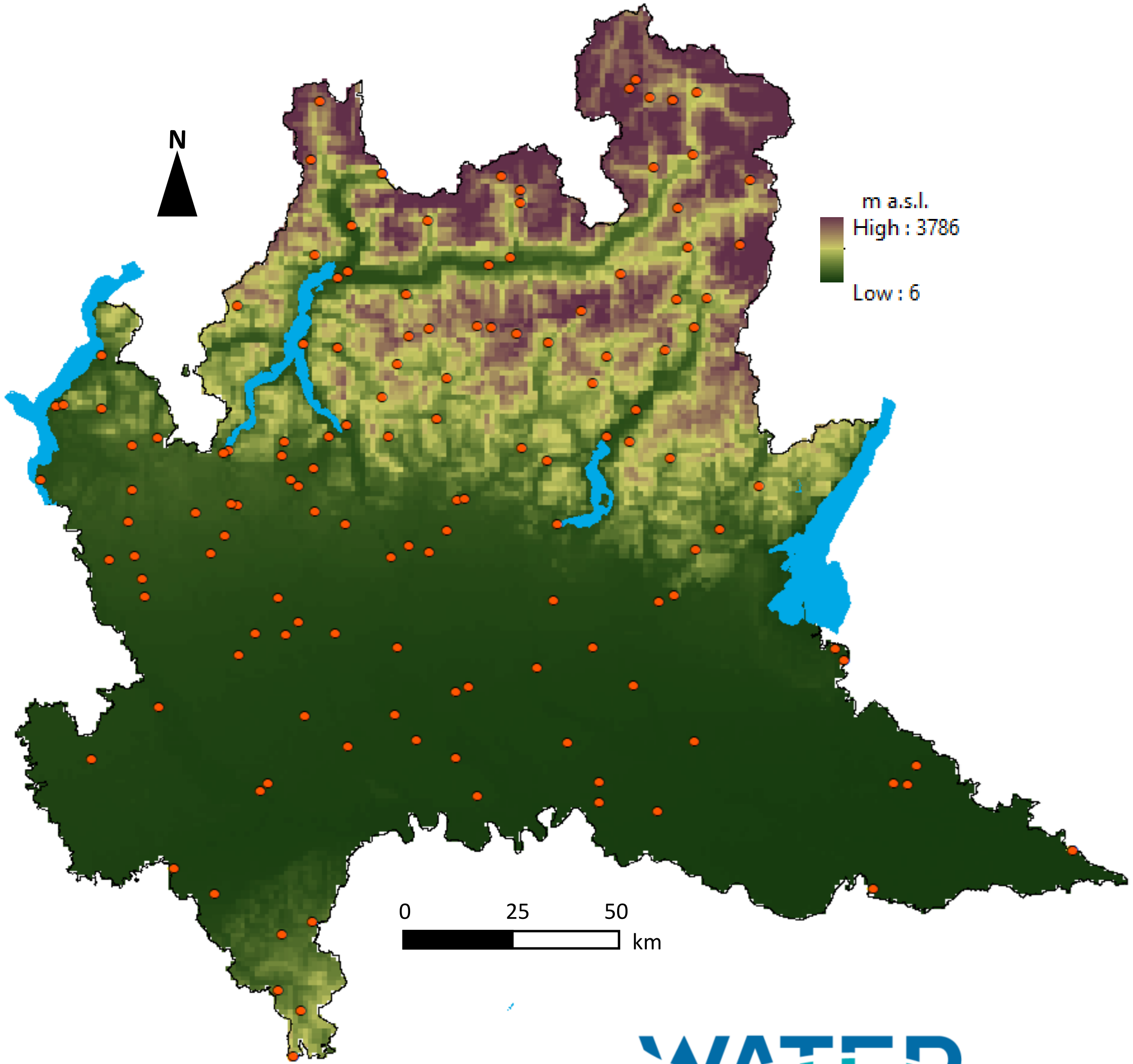
Weather stations

137 weather stations over the 10-year period **2011-2020** obtained from the **ARPA Lombardia** regional website.

Both **mean annual temperature** (°C) and **annual cumulative precipitation** (mm) for each weather station were considered.

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente



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Combiprecip

The CombiPrecip (CPC) product provides information on **hourly precipitation** levels at ground level (**1 km x 1 km resolution**). Using a geostatistical method, radar estimates are **combined with** data from **Swiss rain-gauges**. The CombiPrecip products cover the entire area monitored by the Swiss weather radar network, which includes Switzerland and its neighboring regions.

MeteoSwiss

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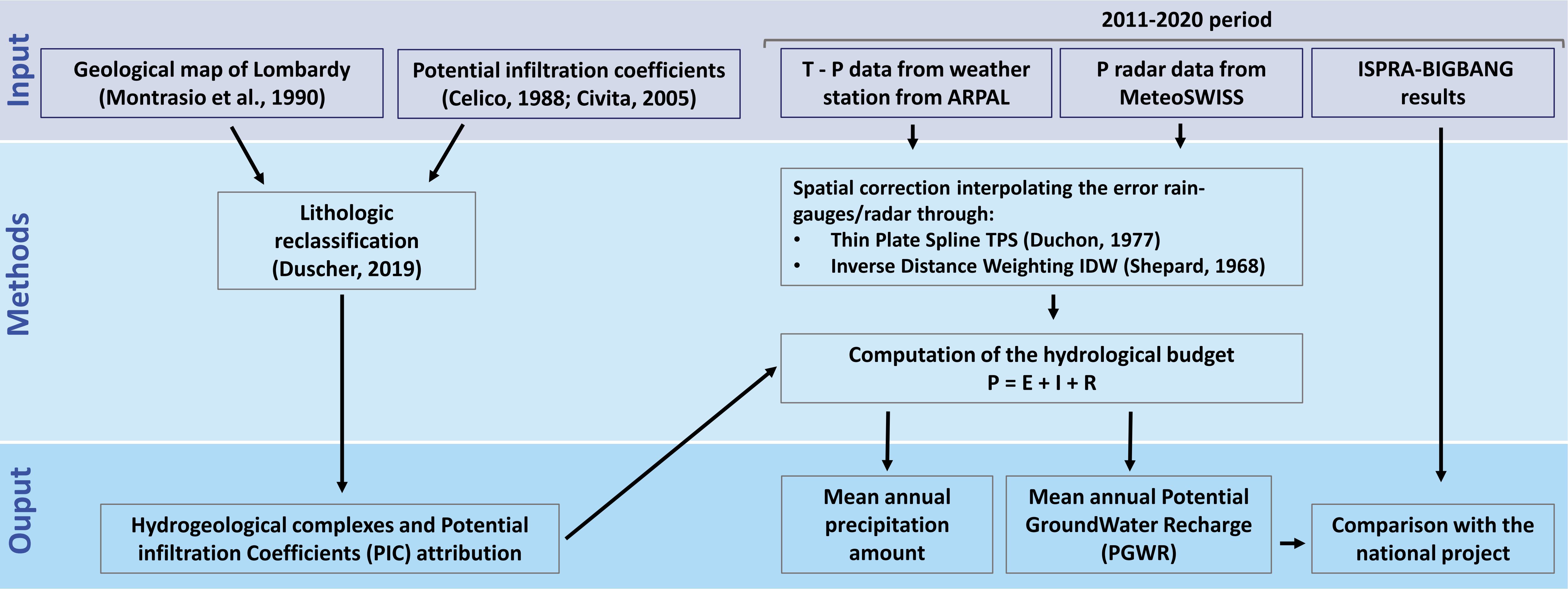
Comparing the values in the cells where the 137 available stations are located, the radar underestimates the values by about 21% → **The radar needs to be corrected for a hydrological application**

Monte Lema – 1626 m a.s.l.

Credit: MeteoSwiss

Methods



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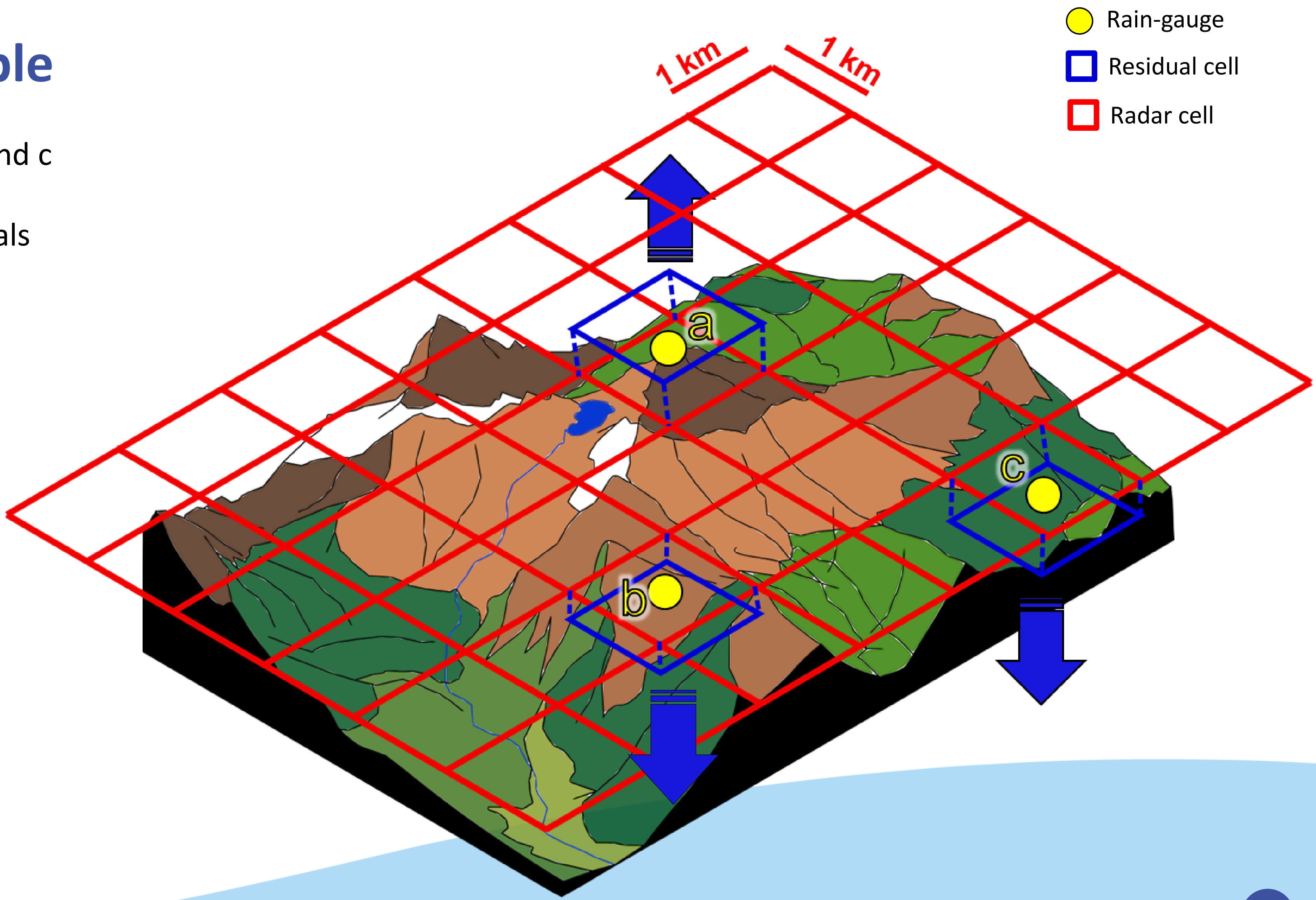
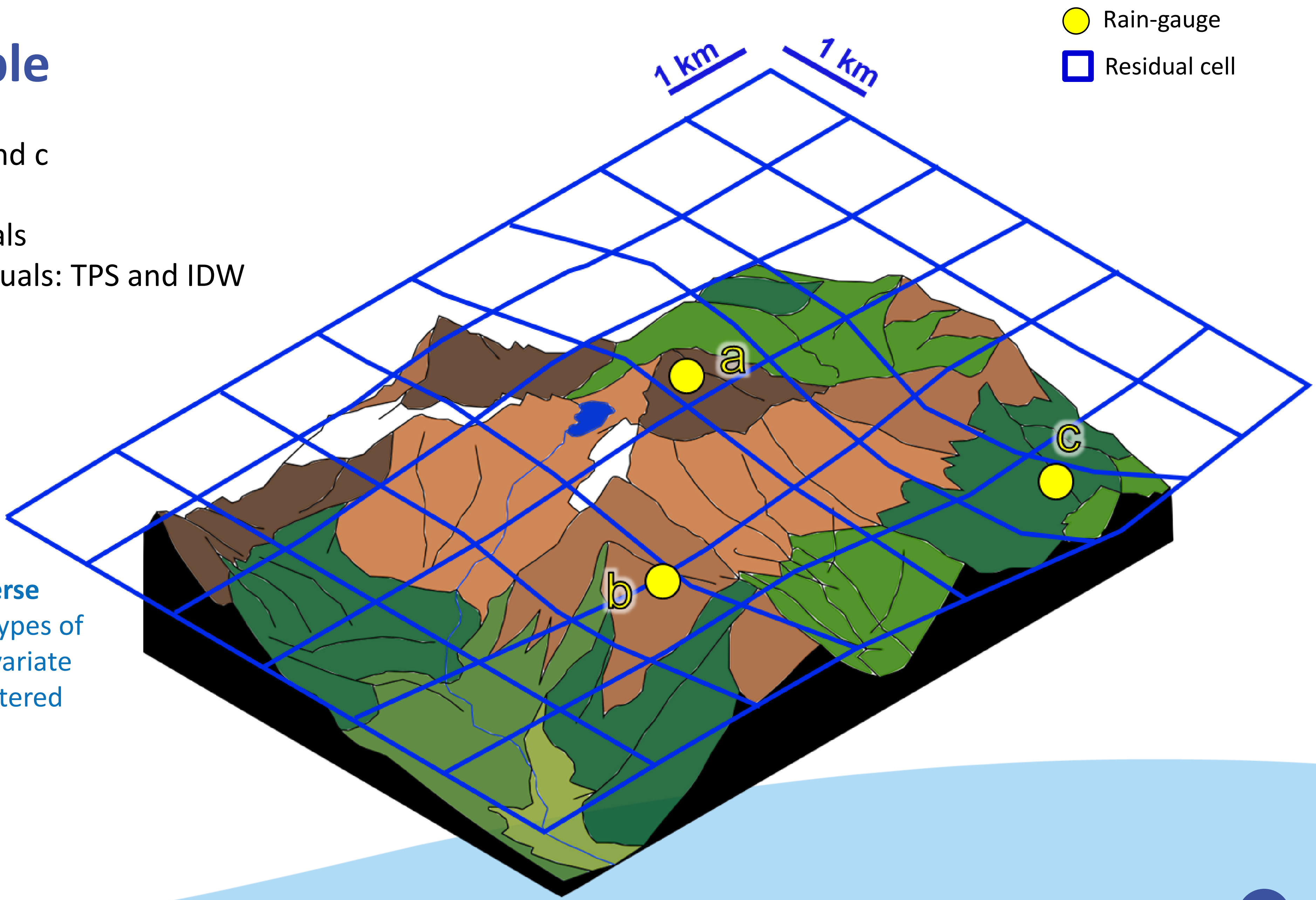
Methods - Example

- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals



Methods - Example

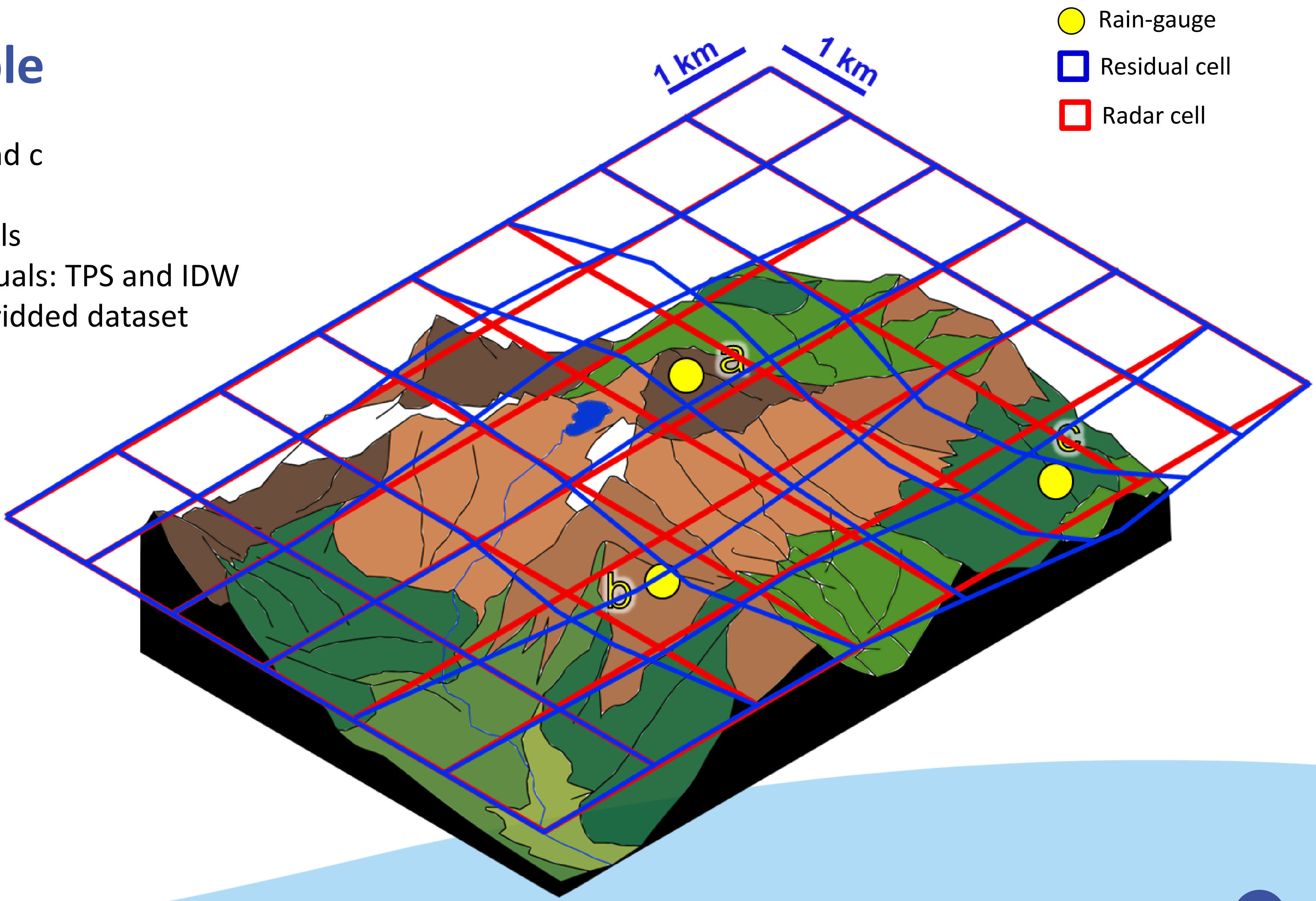
- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals
- Interpolation of the residuals: TPS and IDW



Thin Plate Spline (TPS) and **Inverse Distance Weighting (IDW)** are types of deterministic method for multivariate interpolation with a known scattered set of points.

Methods - Example

- Three rain-gauges a, b, and c
- Gridded radar values
- Calculation of the residuals
- Interpolation of the residuals: TPS and IDW
- Aggregation of the two gridded dataset



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Methods - Example

- Three rain-gauges a, b, and c
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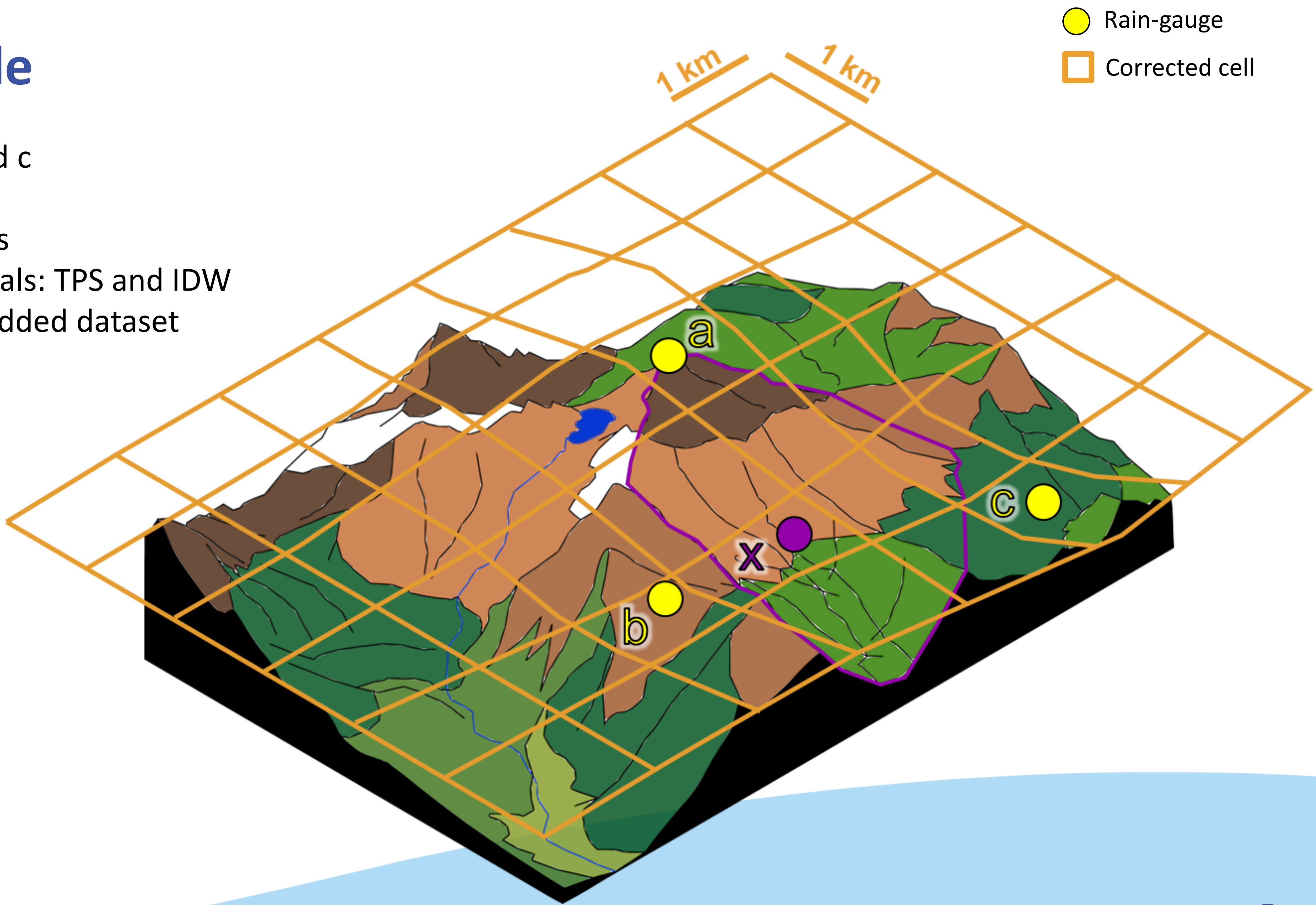

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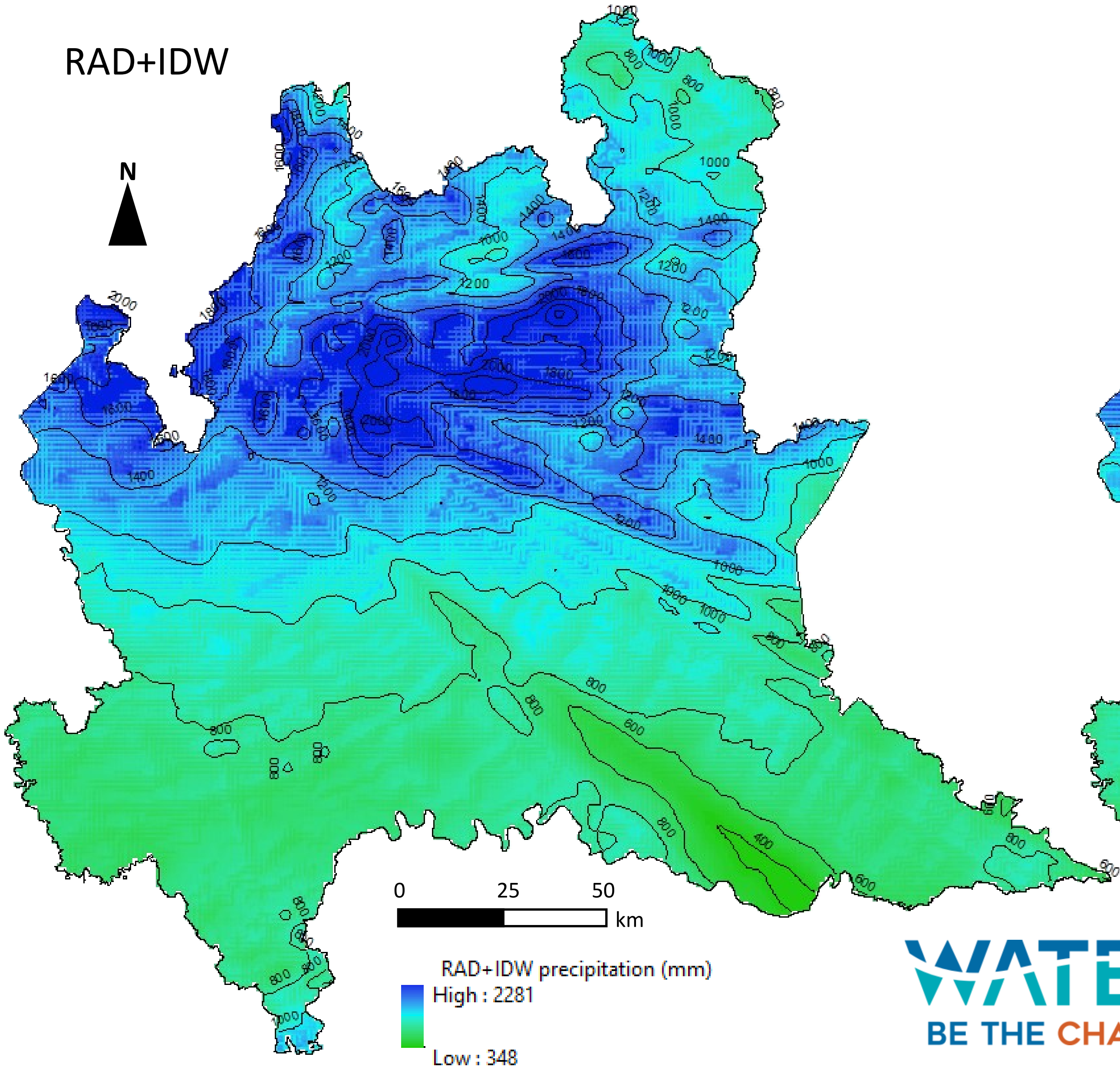
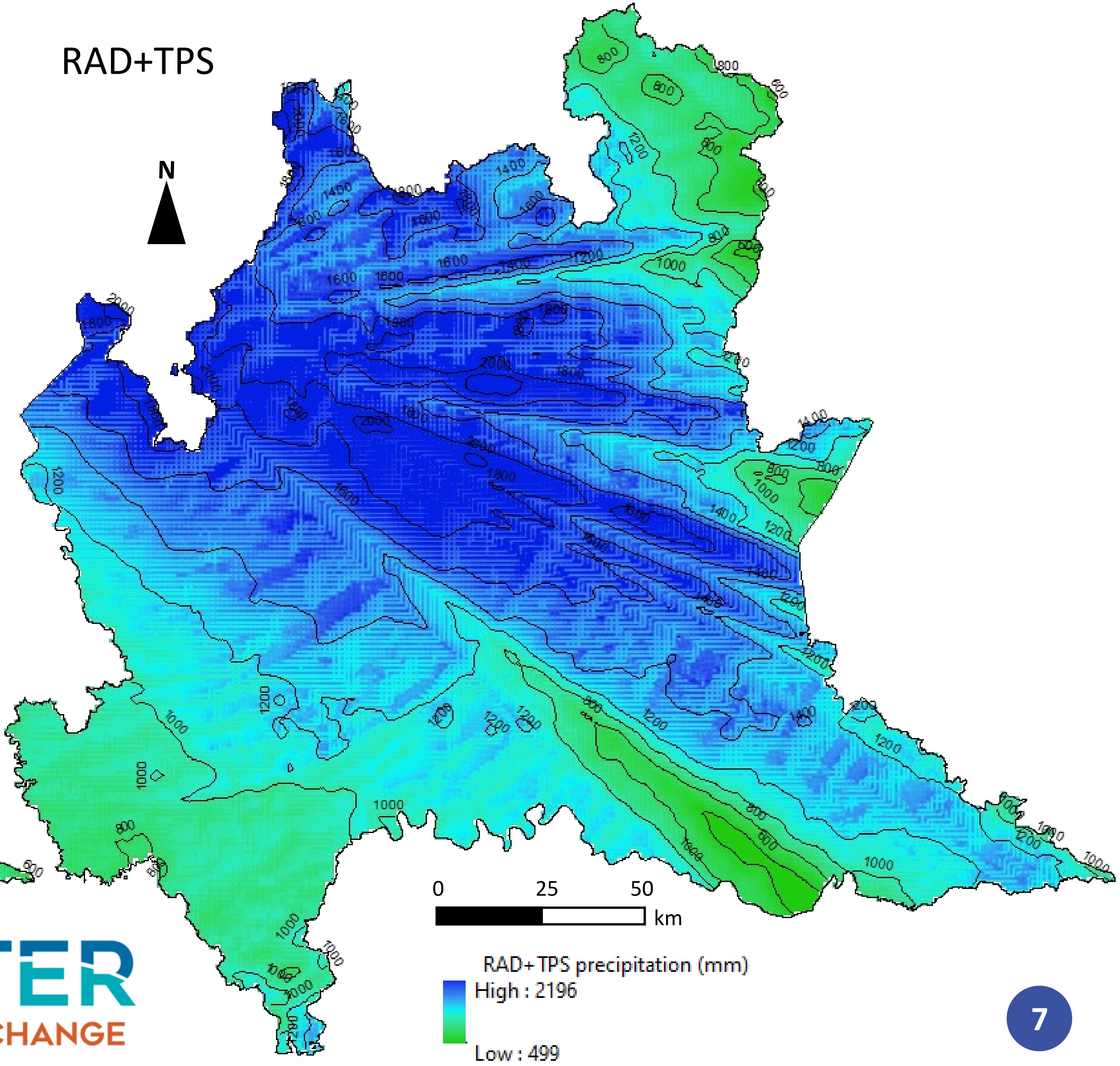
Results – Precipitation correction

RAD+IDW



RAD+TPS



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Results – Precipitation correction (LOO)

	RAD+IDW						RAD+TPS					
years	NSE_rad	NSE_sim	KGE_rad	KGE_sim	PBIAS_rad	PBIAS_sim	NSE_rad	NSE_sim	KGE_rad	KGE_sim	PBIAS_rad	PBIAS_sim
2011	-5.45	0.61	-0.08	0.75	-75.50	0.50	-5.45	0.29	-0.08	0.48	-75.50	0.10
2012	-0.08	0.70	0.48	0.81	-25.20	-0.40	-0.08	0.70	0.48	0.79	-25.20	0.10
2013	-0.45	0.54	0.45	0.72	-22.50	-0.50	-0.45	0.63	0.45	0.75	-22.50	0.20
2014	-0.24	0.70	0.53	0.82	-24.70	-0.60	-0.24	0.73	0.53	0.81	-24.70	0.20
2015	0.29	0.71	0.67	0.84	-16.50	-0.70	0.29	0.70	0.67	0.83	-16.50	0.20
2016	0.24	0.72	0.60	0.85	-15.80	0.00	0.24	0.72	0.60	0.80	-15.80	0.00
2017	0.52	0.81	0.67	0.90	-9.50	-0.70	0.52	0.82	0.67	0.88	-9.50	0.10
2018	0.20	0.62	0.51	0.79	-9.10	-0.60	0.20	0.69	0.51	0.81	-9.10	0.10
2019	0.31	0.59	0.62	0.79	-6.70	-0.60	0.31	0.71	0.62	0.82	-6.70	-0.10
2020	0.26	0.67	0.56	0.83	-8.40	-0.70	0.26	0.71	0.56	0.82	-8.40	0.10
Mean	-0.44	0.67	0.50	0.81	-21.39	-0.43	-0.44	0.67	0.50	0.78	-21.39	0.10

KGE index (Gupta et al., 2009) is an expression of the distance between the simulated point and the ideal model performance in the space

It varies $-\infty < KGE < 1$

Towner et al. (2019)
Andersson et al. (2017)

KGE>0.75 → GOOD!
KGE<0.50 → BAD!

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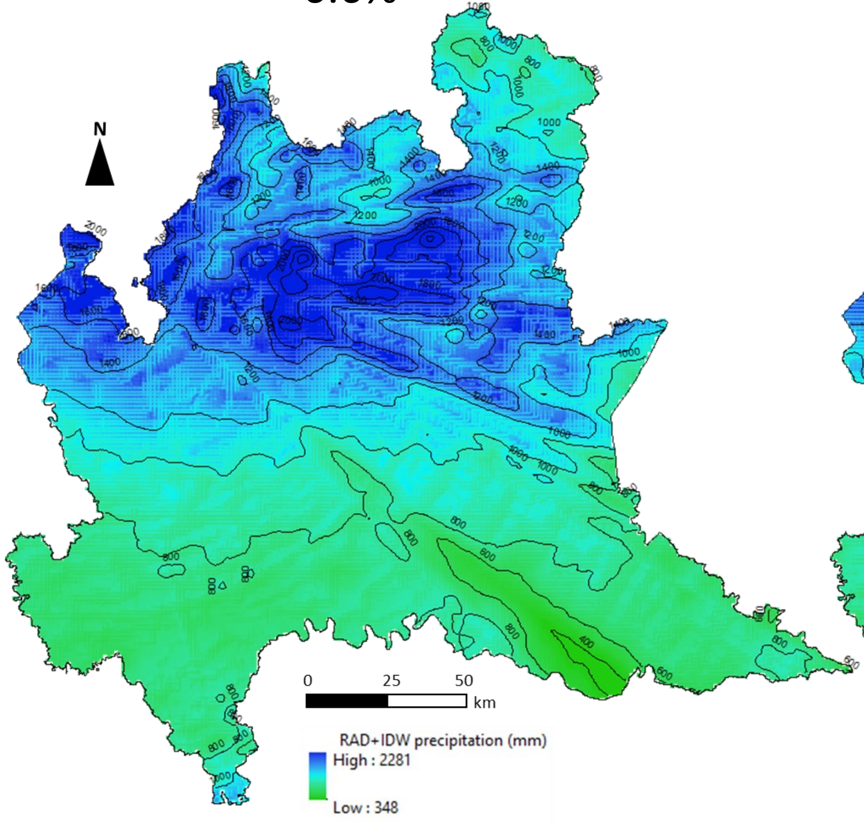
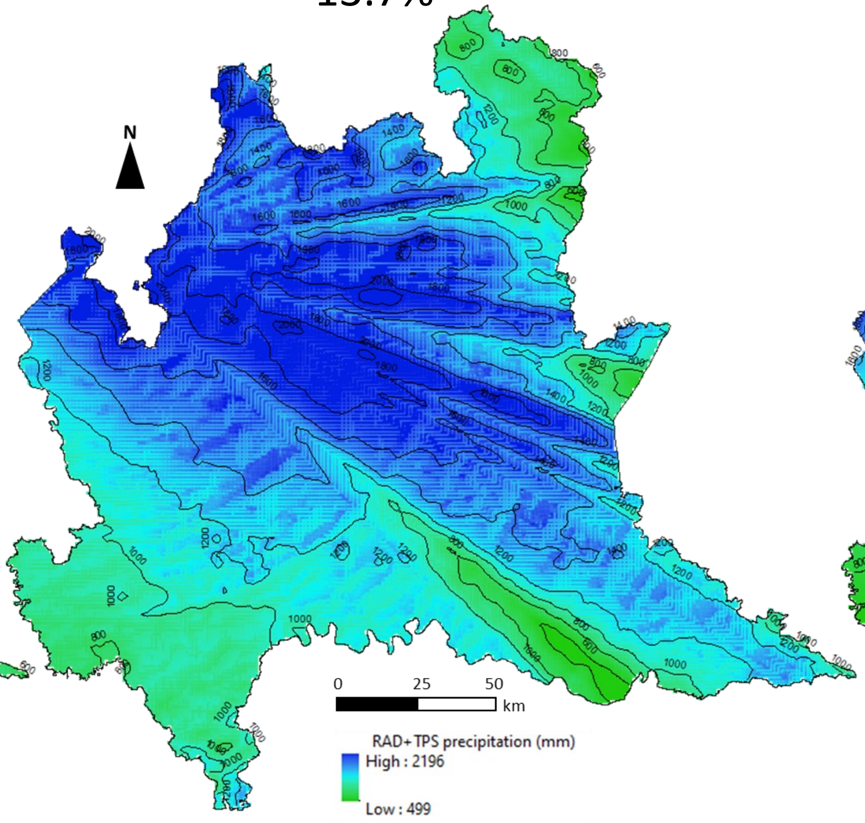
Results – Precipitation correction

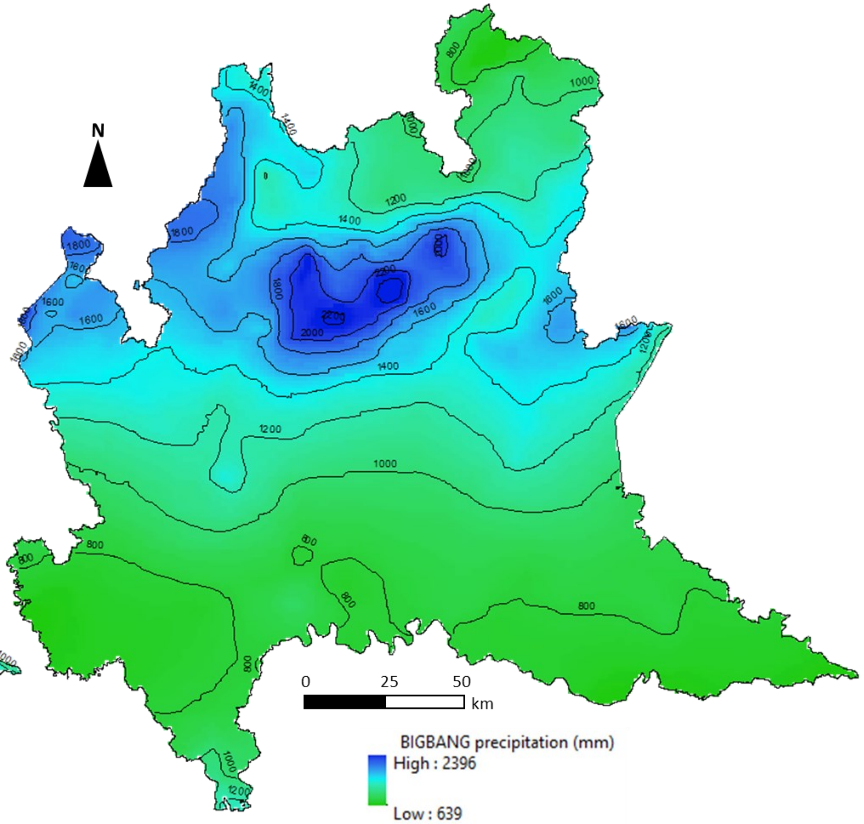
RAD+IDW 25.7 Bm^3
-6.6%



RAD+TPS 31.3 Bm^3
13.7%



BIGBANG 27.5 Bm^3



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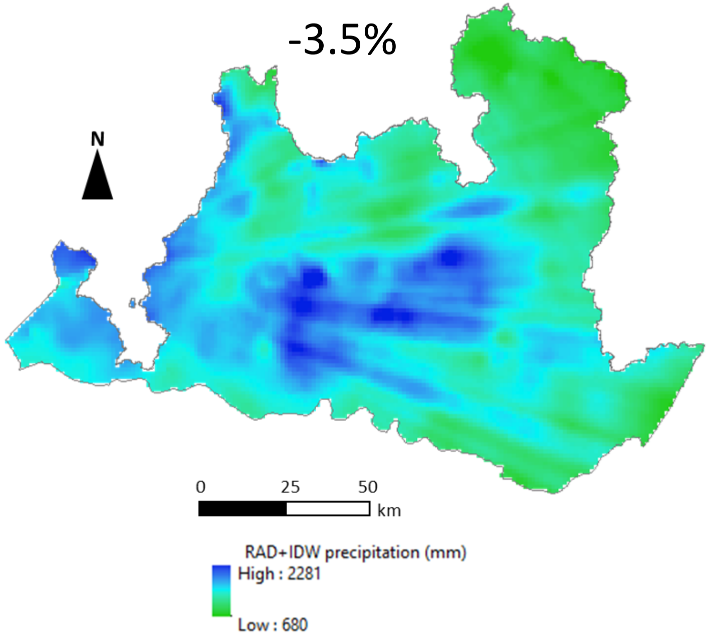
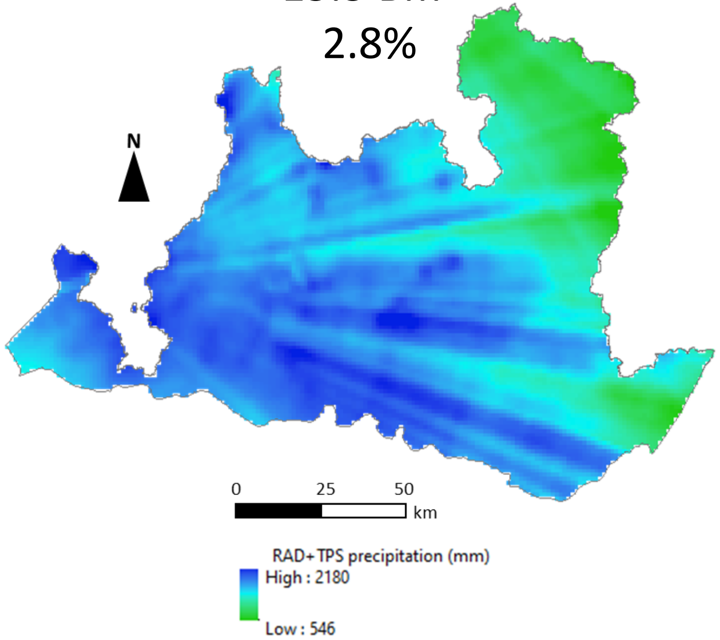
Results – Precipitation correction

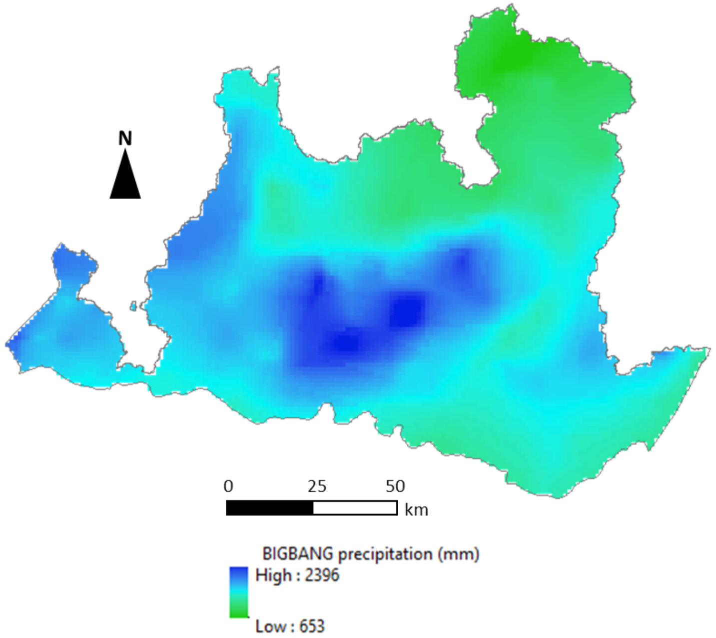
RAD+IDW 14.4 Bm^3
-3.5%



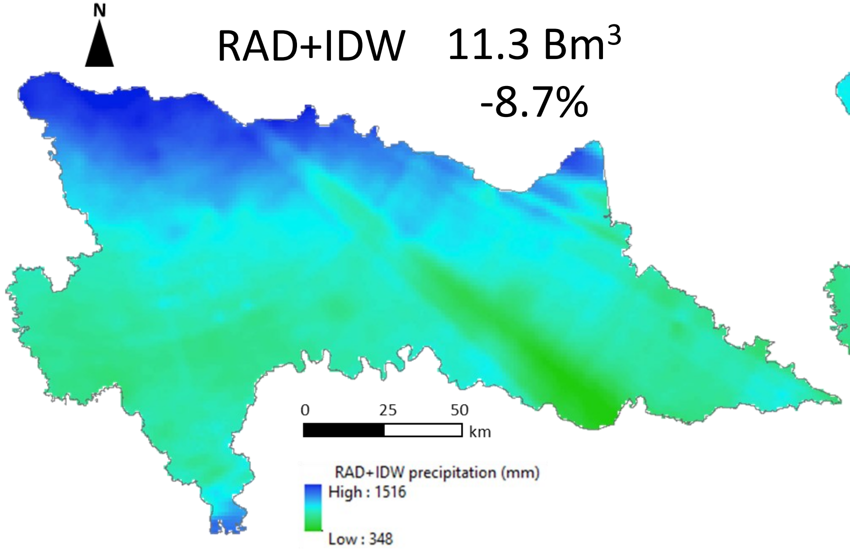
RAD+TPS 15.3 Bm^3
2.8%



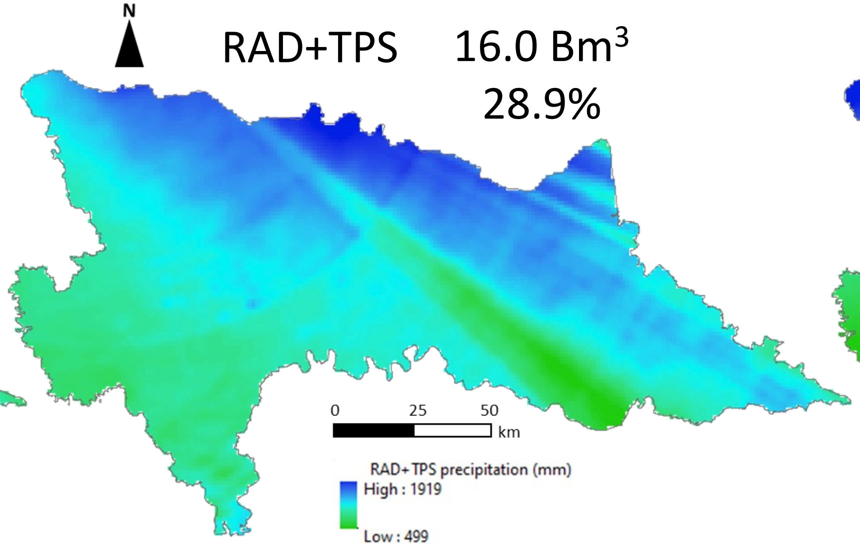
BIGBANG 14.9 Bm^3



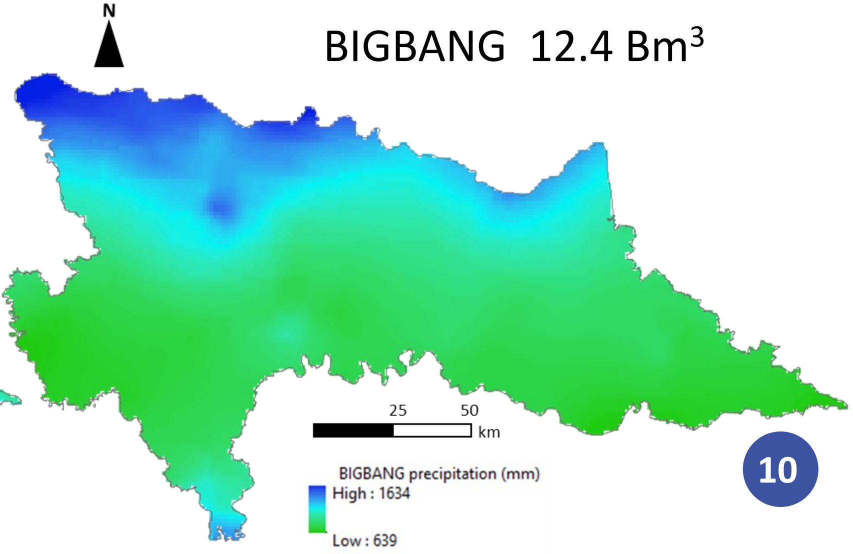
RAD+IDW 11.3 Bm^3
-8.7%



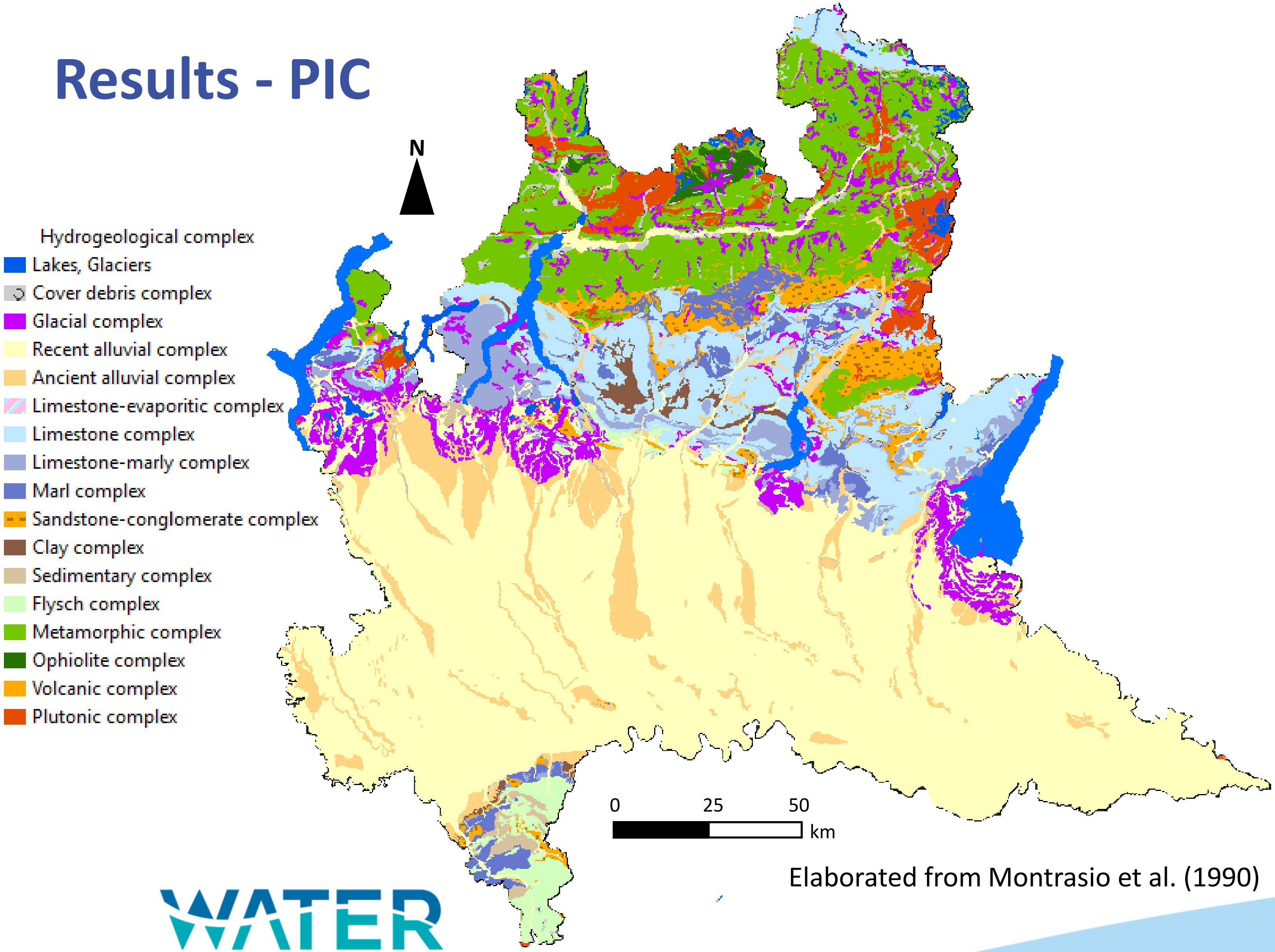
RAD+TPS 16.0 Bm^3
28.9%



BIGBANG 12.4 Bm^3



Results - PIC



Elaborated from Montrasio et al. (1990)

$$P = E + I + R$$

$$E = \frac{P}{\sqrt{0{,}9 + \frac{P^2}{L^2}}}$$

Turc (1954)

$$L = 300 + 25 * T + 0{,}05 * T^3$$

Hydrological complexes

$$ActualP = P - E$$

$$PIC\ (0 \div 1)$$

PGWR= $ActualP \times PIC$

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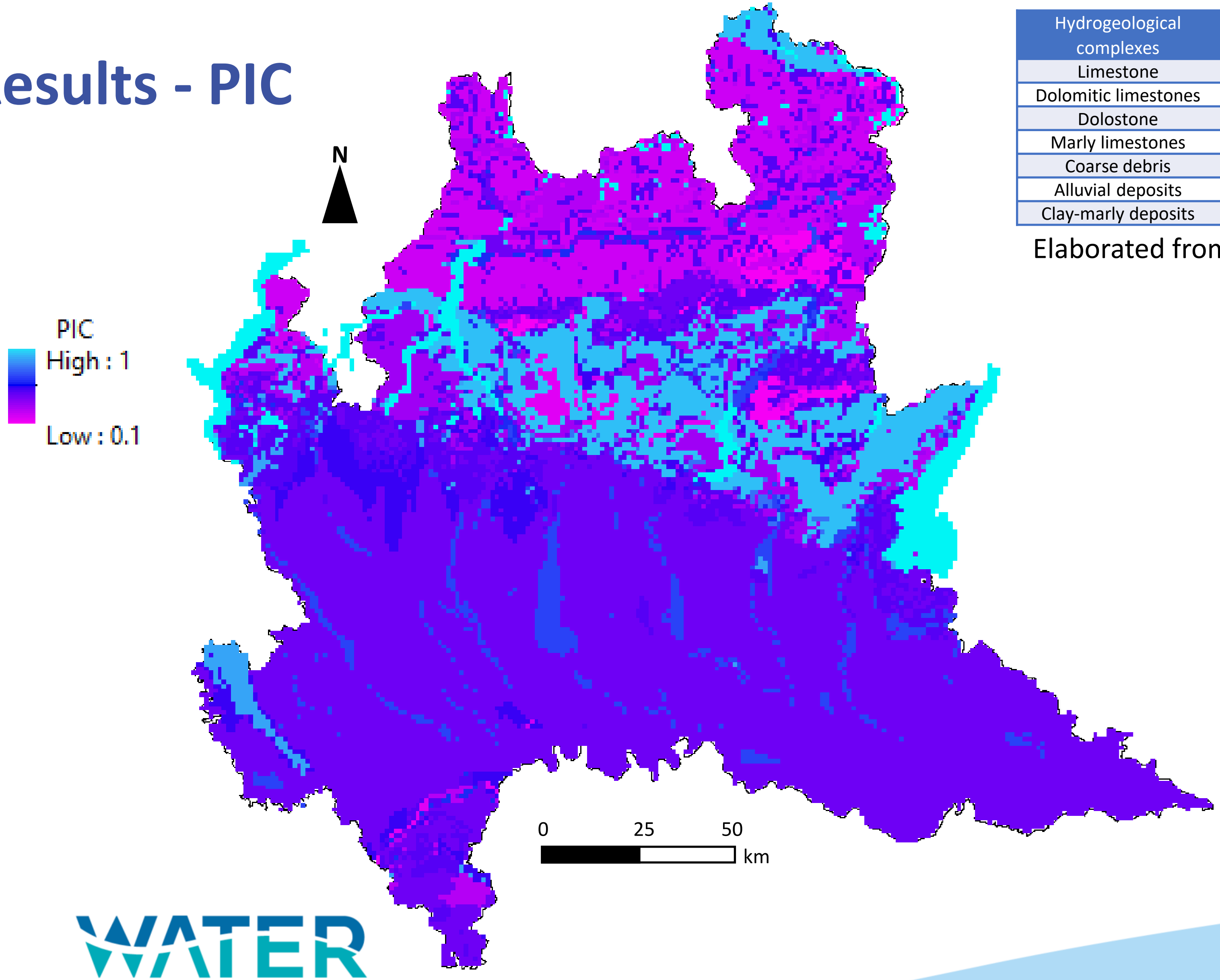
Results - PIC



Hydrogeological complexes	PIC	Suggested value	Hydrogeological complexes	PIC	Suggested value
Limestone	0.90-1.00	0.90	Volcanic deposits	0.90-1.00	0.95
Dolomitic limestones	0.70-0.90	0.80	Pyroclastic deposits	0.50-0.70	0.60
Dolostone	0.50-0.70	0.60	Pyro-volcanic deposits	0.70-0.90	0.80
Marly limestones	0.30-0.50	0.40	Intrusive rocks	0.15-0.35	0.25
Coarse debris	0.80-0.90	0.85	Metamorphic rocks	0.05-0.20	0.15
Alluvial deposits	0.80-1.00	0.90	Sands	0.80-0.90	0.85
Clay-marly deposits	0.05-0.25	0.15	Loamy sands	0.30-0.50	0.40

Elaborated from Celico (1988)

Hydrogeological complexes	PIC	Suggested value
Coarse alluvium	0.65-1.00	0.90
Sands	0.90-1.00	0.95
Sandy formations	0.75-0.90	0.80
Medium to fine alluvium	0.15-0.45	0.30
Clays. silts.	0.00-0.25	0.15
Coarse moraines	0.50-0.70	0.55
Fine moraines	0.15-0.25	0.20
Marls. Argillites	0.10-0.20	0.15
Marly limestone flysch	0.20-0.50	0.35
Marly arenaceous flysch	0.20-0.45	0.25
Sandstones. Conglomerates	0.30-0.50	0.40
Karst limestone	0.75-1.00	0.95
Fissured limestones	0.50-0.85	0.75
Marbles	0.90-1.00	0.95
Fissured dolostones	0.45-0.70	0.60
Acidic fissured volcanites	0.30-0.70	0.50
Basic fissured volcanites	0.75-1.00	0.85
Fine pyroclastites	0.15-0.25	0.20
Fissured plutonites	0.05-0.35	0.25
Phyllites	0.05-0.30	0.10
Gneiss	0.15-0.35	0.25

Elaborated from Civita (2005)

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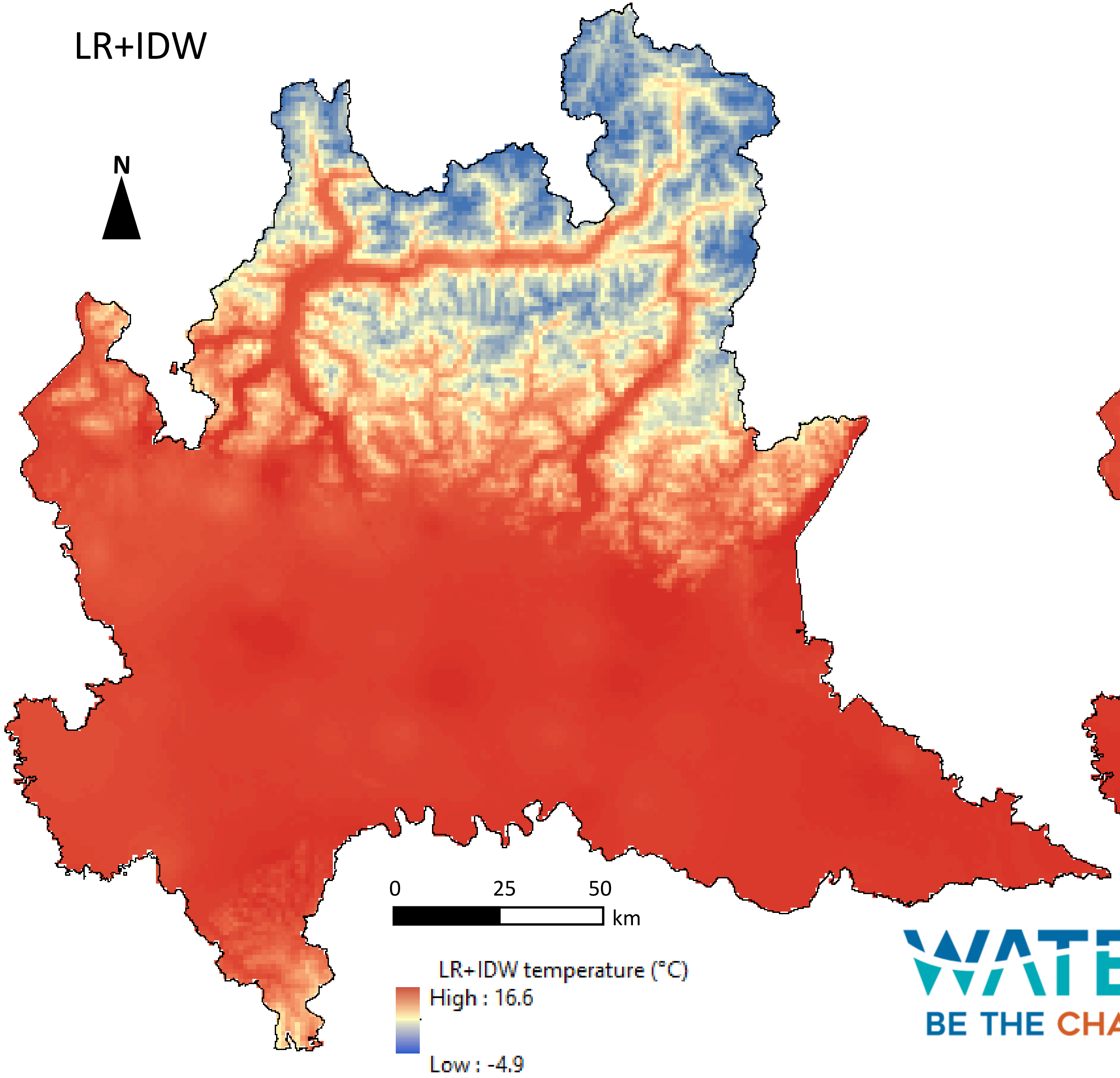
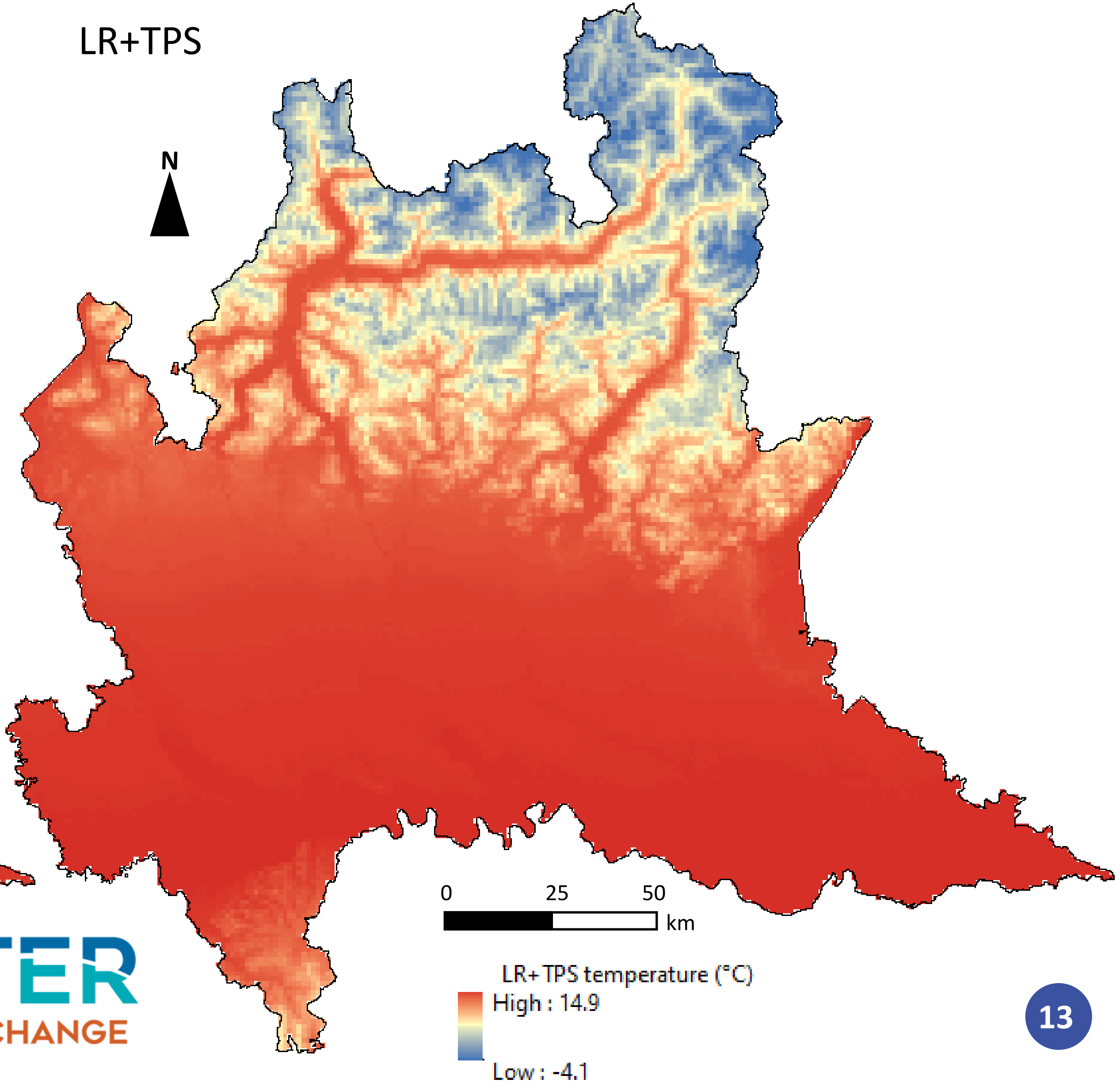
Results - Temperatures

LR+IDW



LR+TPS



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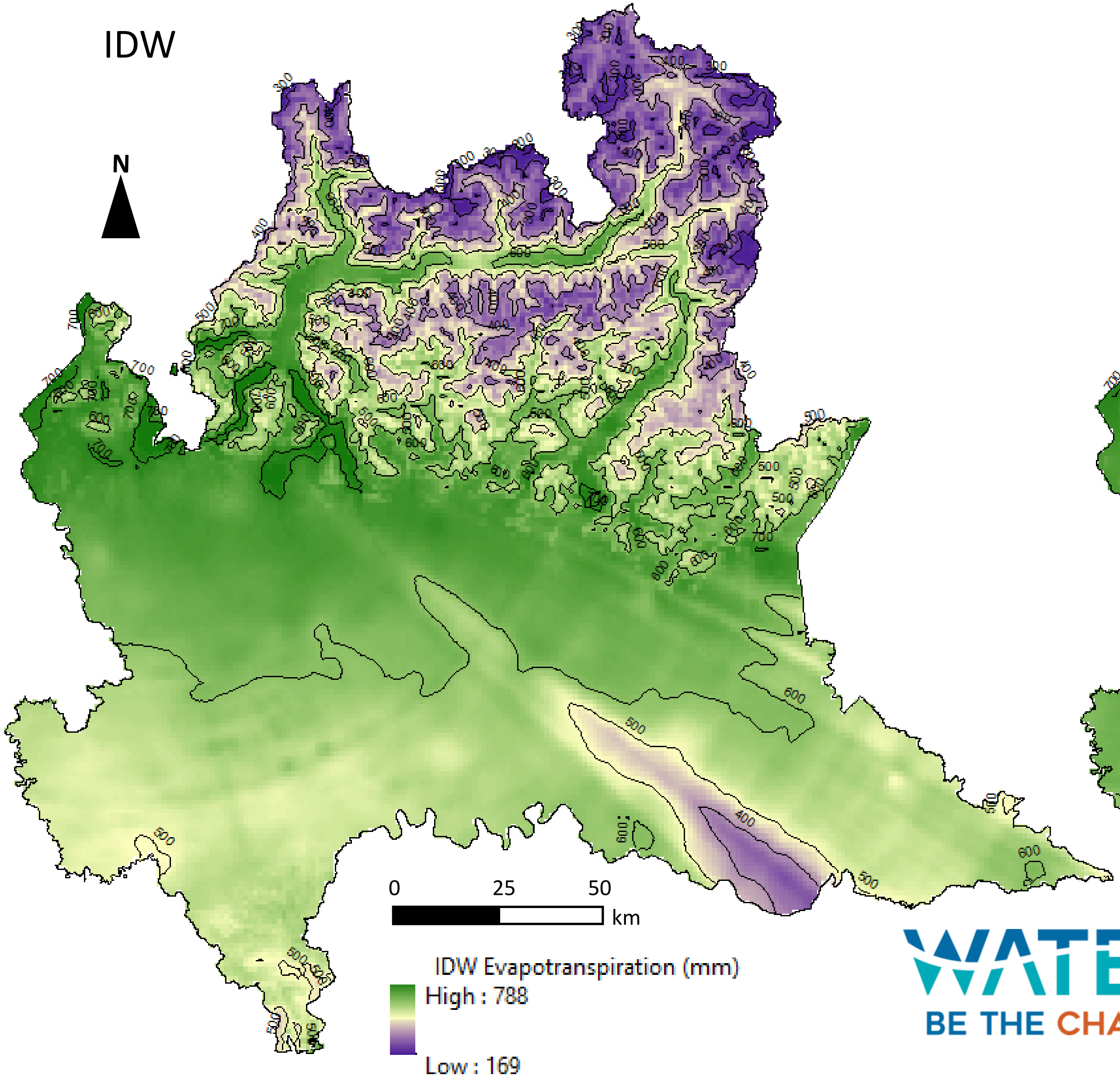
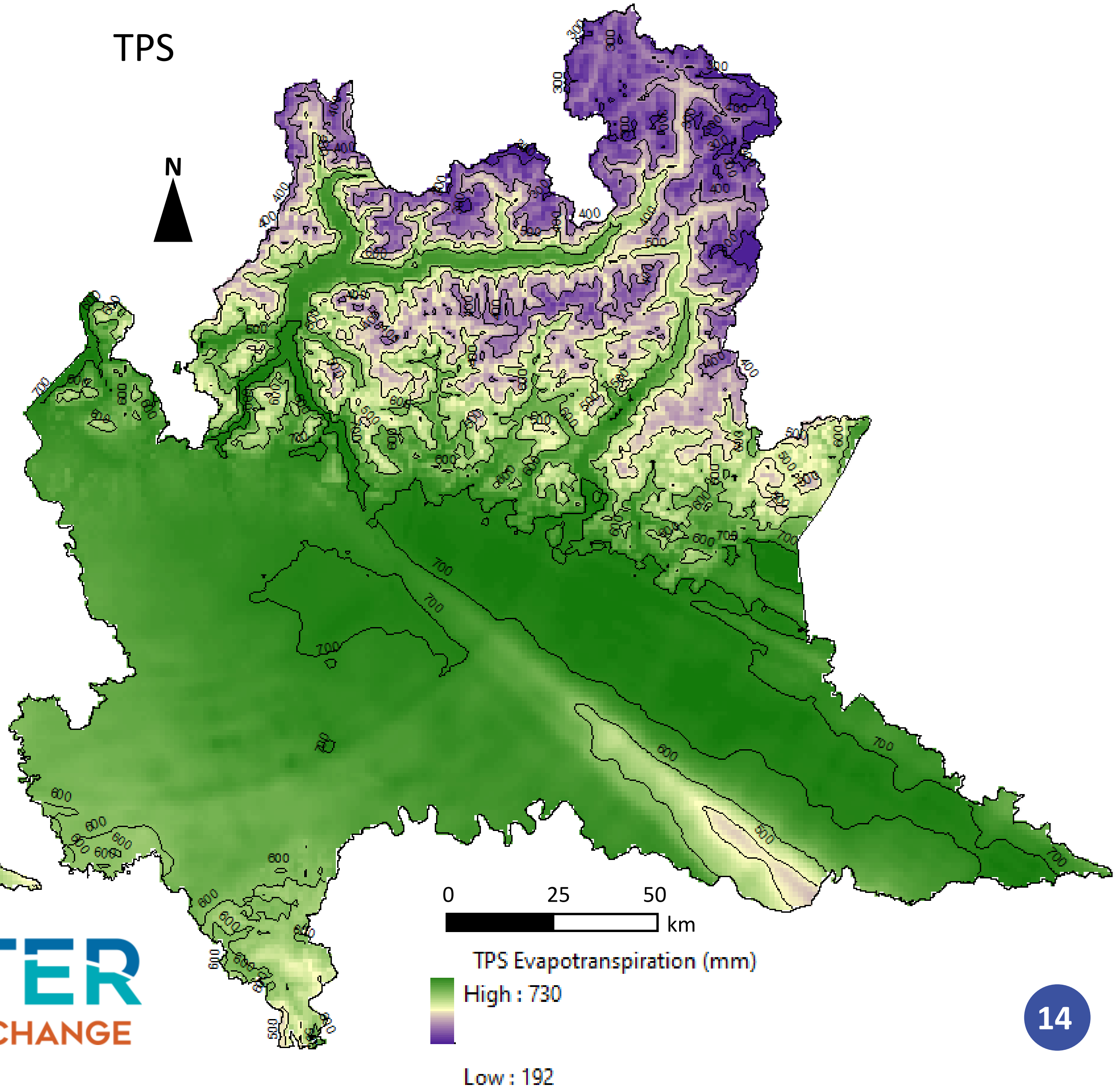
Results – Potential Evapotranspiration





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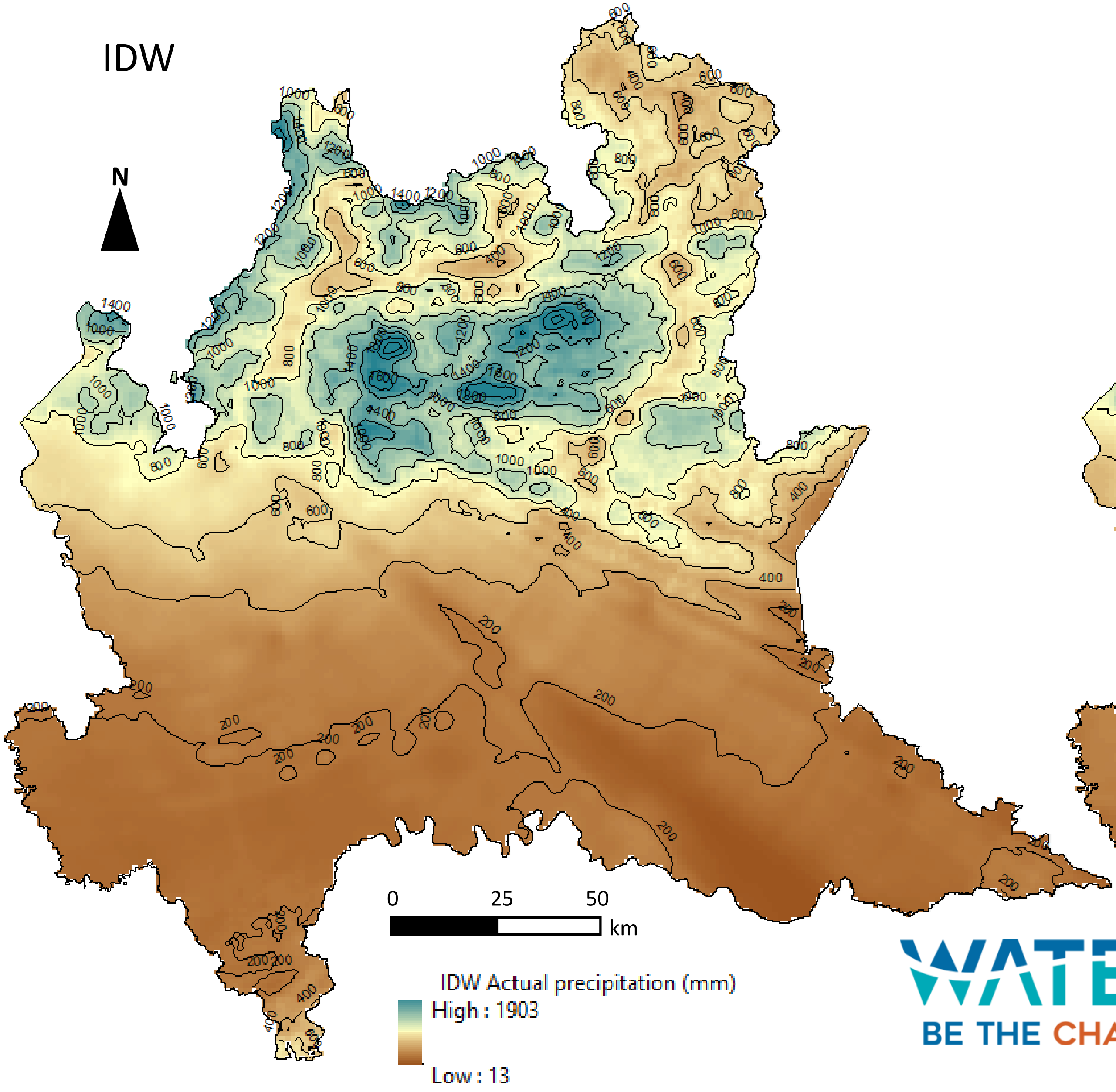
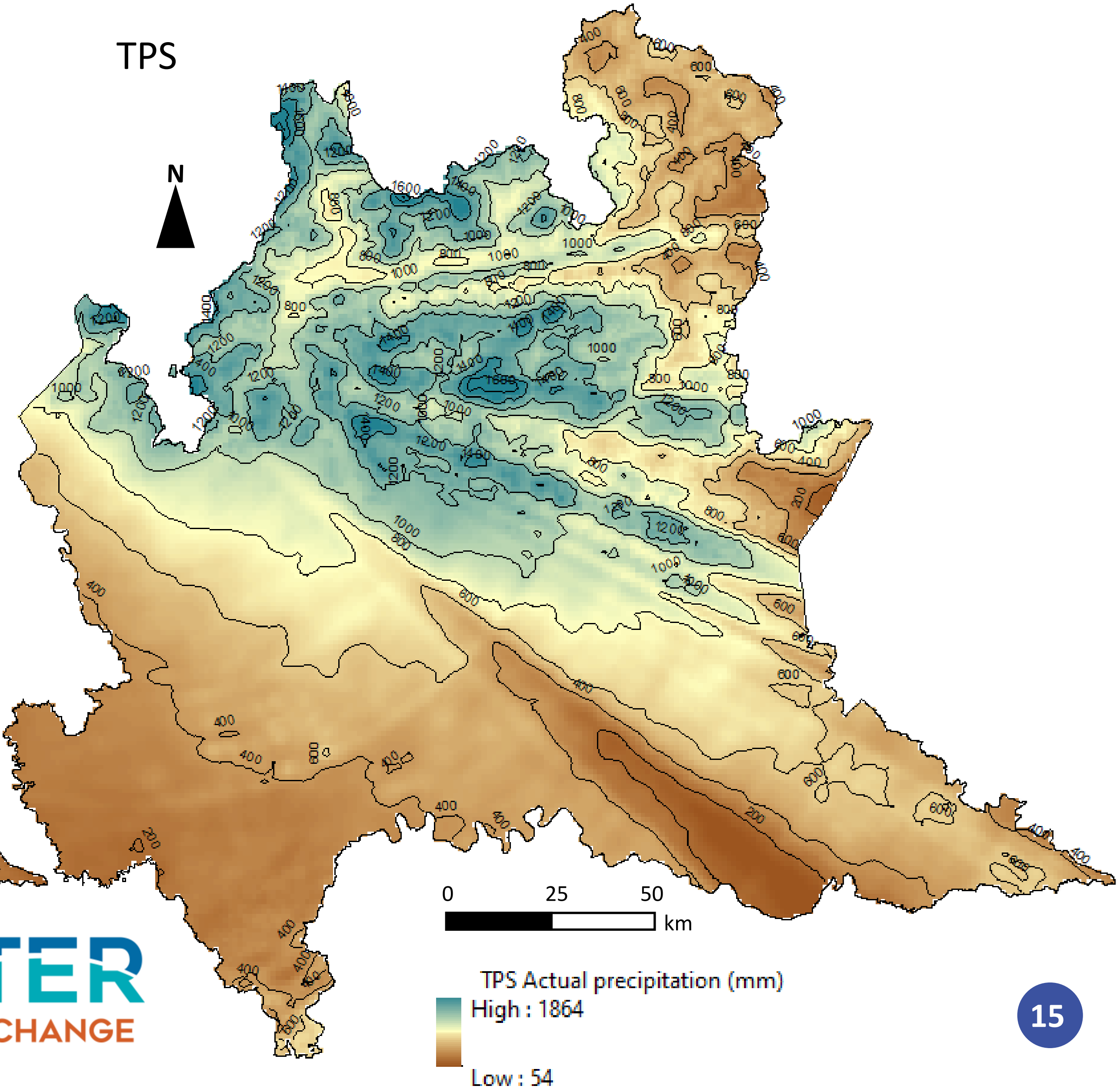
Results – Actual precipitation





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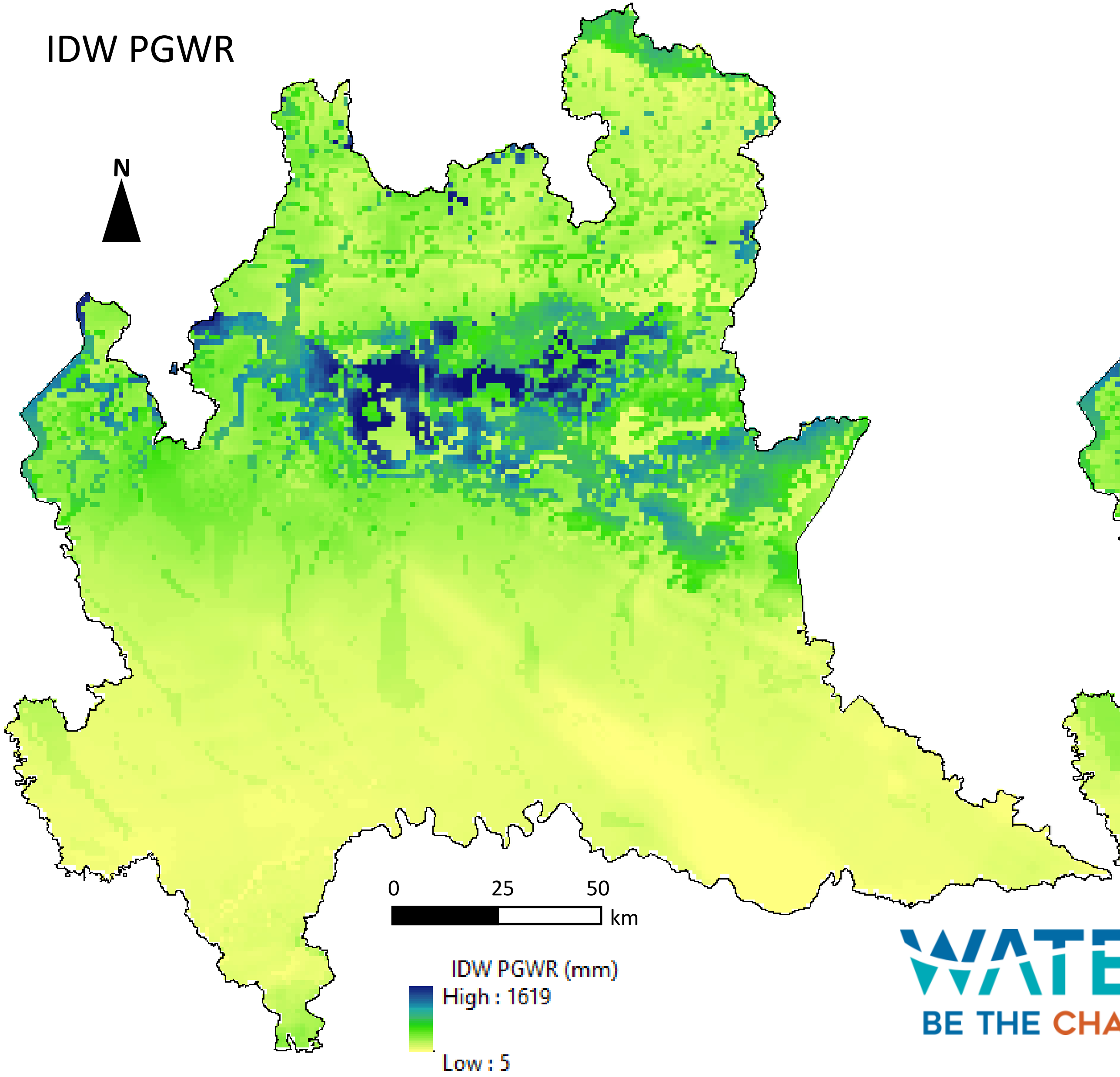
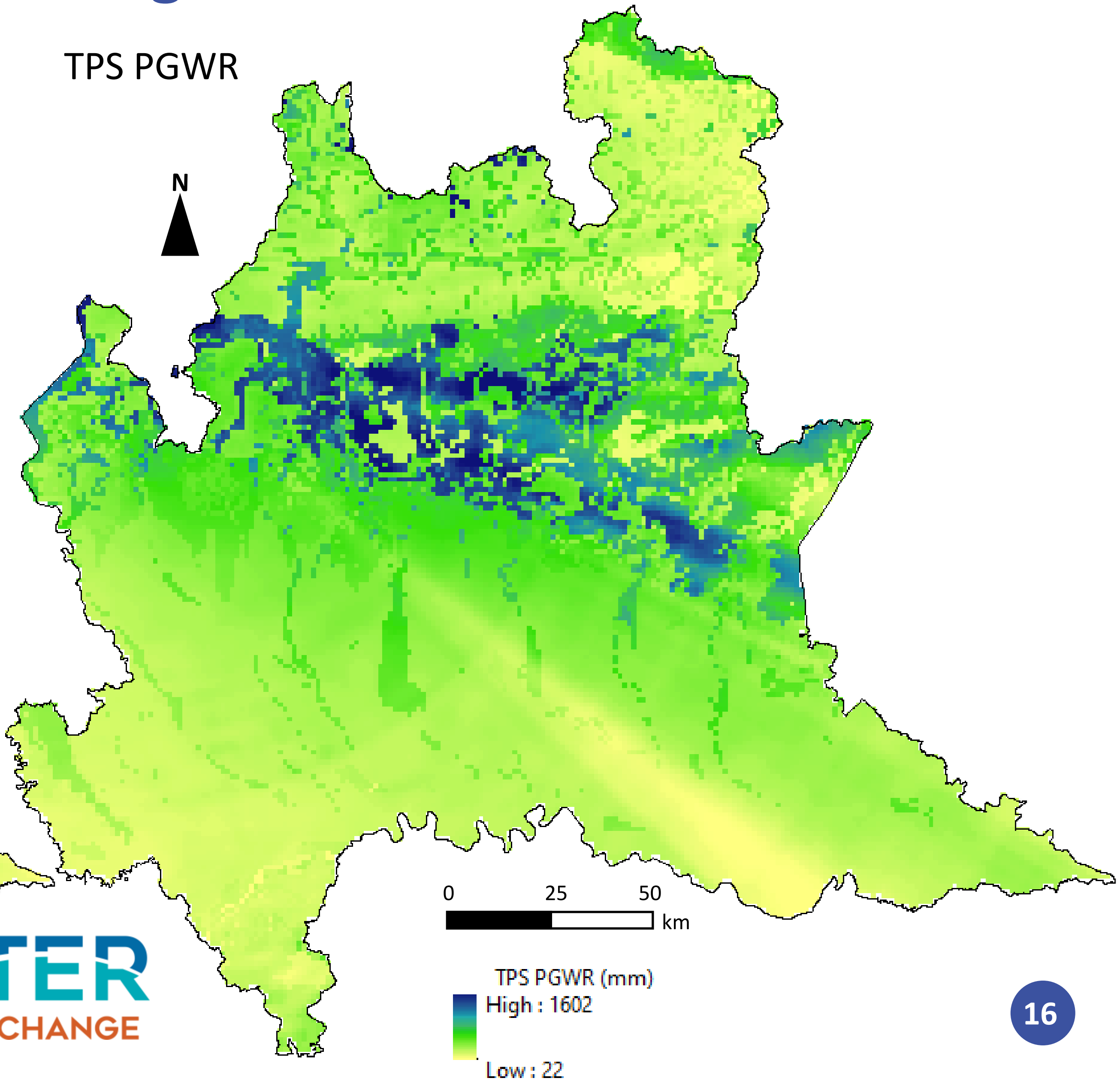
Results – Potential GroundWater Recharge PGWR





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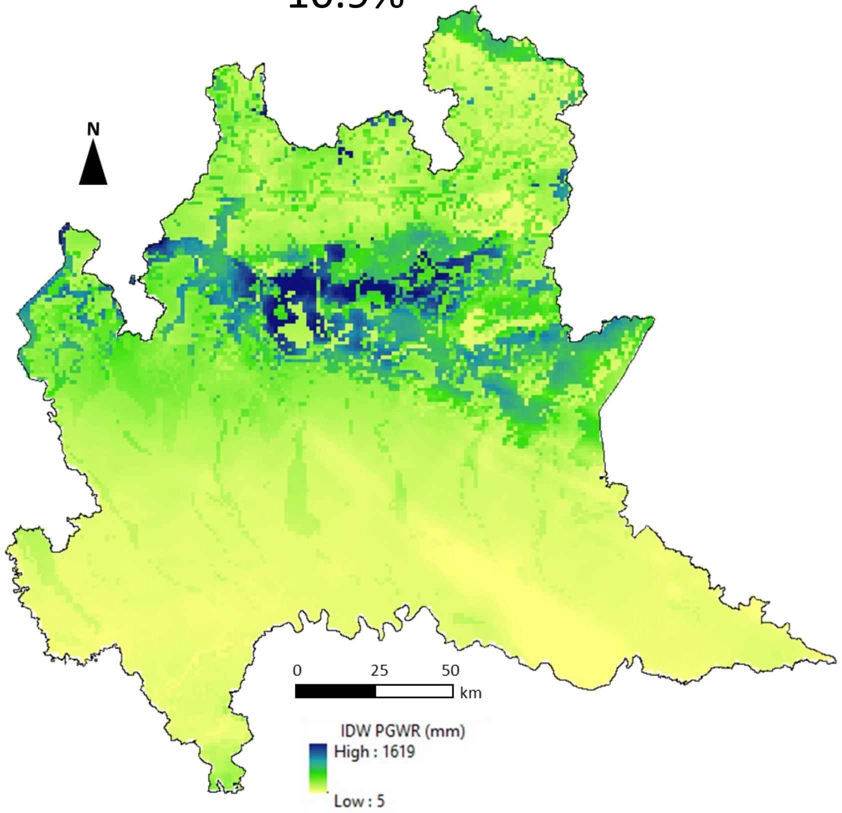
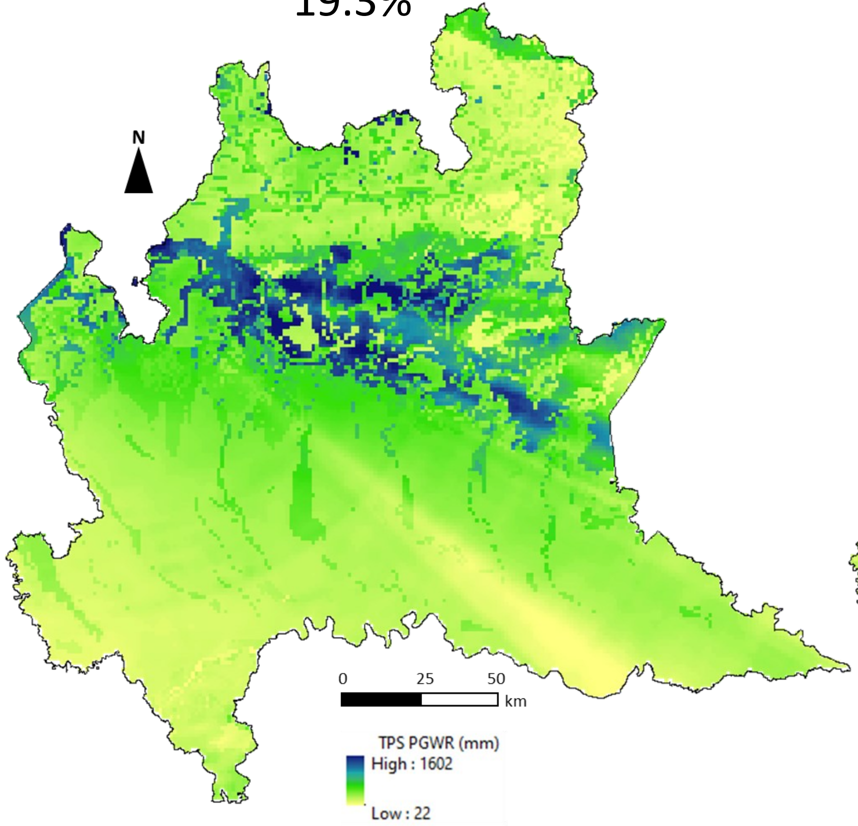
Results – Potential GroundWater Recharge PGWR

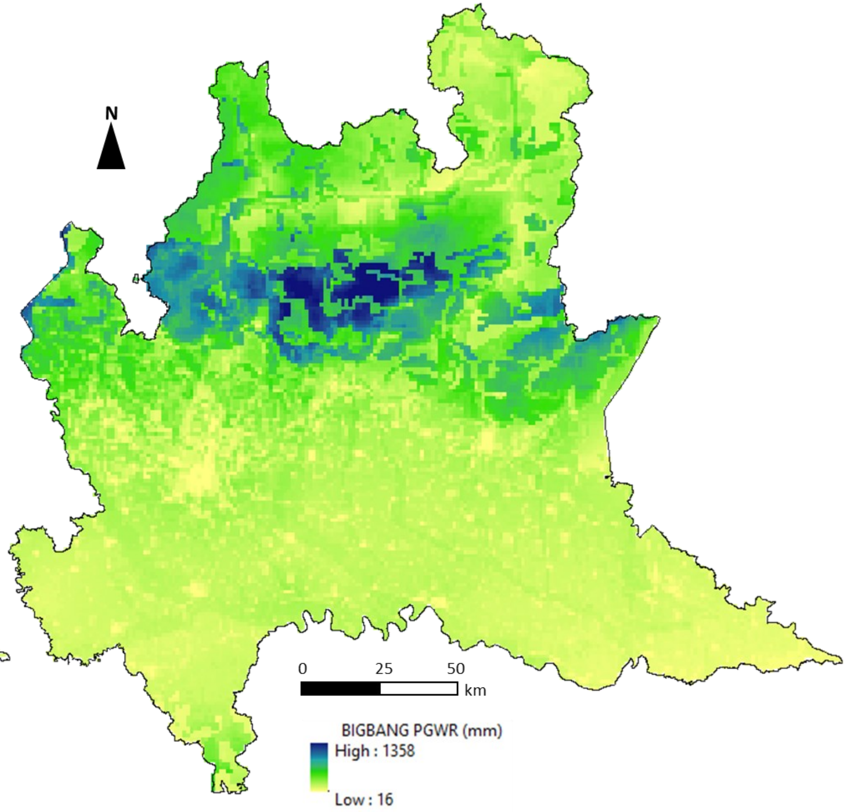
IDW PGWR 5.8 Bm^3
-10.9%



TPS PGWR 7.7 Bm^3
19.3%



BIGBANG PGWR 6.5 Bm^3



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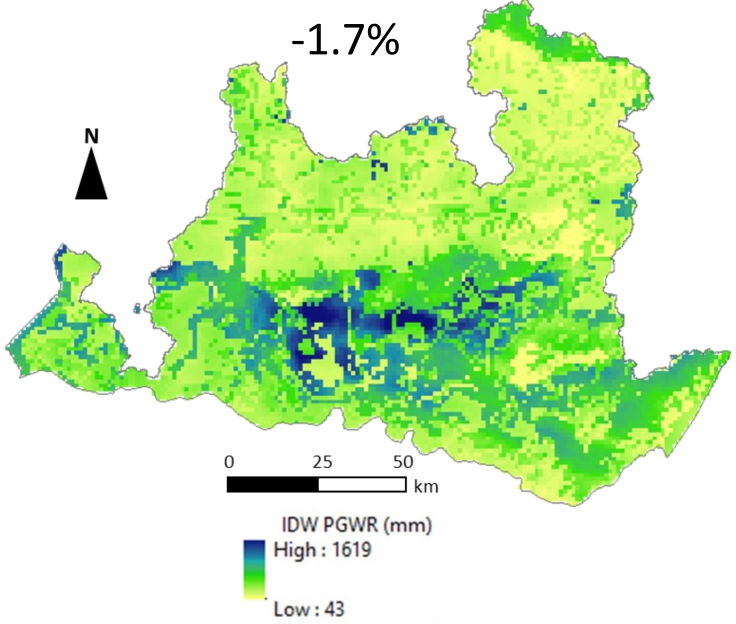
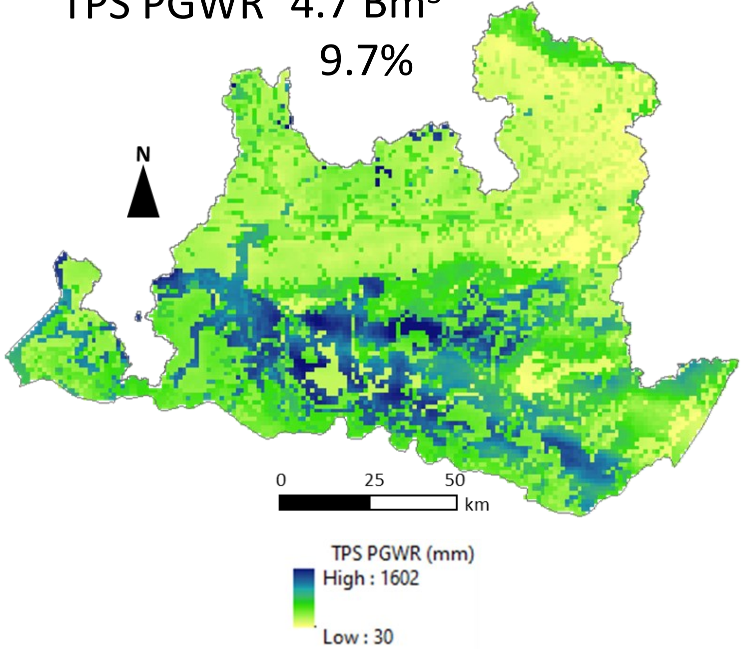
Results – Potential GroundWater Recharge PGWR

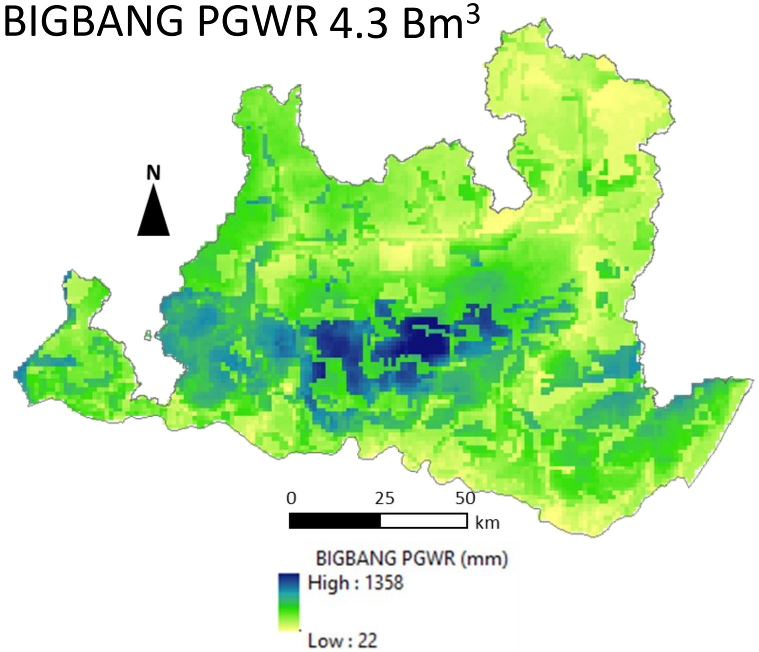
IDW PGWR 4.2 Bm^3 -1.7%



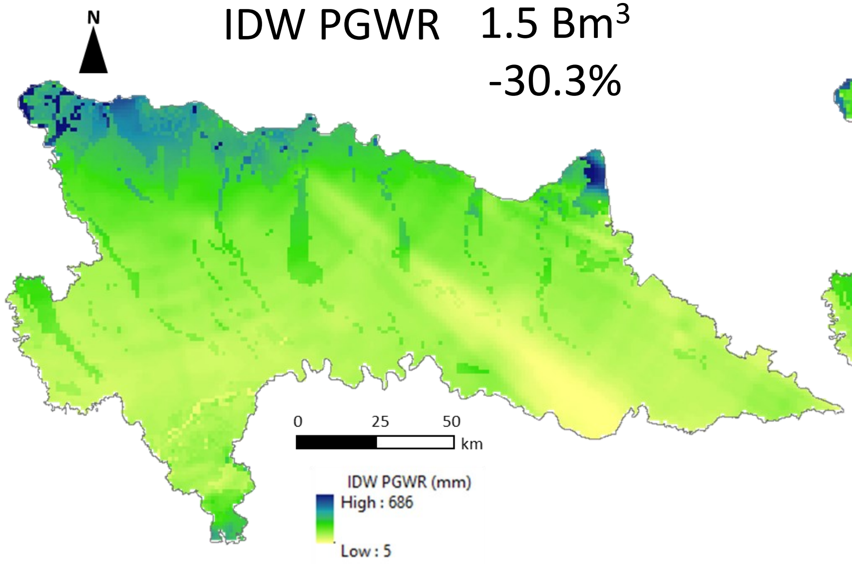
TPS PGWR 4.7 Bm^3 9.7%



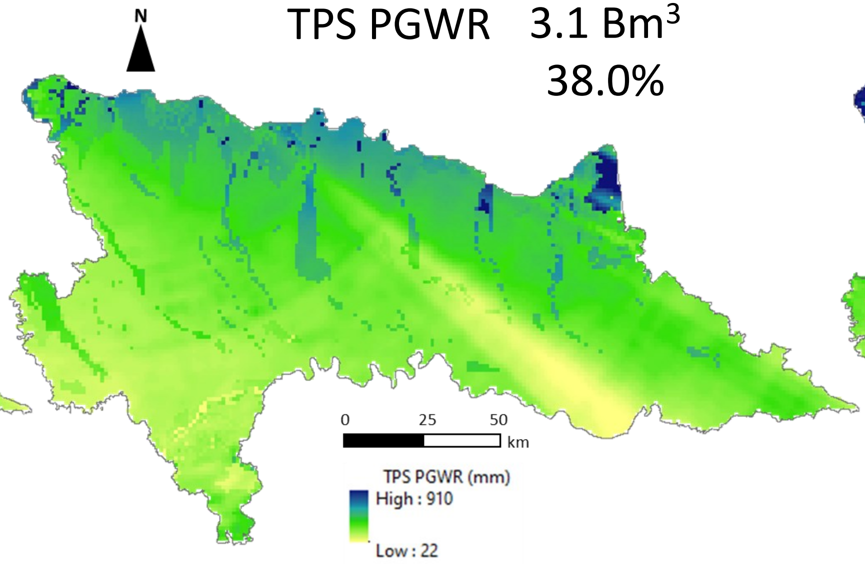
BIGBANG PGWR 4.3 Bm^3



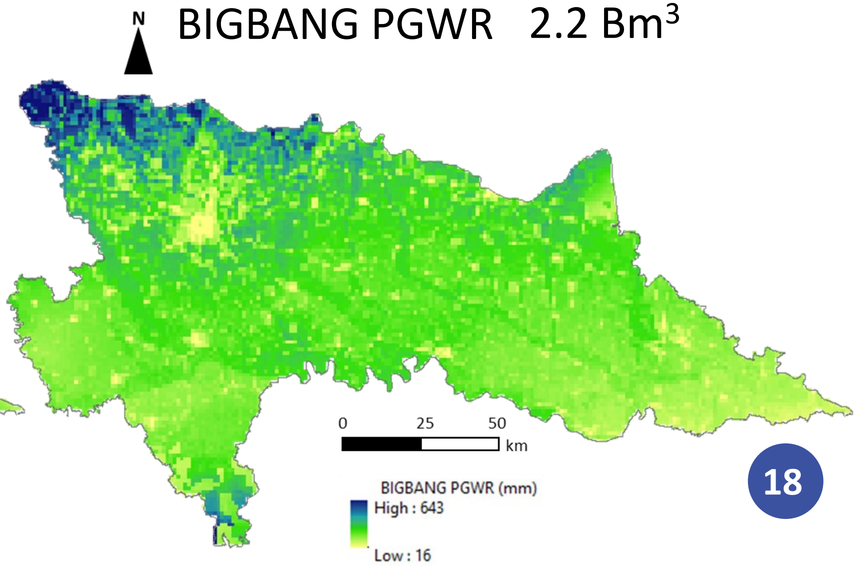
IDW PGWR 1.5 Bm^3 -30.3%



TPS PGWR 3.1 Bm^3 38.0%



BIGBANG PGWR 2.2 Bm^3



Final Remarks

- The mean annual cumulative **precipitation was** successfully **corrected** by integrating data from rain gauges of the Italian network. For instance, **KGE values increase** from 0.50 to 0.78-0.80.

- The **mean annual** Potential GroundWater Recharge (**PGWR**) in the study area in the **2011-2020 period ranges** between **5.8 Bm³** (IDW) **and 7.7 Bm³** (TPS).

- **Comparison with** ISPRA's national project - **BIGBANG** - revealed a **good agreement** with the research results from the point of view of the magnitudes involved, both for precipitation and PGWR, although two different computational methods have been used.

- By considering the precipitation entering the system, the **percentage of water available to infiltration** is around:

	IDW	TPS	BIGBANG
P (m^3)	2.57E+10	3.13E+10	2.75E+10
PGWR (m^3)	5.80E+09	7.70E+09	6.50E+09
%	**22.57**	**24.60**	**23.64**
P mount (m^3)	1.44E+10	1.53E+10	1.49E+10
PGWR mount (m^3)	4.2E+09	4.7E+09	4.3E+09
%	**29.17**	**30.72**	**28.86**
P plain (m^3)	1.13E+10	1.6E+10	1.24E+10
PGWR plain (m^3)	1.5E+09	3.1E+09	2.2E+09
%	**13.27**	**19.38**	**17.74**

which shows that, potentially, **more water is available in the mountainous area for infiltration** than in the lowlands. However, a more complex water balance equation and the introduction of other geomorphological variables (e.g., slope) should be considered to get a comprehensive view of the phenomenon.

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Next steps

This pilot case study in Lombardy Region **demonstrates the practical application of radar technology** and highlights its importance **for managing water resources.** To make this methodology as operational as possible, actions on several fronts are required. **A Master's thesis study** (Matilde Di Nardo) is currently testing multiple approaches to **improve the research project**:

The annual scale has been used for exploratory purposes only: it will **move down** in resolution **to the event scale**.

The weather station database will be expanded including rain-gauges at the border of the Region (Switzerland and neighboring Regions)

Other residual interpolation techniques (rain-gauges/radars), not only deterministic but also geostatistical (e.g., kriging) **will be tested**.

A more **elaborated water balance equation** will be applied **to obtain more accurate results** considering the complexity of the phenomenon.

References

Andersson, J. C., Arheimer, B., Traoré, F., Gustafsson, D., & Ali, A. (**2017**). Process refinements improve a hydrological model concept applied to the Niger River basin. Hydrological Processes, 31(25), 4540-4554.

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Thank you for the attention!

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