IMPACT OF CLIMATE CHANGE IN CONTAMINATION VULNERABILITY OF MESOZOIC KARST AQUIFERS IN BURGOS AREA (SPAIN).

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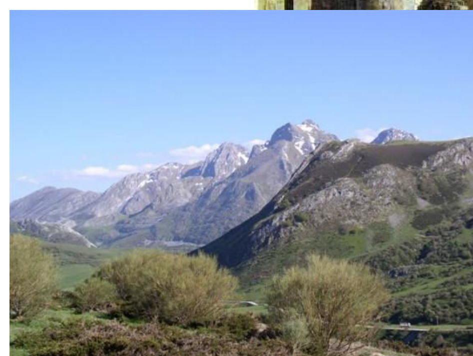

Aquifers in Spain

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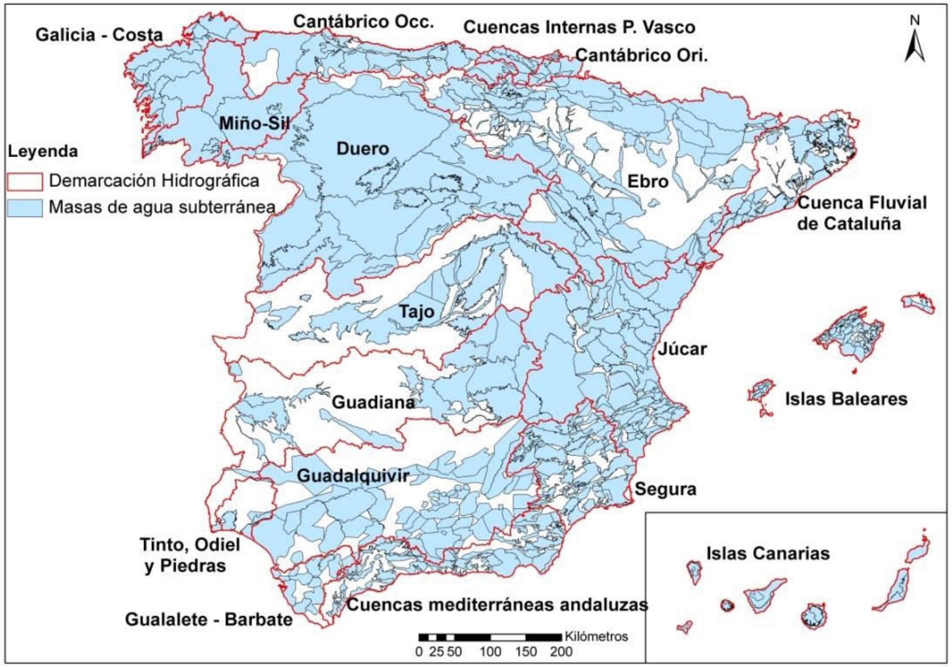
- Spain is among the most arid countries in the EU, with a large hydrogeologic potential with 699 groundwater bodies widely distributed.
- Annual aquifer recharge is about 30% of the total water resources available, mainly used for irrigation, and often concentrated in exploited aquifers in the Mediterranean side.
- Duero Basin is the largest in the Iberian Peninsula, with a surface of 97.290 km2. Climate is Mediterranean, continental.
- The average annual rainfall varies in the range of 400 mm/year in the central depression to 1800 mm/year. Rainfall is irregular, falling mainly from autumn to spring.



- It has a population of 2.2 million, mainly located in the most important cities, with rural areas very unpopulated.
- In the depression predominate tertiary and quaternary detrital aquifers, but Mesozoic karstic aquifers in the surrounding mountain areas.

High Arlanza Basin

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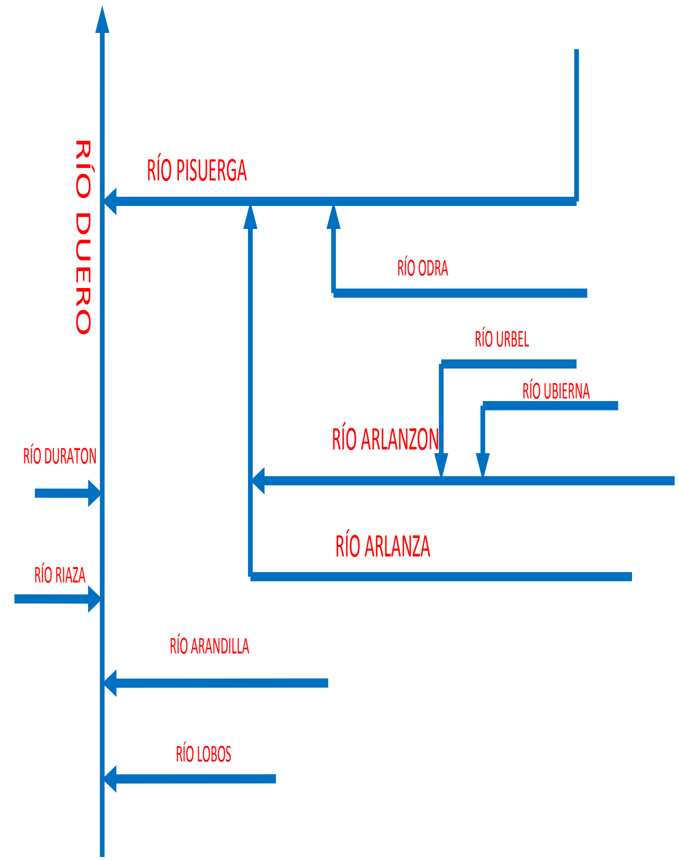

High Arlanza Karstic Aquifers (I)

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- Arlanza basin at the headwater has important karstic aquifers, mainly developed on Mesozoic limestone.
- Unit Surface: 2500 km2.
- Groundwater Resources: 1100 hm3.
- Rainfall recharge: 160 hm3/year.
- Recharge from rivers: 6 hm3/year.
- Pumping discharges: 1 hm3/year.
- Aquifers discharges: 60 hm3/year.
- Main discharges:
  - Total: 105 hm3/year.
  - Big springs (100-500 l/s): 35 hm3/year.
  - Rivers: 55 hm3/year.
  - Diffuse discharges: 15 hm3/year.

High Arlanza Karstic Aquifers (II)

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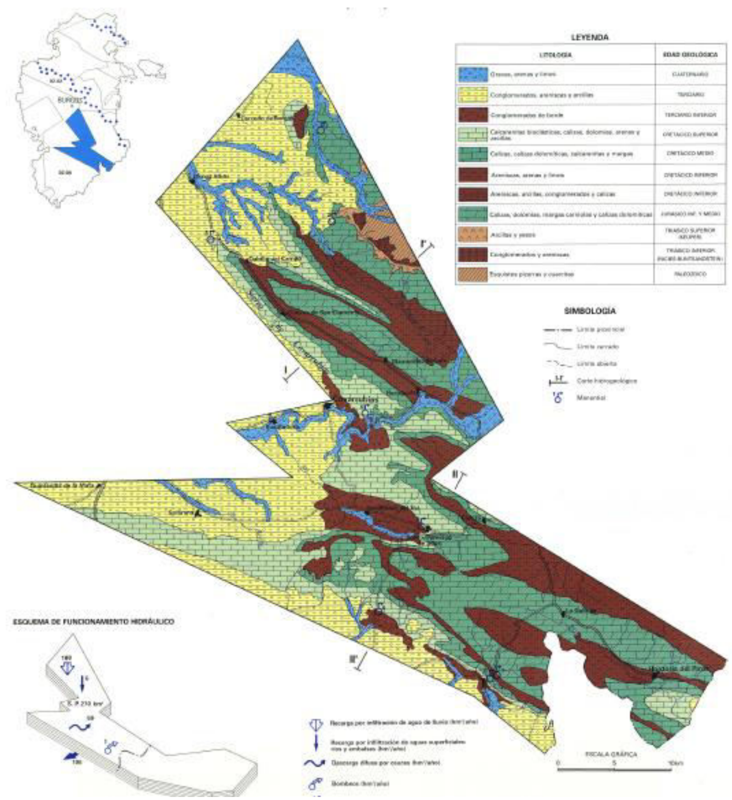

High Arlanza Karstic Aquifers Hydrochemistry

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- 107 groundwater samples.
- Big springs.
  - Medium conductivity
  - Ca-Mg-HCO3
- Small Springs.
  - Low conductivity
  - Ca-HCO3.
- Detrital aquifers.
  - Very low conductivity
  - Ca-HCO3

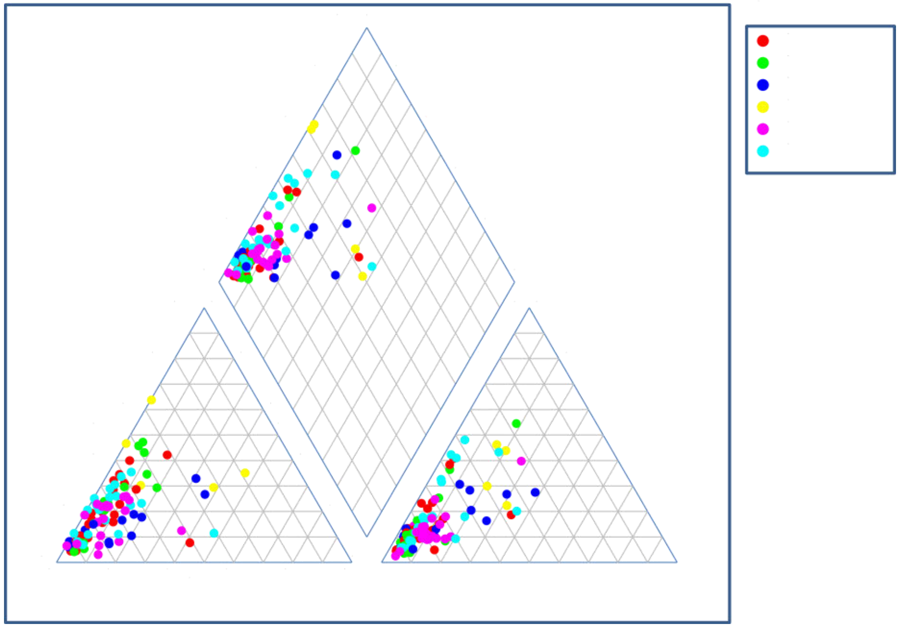

Diagrama Piper de todas las muestras

Multivariate Analysis

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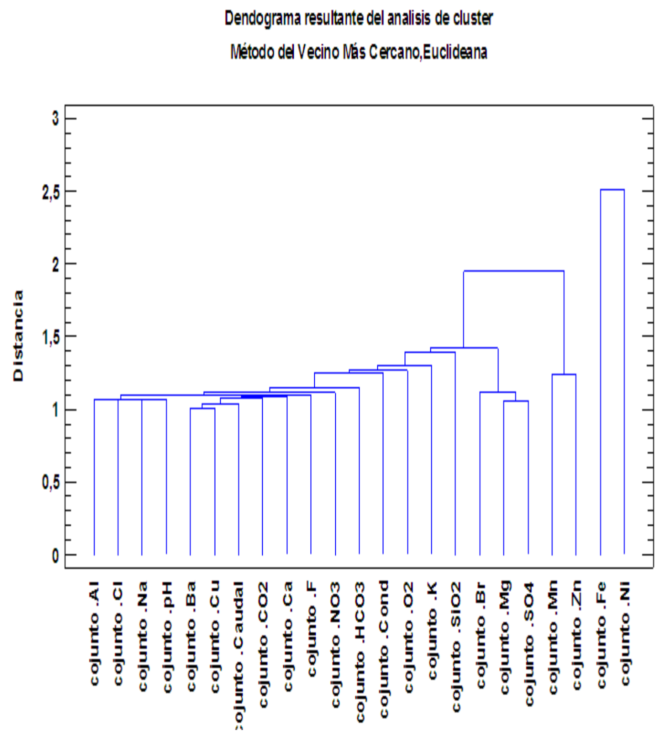
- Cluster of chemical variables based in lithological factors:
- Fe-Ni.
- Mn-Zn.
- Mg-SO4-Br.
- SiO2.
- K-HCO3-Ca-NO3-F-CO2.
- Al-Cl-Na-pH.



Factor Analysis (I)

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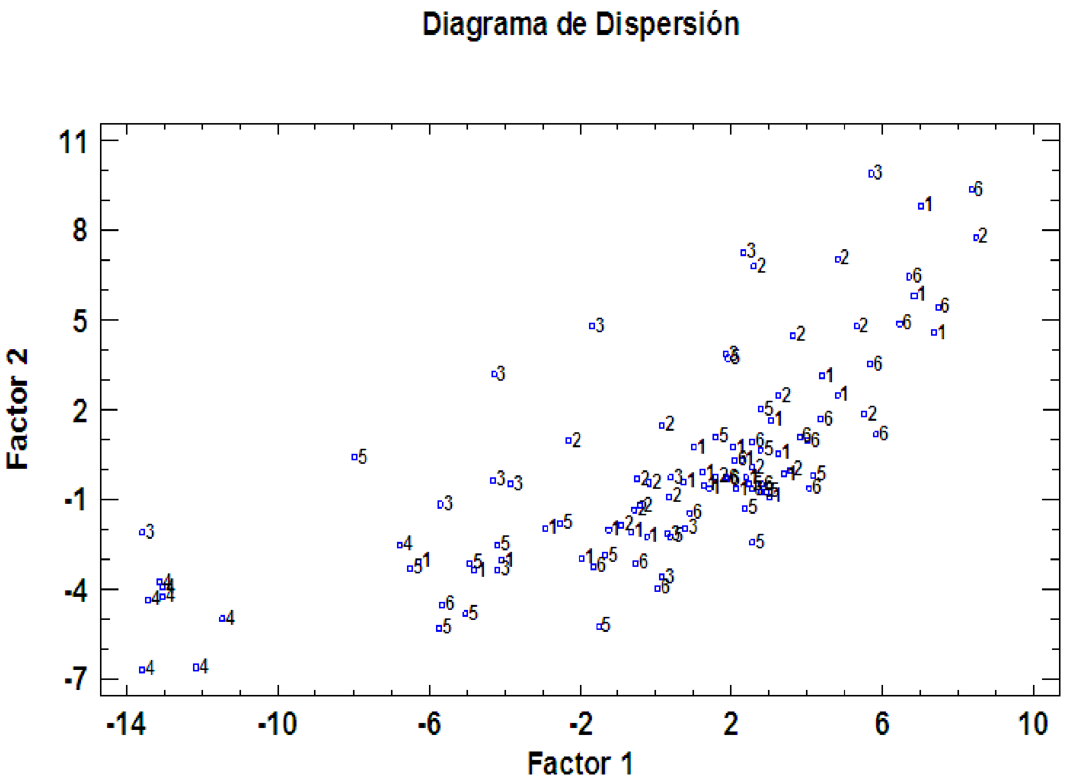
Factor Analysis and Variables Clustering:

- Factor 1:
  - Cond-Ca-HCO3-pH-Mg-SO4.
- Factor 2:
  - NO3-Na-Cl-Ba-K-SiO2.

Componente Número	Eigenvalor	Porcentaje de Varianza	Porcentaje Acumulado
1	4,52091	21,528	21,528
2	2,68487	12,785	34,313
3	2,23023	10,620	44,933
4	1,61034	7,668	52,602
5	1,39123	6,625	59,227
6	1,25571	5,980	65,206
7	1,15821	5,515	70,721
8	0,960915	4,576	75,297
9	0,890213	4,239	79,536
10	0,744311	3,544	83,081
11	0,695074	3,310	86,390
12	0,63278	3,013	89,404
13	0,554011	2,638	92,042
14	0,485167	2,310	94,352
15	0,358422	1,707	96,059
16	0,223088	1,062	97,121
17	0,18692	0,890	98,011
18	0,177053	0,843	98,854
19	0,149607	0,712	99,567
20	0,0771388	0,367	99,934
21	0,0138118	0,066	100,000

Factor Analysis (II)



Vulnerability DRASTIC

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- Altitude: 800-1200.
- Slope: 2-30%
- Ann. Tª: 8,5-10,5 ºC.
- Ann. Rainfall: 600-1100 mm.
- Ann. Infiltration: 80-300 mm.
- Depth Water: 40-150 m
- Hydraulic conductivity: 1x10-4 – 3x10-3
- DRASTIC INDEX: 20-60.

Tabla 1

Peso de cada variable según su importancia de acuerdo con DRASTIC

PARÁMETROS	Peso (W) General	Peso (W) Pesticidas
D- Deep Water (Profundidad del acuífero) (m)	5	5
R- Recharge Net (Recarga Neta) (mm/año)	4	4
A- Aquifer media (Tipo de Acuífero)	3	3
S- Soil Media (Tipo de Suelo)	2	5
T- Topography (Topografía, Pendiente) (%)	1	3
I- Impact of Vadose Zone (Impacto de la Zona Vadosa)	5	4
C- Conductivity, Hydraulic (Conductividad Hidráulica del Acuífero) (m/día)	3	2

Climate Change Impacts (I)

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<u>Models for 2071-2100 show scenarios in North Central Spain (Arlanza Basin):</u>

- T summer +5-6ºC.
- T winter +2ºC.
- P summer -0,25 mm/d.
- P winter ===.
- Annual P – 8%
- PET increases.
- Water Resources – 20%

<u>Effects on Groundwater:</u>

- Aquifer Recharge -25%
- Dry up small Springs.
- Big Springs Flow reduced.
- River Flow reduced.
- High impact in flow by extreme droughts.
- Deep Water Table.
- Increase of Water Demand.
- Reduction on permeability.

Climate Change Impacts (II)

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Water Quality:

- Increase in CO2 concentration.
- Increase in Limestone disolution.
- Increase in dust feed.
- Increase in chemical from forest fires.
- Increase in Residence time in Karst Aquifers.
- Increase Conductivity and Dissolved Solids in Water.
- Organic Metabolites increased.

Conclusions

- More control and research on Climate Change effects.
- Reduction on Greenhouse Gases Emissions.
- Increasing Aquifer Artificial Recharge.
- Use of Aquifers as buffers systems.