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Severe drought in Catalonia: An anomaly or a new normal?

Analyzing 70 years of climate and water resources data in Catalonia using the ZeroError approach

New York & Barcelona, Feb 2025

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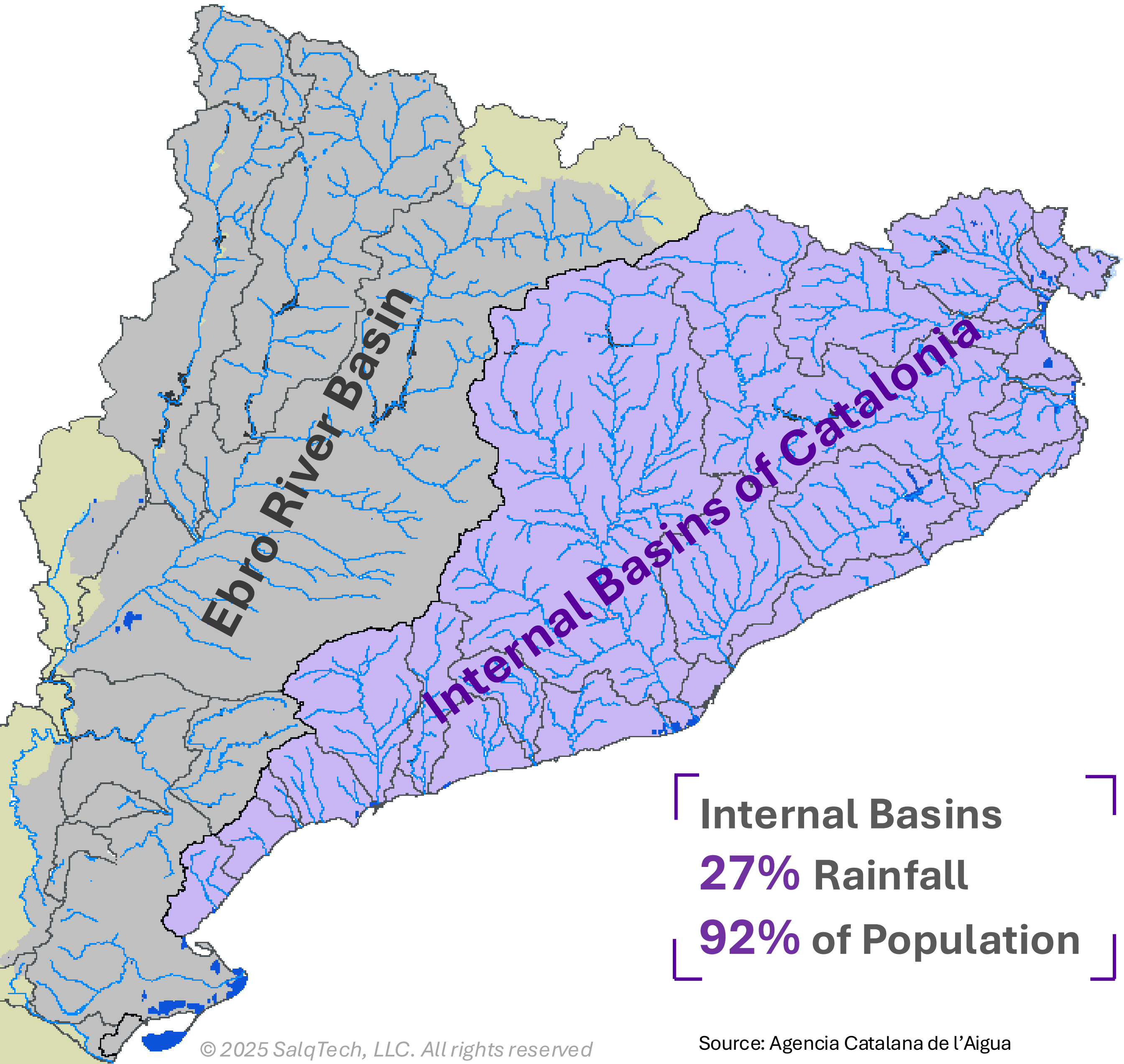


Internal Basins
27% Rainfall
92% of Population

Source: Agencia Catalana de l'Aigua

A Tale of Two Regions

Catalonia's hydrological landscape is distinctly bifurcated, delineated by its geographical structure, river systems, and water distribution patterns. This division gives rise to two primary regions: the Ebro River Basin (Conca Catalana Ebre) and the Internal Basins of Catalonia (Conques Internes Catalanes).

A stark contrast exists between these two regions. The Ebro River Basin encompasses 48% of Catalonia's land area, receives a substantial 73% of the region's precipitation, and boasts a reservoir capacity of 2,279 hm^3. Conversely, **the Internal Basins, despite housing 92% of Catalonia's population, receive only 27% of the total precipitation and possess a significantly smaller reservoir capacity of 694 hm^3**. This disparity means the Internal Basins contend with approximately one-third of the precipitation and reservoir capacity available to the Ebro River Basin.

Crucially, the concentration of population within the Internal Basins (92%) means that **discussions of drought in Catalonia are, in essence, discussions of water scarcity within the Internal Basins**. Therefore, this study focuses exclusively on the hydrological challenges and vulnerabilities of the Internal Basins of Catalonia, recognizing their unique susceptibility to water scarcity.

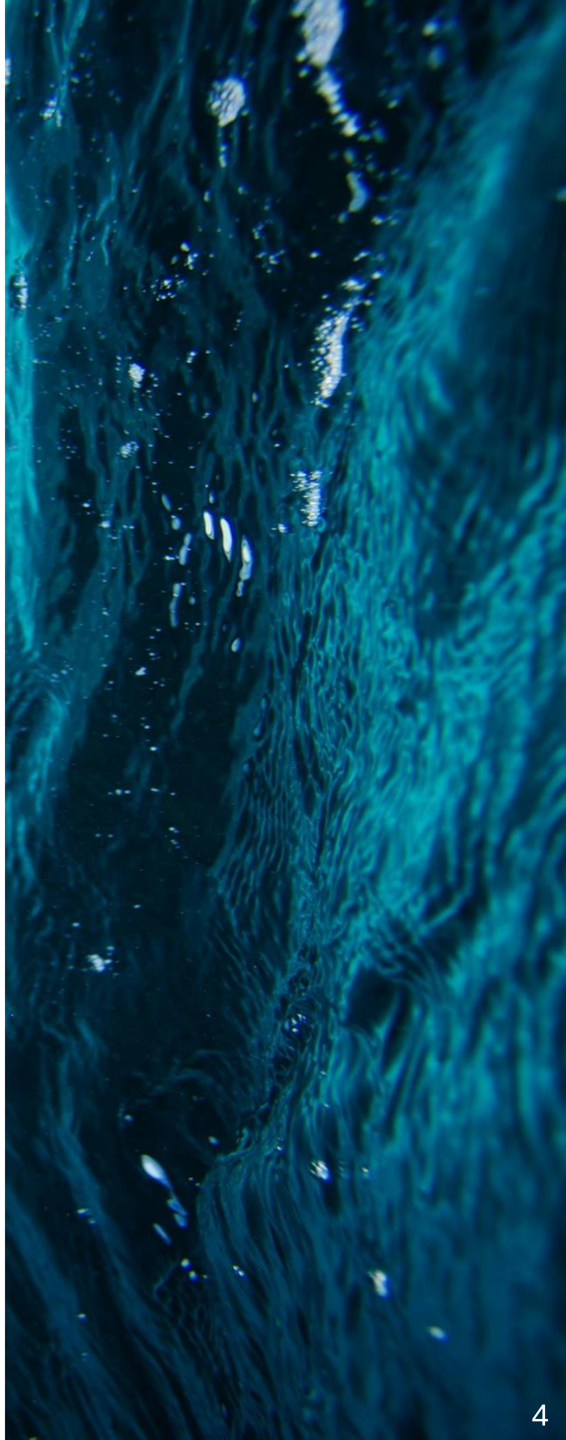
Summary of Findings

This study aims to clarify and provide insight into Catalonia's evolving water availability. **Focusing on recent drought drivers, we seek to understand the growing risk of future water scarcity.** To achieve this, we employed ZeroError to analyze three extensive time series datasets: (1) daily temperature and precipitation, (2) daily reservoir levels, and (3) district (Comarca) water consumption.

The study's key takeaway is that Catalonia's water scarcity risk is increasing, particularly in the Internal Basins due to high population density, lower precipitation, and limited reservoir capacity. This conclusion is based on three primary findings:

1. Clear evidence of rising temperatures and increased frequency of low precipitation periods.
2. **Reservoirs demonstrate high susceptibility to low precipitation and high temperatures; severe scarcity can result from a few exceptional months.**
3. Consumption efficiency is nearing best-in-class, limiting its effectiveness as a palliative measure for water scarcity.

We conclude that Catalonia's Internal Basin regions have likely **entered a "new normal," with more frequent dramatic reservoir level declines**. Reduced consumption appears insufficient to combat water scarcity. Therefore, investments in new water supply sources should be prioritized to ensure water independence.

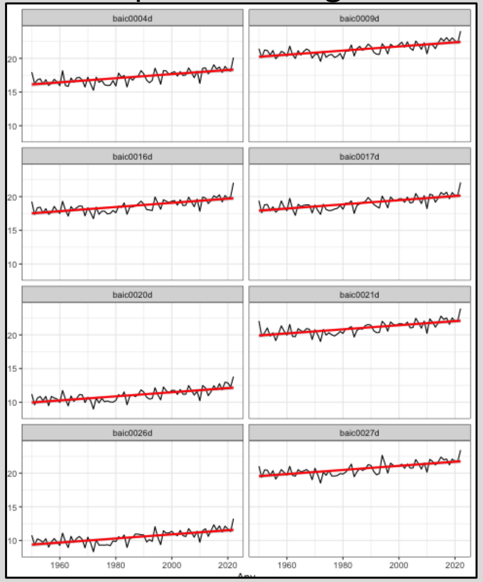


Is climate changing in Catalonia?

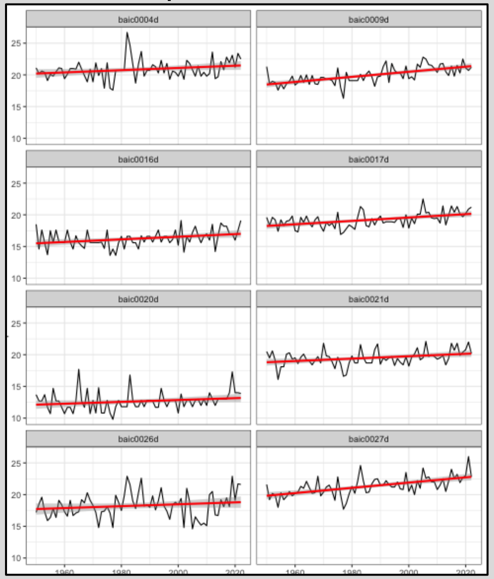
Analysis of precipitation and temperature trends

Internal Basins: Temperature Trends

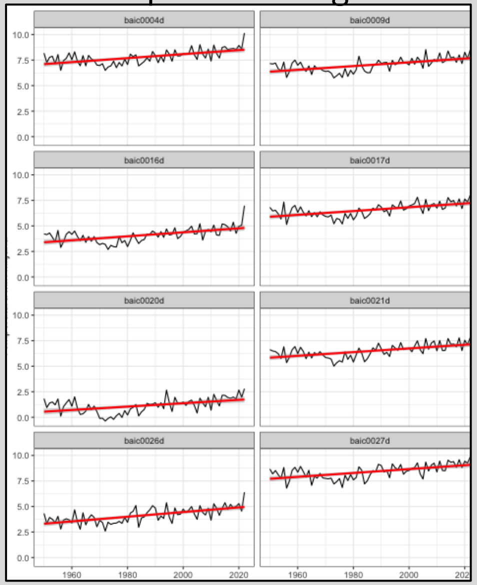
Temp Max Average



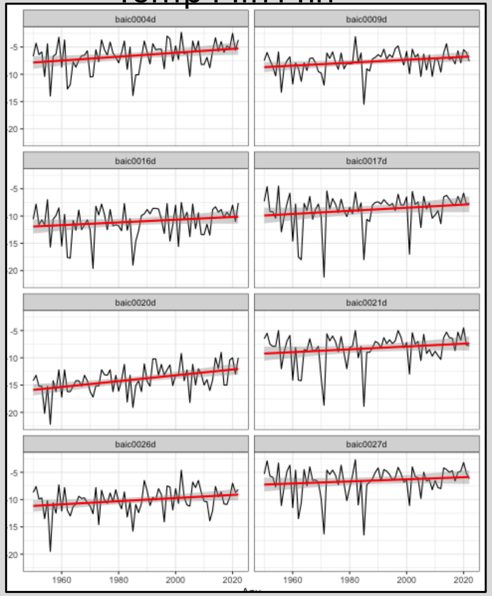
Temp Max Max



Temp Min Average



Temp Min Min



Source: Dades Obertes; Datancia Analysis

Climate Trend

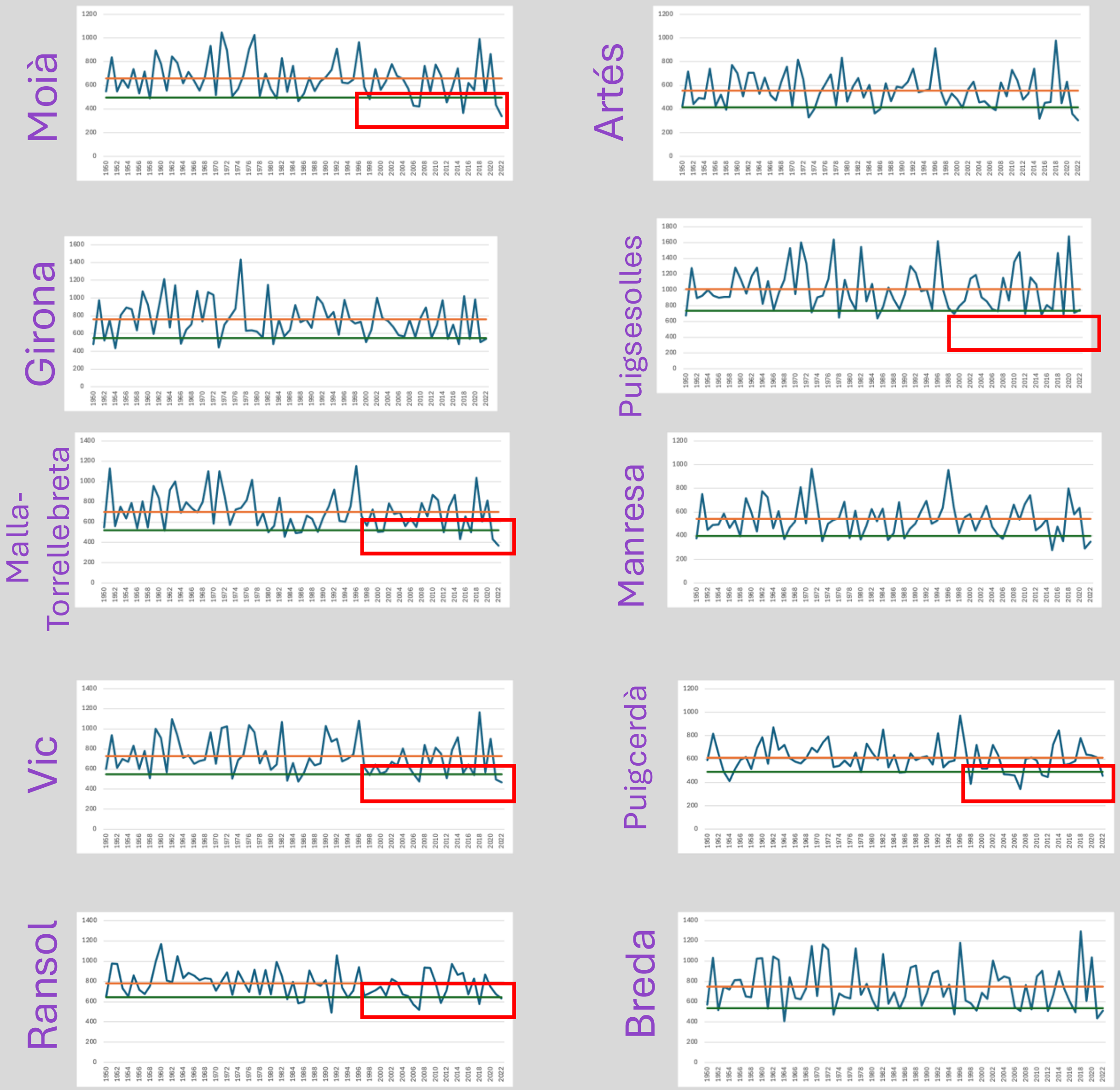
Daily Data – 1950 to 2022

This study has analyzed daily climate data series for 72 weather stations across Catalonia. ZeroError and Datancia analyzed a data set of 3.5 million data points including daily precipitation and daily minimum and maximum temperature. This rich dataset allows us to see how precipitation and temperature have evolved since 1950, giving us insight into trends, fluctuations, and differences or similarities across locations.

The first major observation should not be a surprise: **temperature trends show increases across the board, in all locations and for both maximum and minimum daily temperatures.**

All weather stations show a consistent temperature increase trend over the last 70 years

Internal Basins: Annual Precipitation by Station



Source: Dades Obertes; ZeroError Analysis

At a first glance, the precipitation patterns have remained similar from 1950 to 2022. Average precipitation in weather stations across Internal Basins remained fairly stable with high precipitation periods every few years.

Basic time-series statistical methods like trend analysis and moving averages tell us that average precipitation is generally constant or maybe moving slightly downward but not in a meaningful way. Volatility analyses do not indicate a dramatic change in size of fluctuations, given that seasons with high peaks have always existed.

The majority of weather stations are showing a higher frequency of low precipitation years since 2000

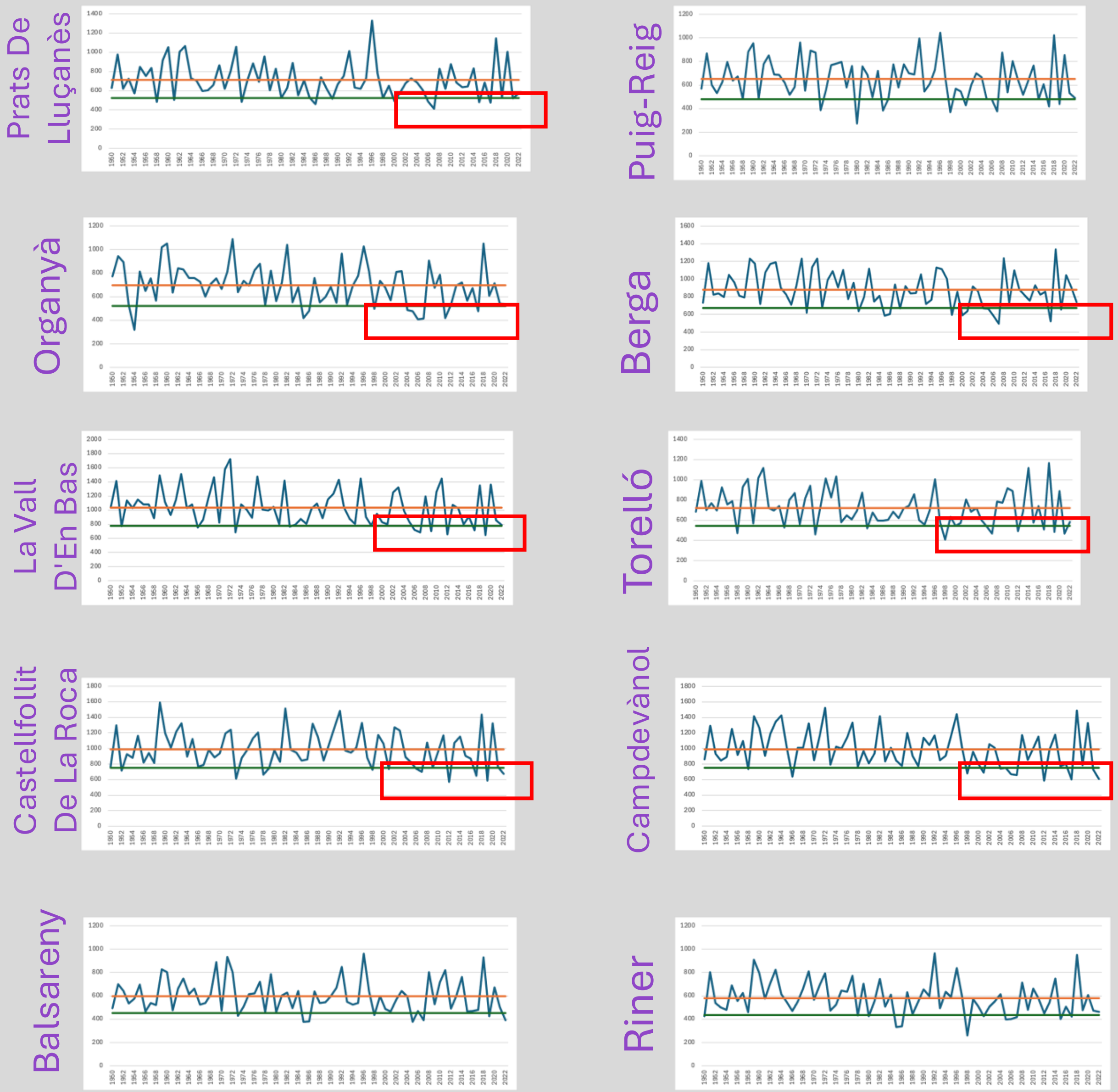
However, ZeroError analysis has identified one type of potential anomaly that is worth exploring. **Since 2000, there has been an increase in the frequency of years where annual precipitation is significantly lower than historical average.**

ZeroError impact analysis ranked all the years from 1950 to 2022 based on the number of locations that have exceptional low precipitation in any given year. The score was based on a combination of annual, monthly, and daily precipitation metrics. Each of them compared against the historical behavior within each location.

6 of the top 10 worst precipitation years since 1950 happened after 2006

Since the early 2000s, Catalonia has experienced an increase in the frequency of years with an exceptionally low level of precipitation across a large percentage of the weather stations population. Therefore, **while average precipitation is still aligned with historical levels, the probability of having a low precipitation year, or multiple low precipitation years in a row is likely increasing**

Internal Basins: Annual Precipitation by Station



Source: Dades Obertes; ZeroError Analysis

When temperature and precipitation metrics are combined using Zero Error impact analysis, it reveals that 9 out of the 10 worst years, in terms of high temperature and low precipitation, have occurred since 2001. Furthermore, 7 of those occurred since 2011, indicating a potential acceleration of trends toward hotter and drier years.

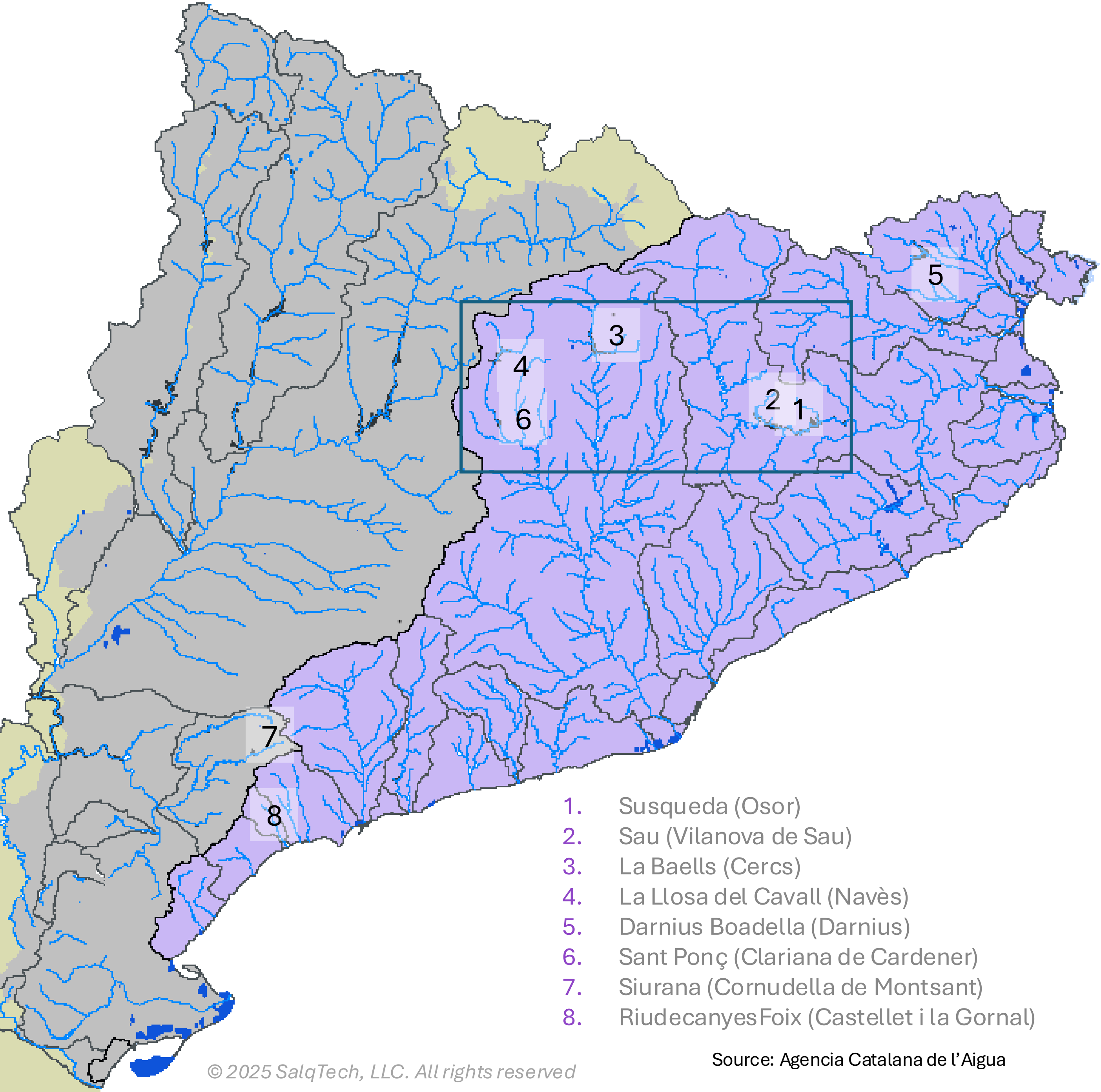
Catalonia has likely entered a "new normal" where exceptionally low precipitation years, combined with high temperatures, occur more frequently.

YEAR	LowRainDays	LowAnnualPrec	LowPrecMonths	HighAnnualTempHighs	HighAnnualTempLows	HighTempeMonths	Alerts
2017	14	37	8	8	4	5	
2006	12	68	8	8	7	5	
2022	12	61	8	8	43	5	
2021	11	33	6	8	1	5	
2012	10	61	6	8	4	5	
2015	8	34	8	8	20	5	
2019	8	56	8	8	1	5	
2001	7	31	1	8	1	5	
2011	3	49	7	8	9	5	
1994	1	32	7	8	9	5	

Source: Dades Obertes; ZeroError Analysis

Impact of temperature and precipitation changes on Reservoirs

Analysis of reservoir levels – patterns, trends, and anomalies



1. Susqueda (Osor)
2. Sau (Vilanova de Sau)
3. La Baells (Cercs)
4. La Llosa del Cavall (Navès)
5. Darnius Boadella (Darnius)
6. Sant Ponç (Clariana de Cardener)
7. Siurana (Cornudella de Montsant)
8. RiudecanyesFoix (Castellet i la Gornal)

Source: Agencia Catalana de l'Aigua

Reservoir Levels

Analysis of Daily Reservoir Levels since 2000

Reservoirs are a key "safety net" for regional water systems. Catalonia's Internal Basins have a total reservoir capacity of 694 hm^3. To put this in perspective, this number is only one-third of the Ebro River Basin's capacity. Furthermore, this capacity can approximately support only 13 months of consumption.

Susqueda	→	233 hm3
Sau	→	165 hm3
La Baells	→	109 hm3
La Llosa del Cavall	→	80 hm3

An additional observation is that reservoir capacity is concentrated in four key reservoirs within a relatively small area. Consequently, precipitation and temperature in the areas surrounding Susqueda, Sau, La Baells, and La Llosa del Cavall can have a dramatic impact on the overall "safety net" capacity.

80% **of the reservoir water for the Internal Basins is concentrated in four locations.**

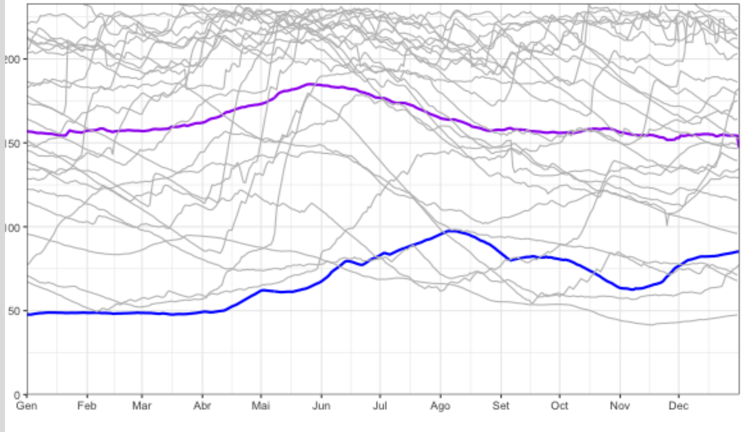
An analysis of daily reservoir levels for the last 24 years show that reservoirs follow a consistent seasonal pattern. As expected, reservoir levels grow during spring months and then decline in summer and early autumn.

2024 Reached the lowest levels across the three major reservoirs in the Internal Basin

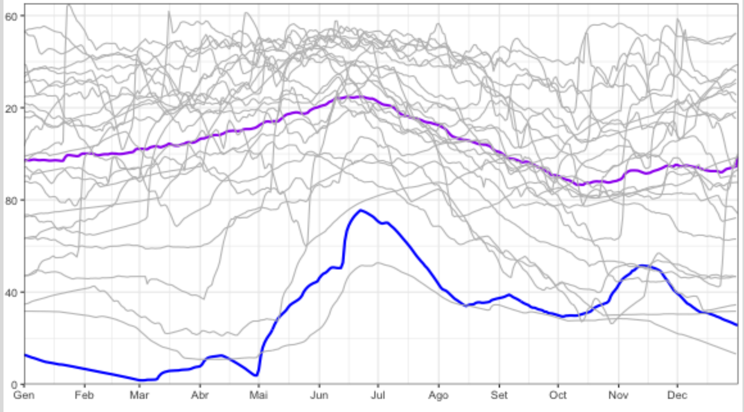
Reservoir Levels

hm3

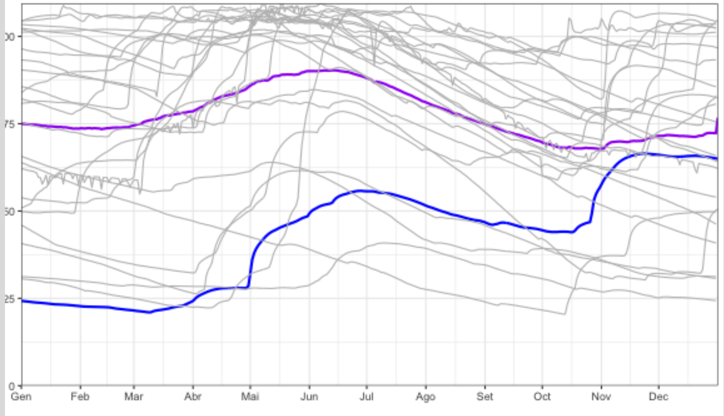
Susqueda



Sau



La Baells



Average 2024

Source: Dades Obertes; Dataancia Analysis

To understand what drives sharp reservoir level declines, ZeroError explored machine learning models, assessing how temperature and precipitation predict major drops.

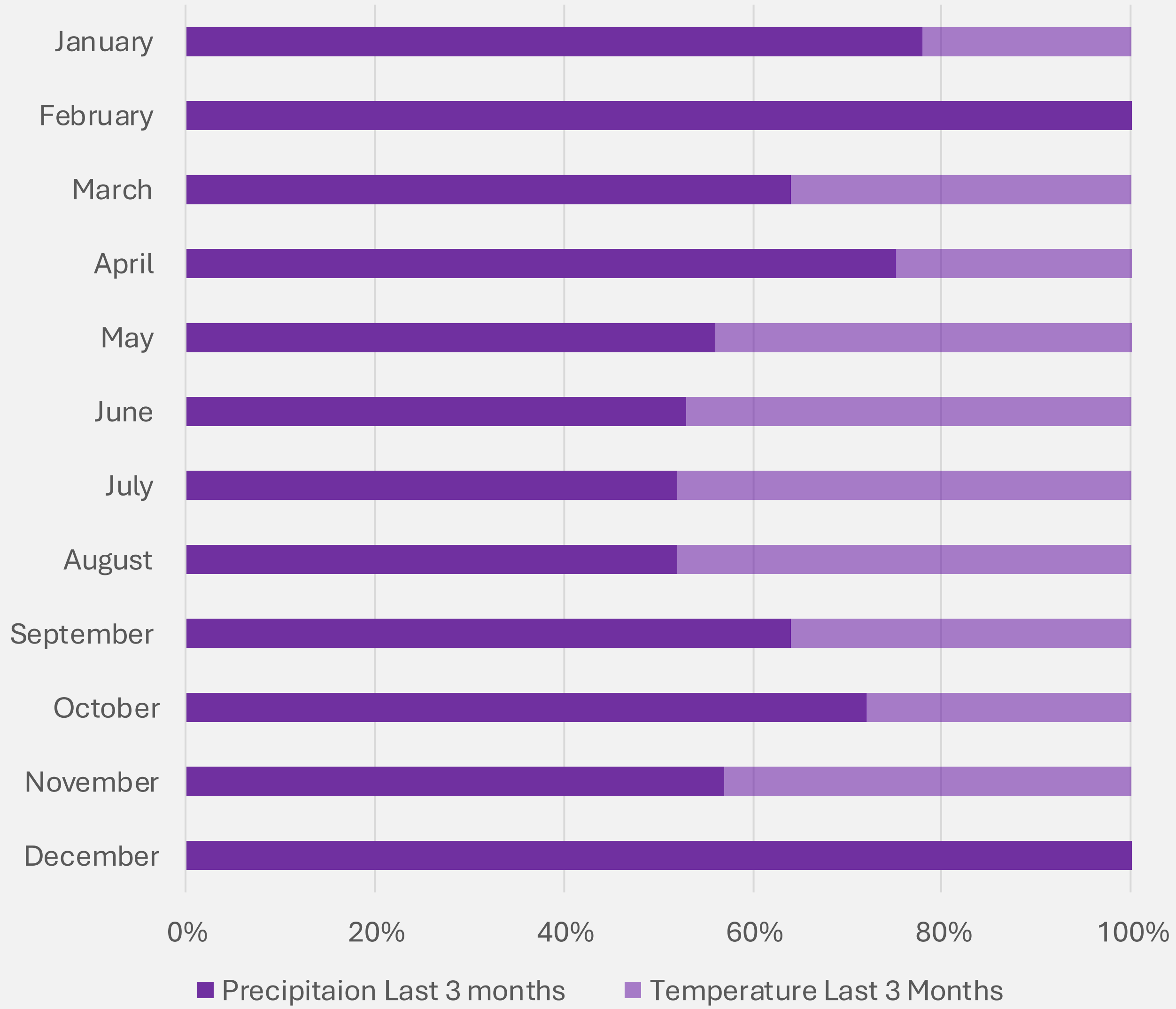
Key findings: Models predicted roughly 90% of major declines using only the previous three months' precipitation and temperatures. As expected, precipitation was a primary driver. Notably, high temperatures had a similar impact to low precipitation, particularly in summer.

Additionally, the models suggested a monthly capacity loss of 6%-12%, higher in summer and lower in winter.

90% **of reservoir levels changes can be explained by recent precipitation and temperature**

Relative Importance of Precipitation vs Temperature to Explain Reservoir Level

Estimate based on Machine Learning Model Weights Given to Precipitation and Temperature Predictors



Source: Dades Obertes; ZeroError Analysis

Reservoir levels highly susceptible to precipitation and temperature conditions from previous months

+

Increasing frequency of periods with low precipitation and high temperatures

=

Increasing frequency of situations of severe water scarcity

Reservoir levels are highly sensitive to low recent rainfall and high summer temperatures. With an approximate 8% monthly loss, these conditions rapidly deplete reservoirs, leading to water scarcity.

Given the increasing frequency and severity of high temperatures and low precipitation, significantly below-average reservoir levels are likely to become more common.

Evolution of Consumption

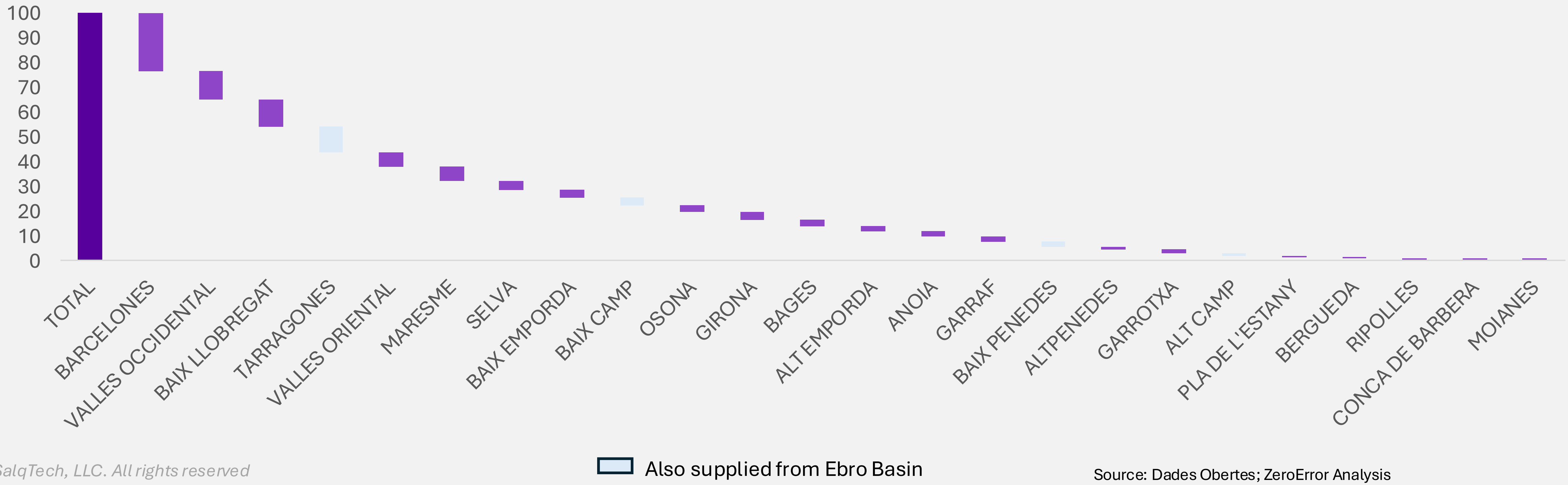
Analysis of consumption trends, behaviors and anomalies

This study analyzed domestic and commercial water consumption across districts. Consumption generally aligns with population, except in industrial areas where commercial use significantly impacts demand. As expected, densely populated and industrial districts drive the highest water consumption.

70% of water comsumption is concentrated in only 6 districts (Comarques)

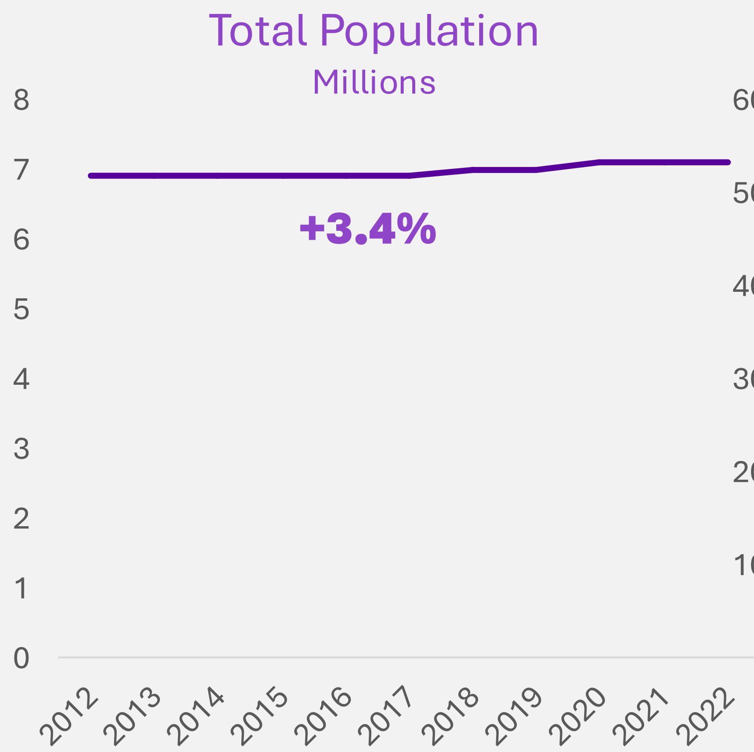
Internal Basins: Consumption

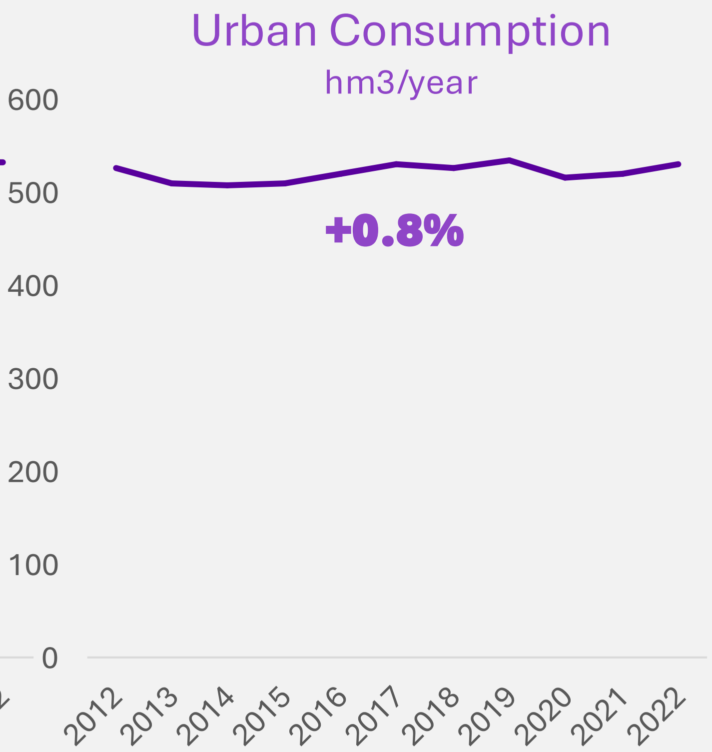
Percentage

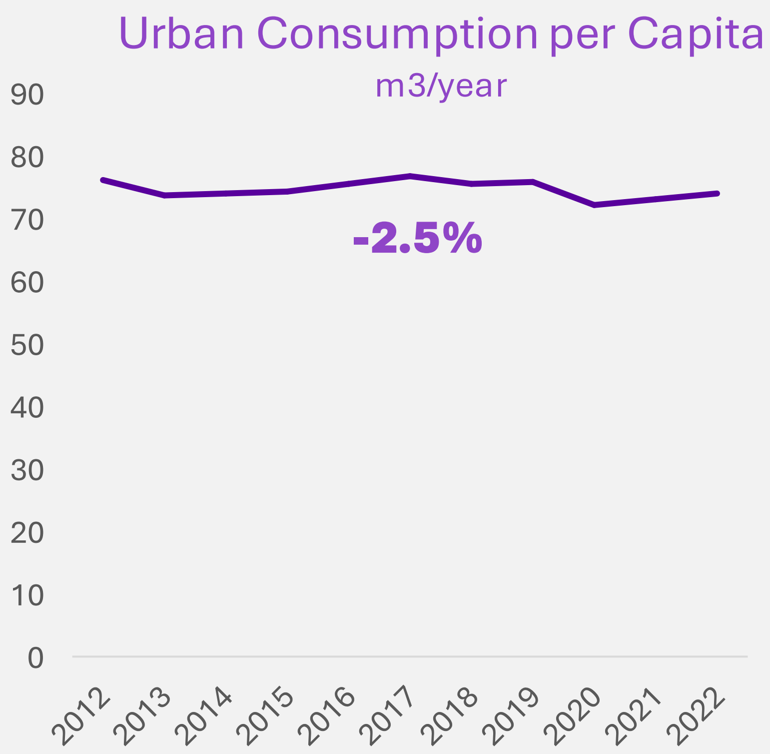


Source: Dades Obertes; ZeroError Analysis

Internal Basins: Evolution of Consumption







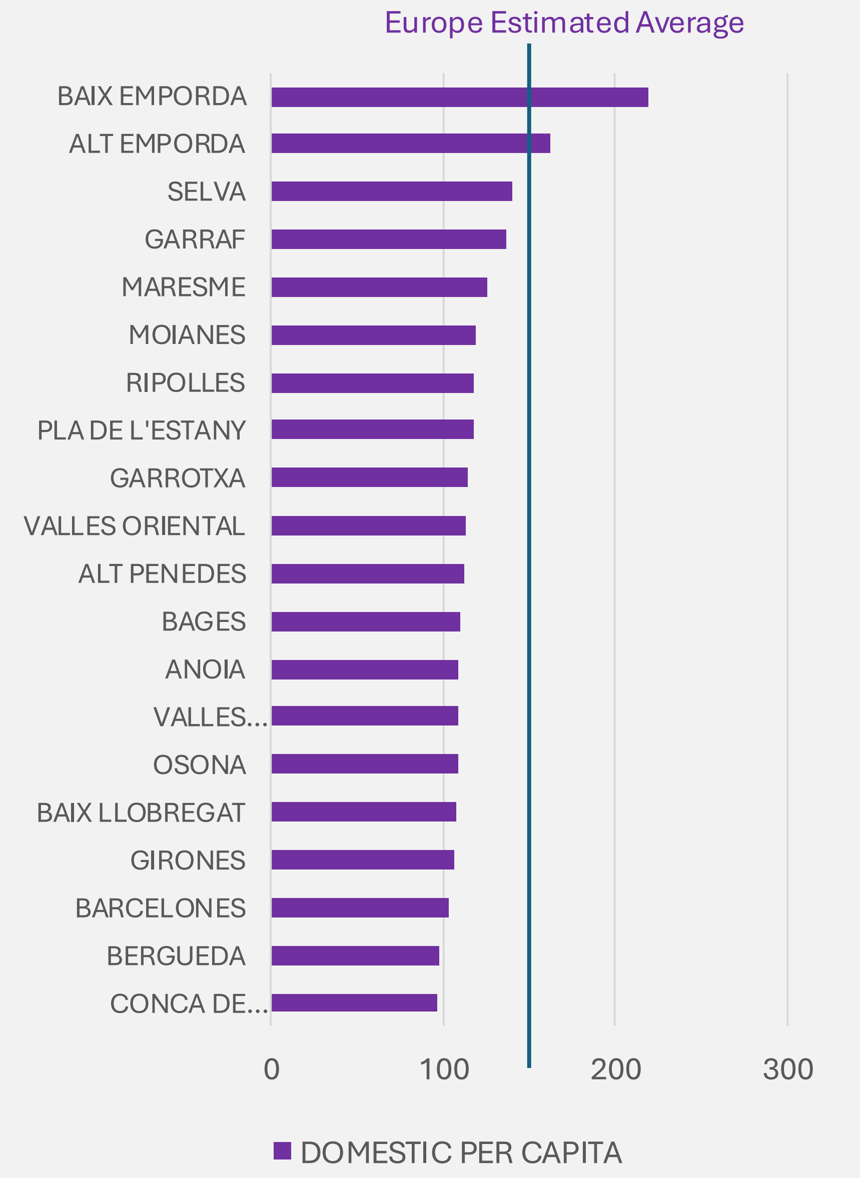
Notably, water consumption growth has significantly trailed population growth, demonstrating improved water efficiency in Catalonia's Internal Basins region. This reduction in per capita consumption likely reflects advancements in distribution systems and shifts in consumption behavior, potentially motivated by recent water scarcity events.

This positive trend prompts the question: **is there scope for further meaningful improvement?**

Source: Dades Obertes; ZeroError Analysis

Domestic Consumption per Capita

Liters/Day



Source: Dades Obertes; ZeroError Analysis

ZeroError methodology uses anomaly detection to identify improvement opportunities. High ZeroError quality scores generally signify low data anomalies, indicating limited potential for further improvement.

This is the case for water consumption in the Internal Basin. Metrics show low anomaly levels compared to internal and external data. External benchmarks reveal per capita consumption aligned with, or better than, other regions. Internal consistency analysis (comparing districts and years) shows few significant deviations, mostly explainable by higher commercial activity.

In summary, while some improvement in water consumption efficiency may exist, Catalonia's Internal Basins is likely near "best-in-class." Relying solely on consumption efficiency gains may prove challenging

.

We conclude that **Catalonia's Internal Basins region has likely entered a "new normal", where dramatic low levels in Reservoirs will happen more frequently.** Lower consumption does not seem a viable option to fight water scarcity. Therefore, efforts to invest in new sources of water supply should be welcomed and prioritized, to ensure water independence.

Water Supply
Low precipitation, high summer temperatures, and low reservoir levels likely to happen more frequently

Water Demand
Probably reached close to "best-in-class"; further improvements could prove to be extremely hard

Path to Water Independence and Resilience
Efforts to invest in new source of water supply should be welcomed and prioritized

Authorship & Acknowledgments

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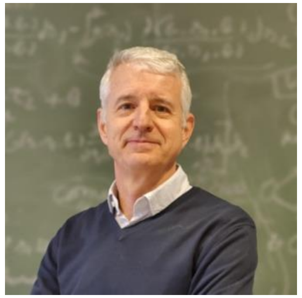

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About ZeroError

ZeroError is a fast, scalable and highly automated AI-driven Data Quality platform for large corporations and mid-size companies. This presentation is provided for information purposes only and should not be relied upon for any other use.