Hydrogeochemical and isotopic tools to characterize the salinization processes of crystalline fractured aquifers in semi-arid regions

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INTERNATIONAL CONFERENCE

GROUNDWATER, KEY TO THE SUSTAINABLE DEVELOPMENT GOALS

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Introduction and research context

→ Climate

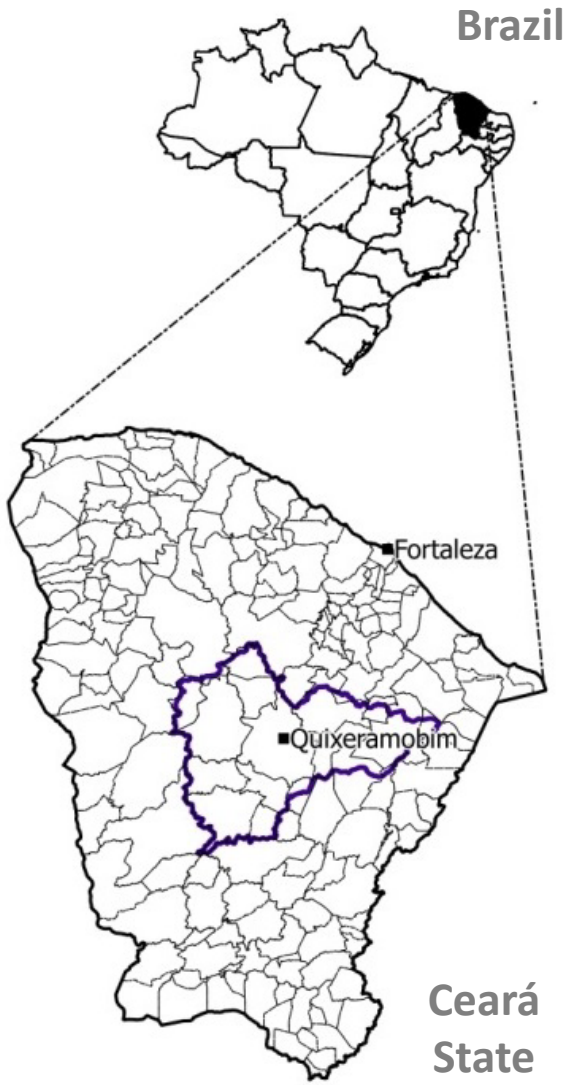
In semi-arid Northeastern Brazil → High water deficit (> 1000 mm/yr)

- P annual < 800 mm
- High rates of PET

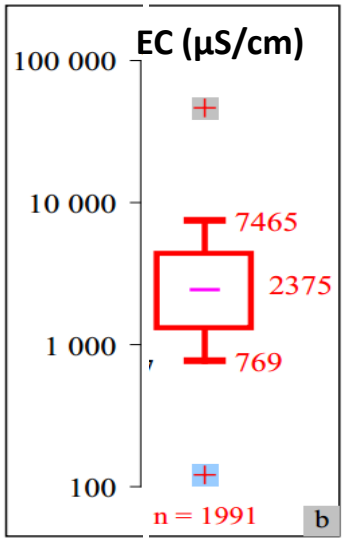
→ Water Resources

Surface water stored in dams during the rainy season dries up during prolonged droughts

Groundwater = only reliable water resource for rural communities **=> SDG 6 !!!**



In Ceará, Crystalline fractured aquifers = dominant geologic feature, HOWEVER :



Burte,2008

HIGH GROUNDWATER SALINITY OF CRYSTALLINE AQUIFERS
Despite the presence of youngs waters...

→ Origin and dynamics of the groundwater salinity ?

Origin of the water ? Water residence times ?
Recharge processes ? Origin and type of salts ?

Methodology

→Hydrodynamic study: multi-tracer approach combined with piezometric monitoring

^{18}O, ^{2}H — Origin of water, Recharge processes

^{14}C, ^{3}H, CFC, SF_6 — Water residence times

\+ Monthly and hourly piezometric monitoring

→ Hydrodynamic characteristics

Sampling of CFC and SF_6

→Hydrochemical study : chemical sampling and Electrical Conductivity monitoring

Major ions minor ions — Type of salts

pH, T°, EC — Spatio-temporal variability of salts

\+ Simulations of salinization

Sampling of major ions

Hydrodynamic – Piezometric monitoring

→ Rain Period:

Seazonal recharge of the crystalline aquifers between feb.- may (≈ 1-4 months/yr)

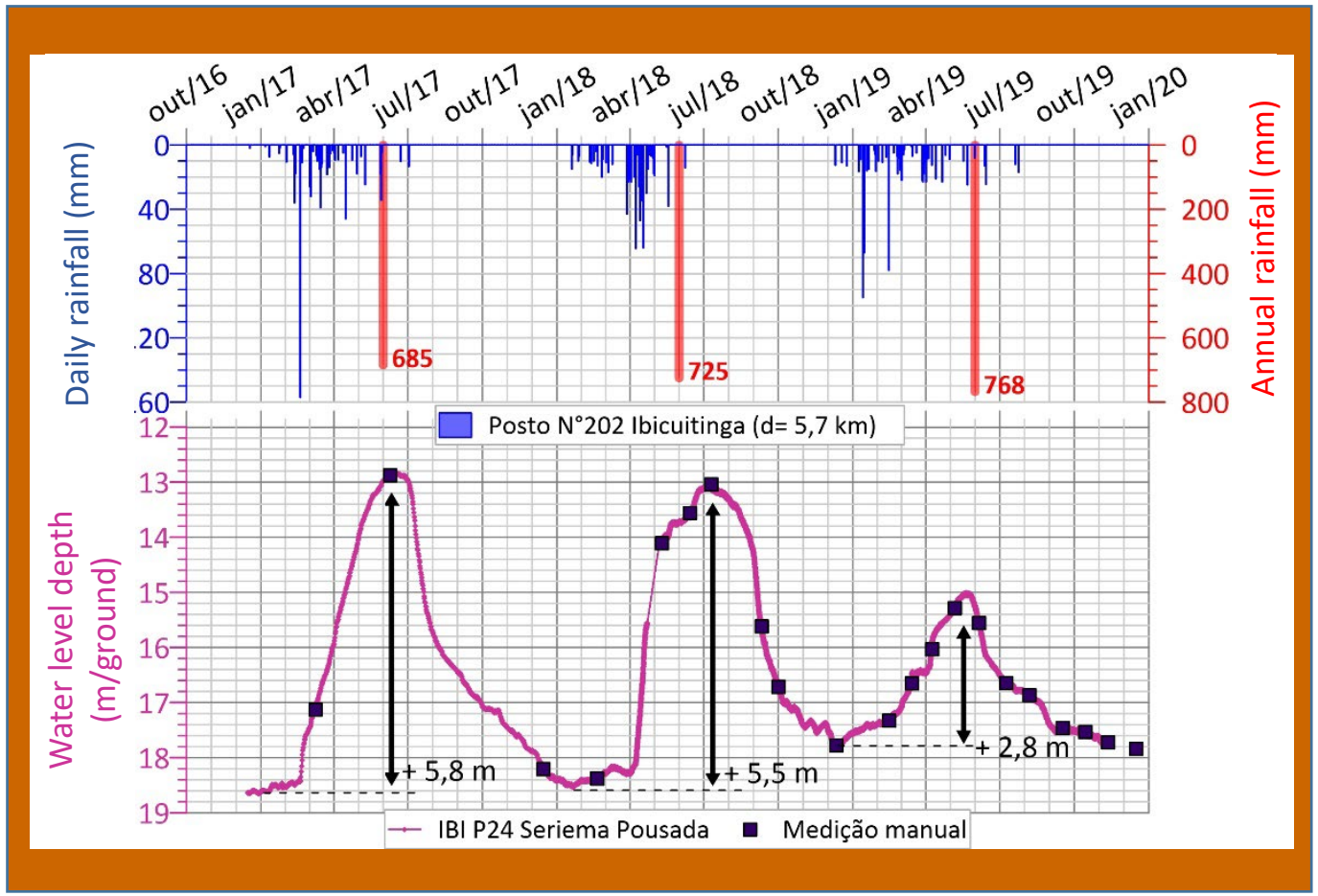
Dissymmetric variations, depending on the distribution and amounts of daily rainfall, surface runoff

→ typical of semi-arid areas

→ Dry Period :

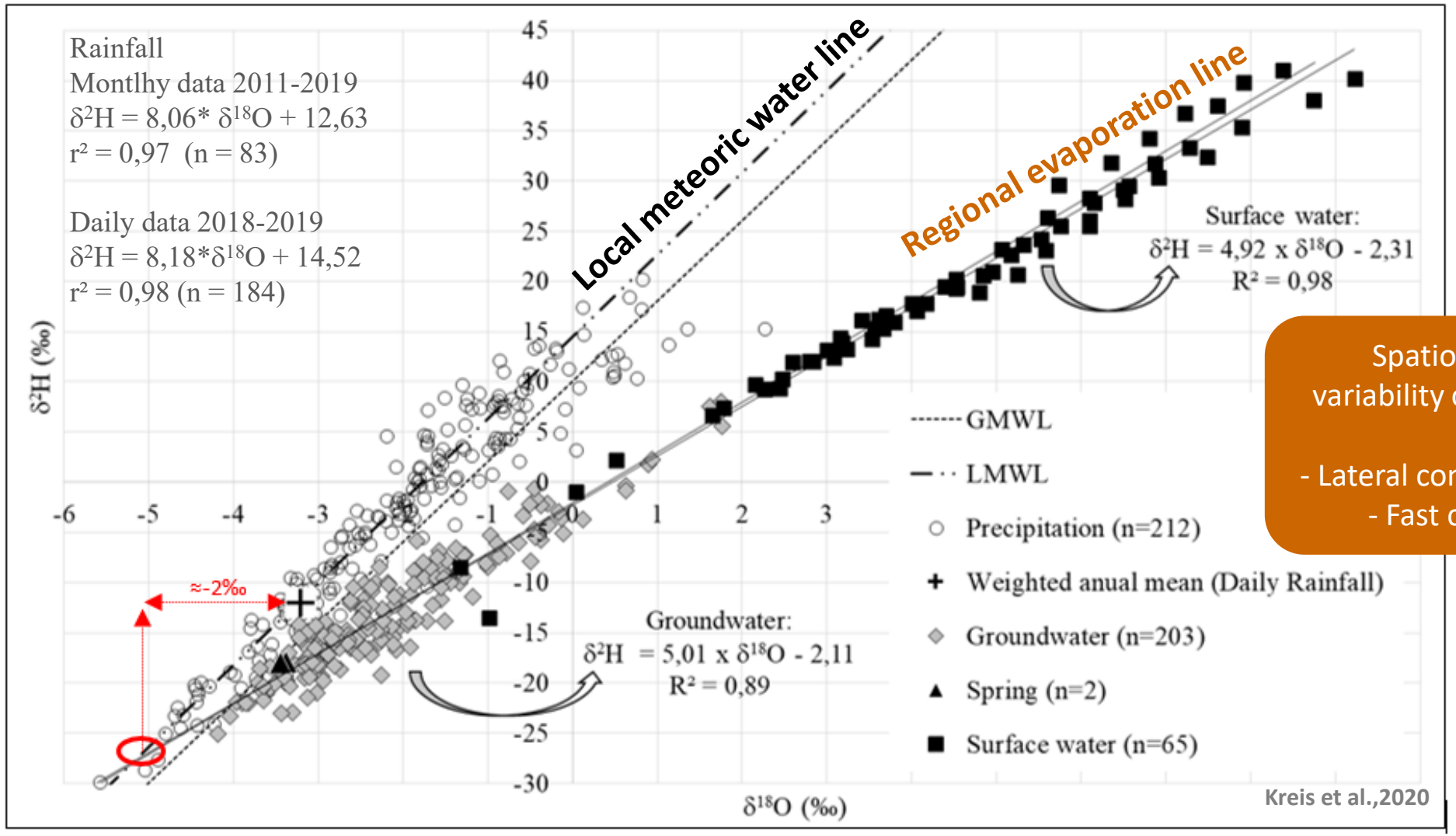
Observable groundwater discharge
(lasts all year long !)

Gradual variation = outflow (rivers, alluvium, other aq., spring), evaporation or evapotranspiration of the groundwater



Piezometric and rainfall evolution between 2016-2019

Hydrodynamic – Stable isotope monitoring

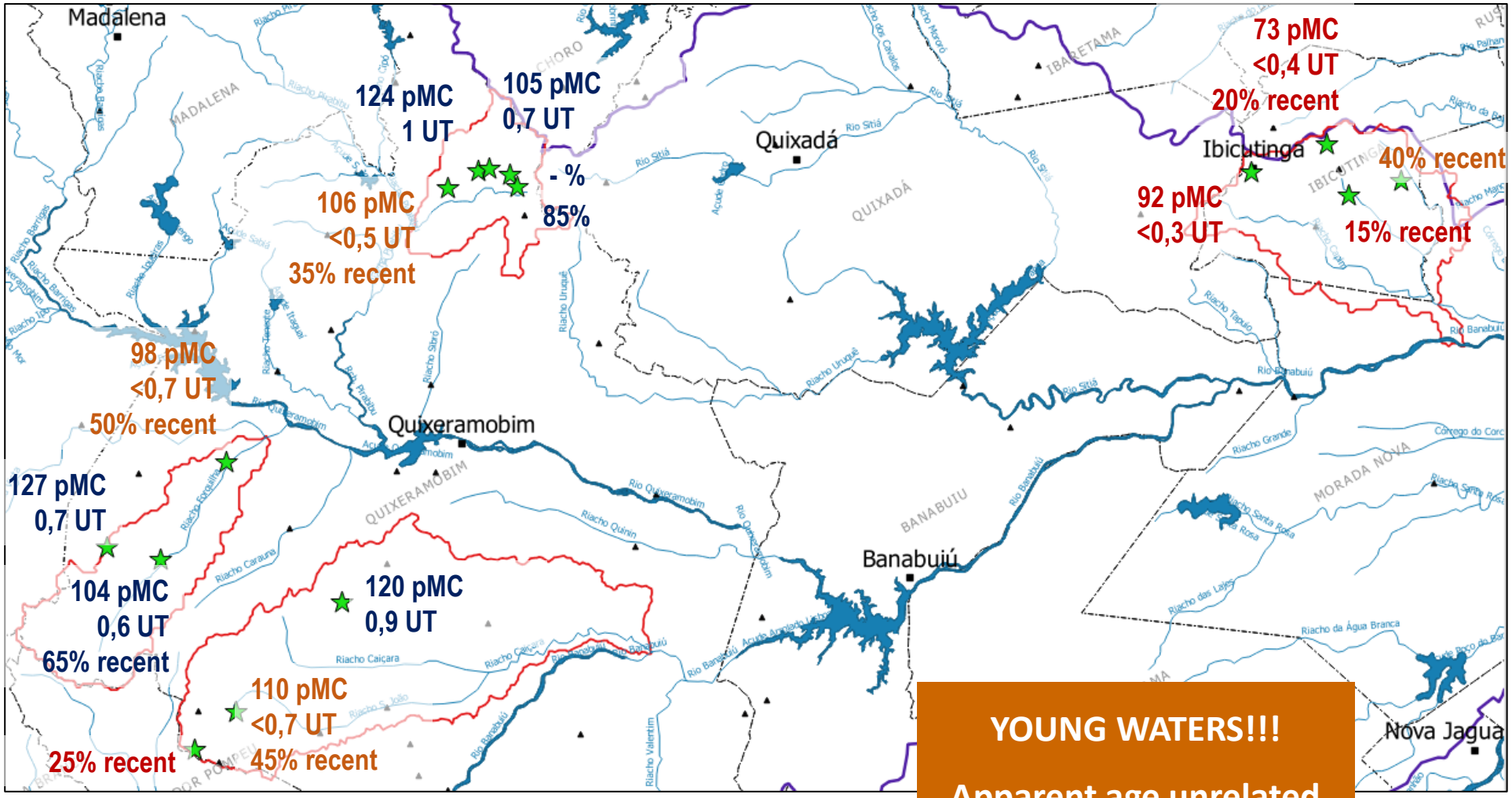


Spatio- temporal variability of $^{18}0$ in GW =>

- Lateral compartmentation
- Fast circulations

Isotopic composition of Groundwater, Surface water and Precipitation

Hydrodynamic – Multi-tracer dating (^{14}C, ^{3}H, CFC, SF_6)



Water residence time

YOUNG WATERS!!!

Apparent age unrelated to salinity

- **Group 1 (post 1950) :**

  ^{14}C >100 pMC
  ^{3}H detectable
  High fraction of recent water > 65%
  (in blue)

- **Group 2 (intermediary):**

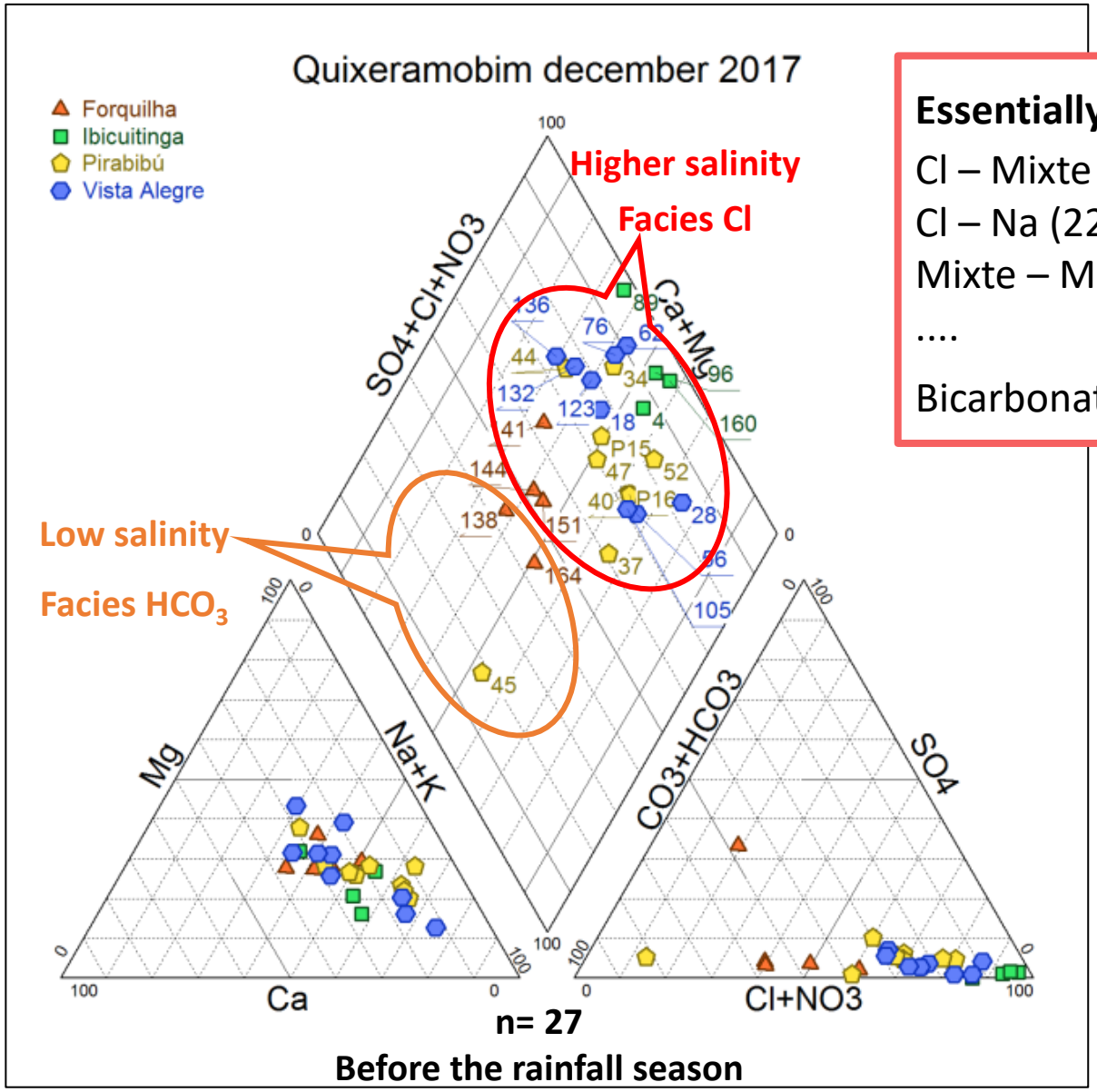
  ^{14}C ≈100 pMC
  ^{3}H non-detectable
  Fraction of recent water between 35 and 50%
  (in orange)

- **Group 3 (50 – 200 yrs) :**

  ^{14}C <100 pMC
  ^{3}H non-detectable
  Fraction of recent water < 25 %
  (in red)

Hydrochemistry – major and minor ions

Piper diagram



Essentially chloride facies :

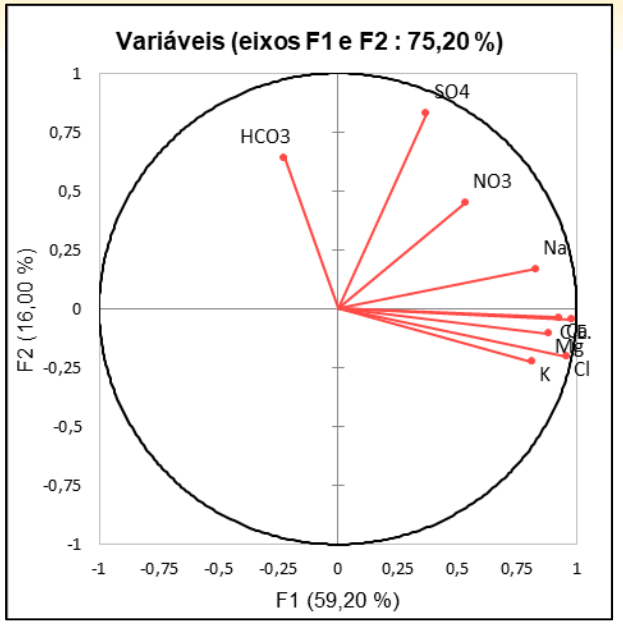
Cl – Mixte (49%)

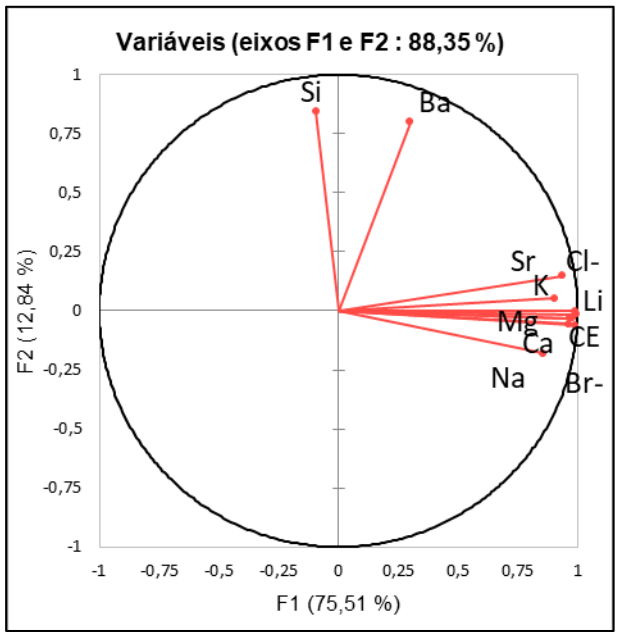
Cl – Na (22%)

Mixte – Mixte (11%)

....

Bicarbonated facies: <10%





Axis **F1** = **dissolution of evaporitic salts**

Axis F2 = **hydrolysis** of silicate or sulphide minerals (pyrite type) + impact of **anthropogenic activities**

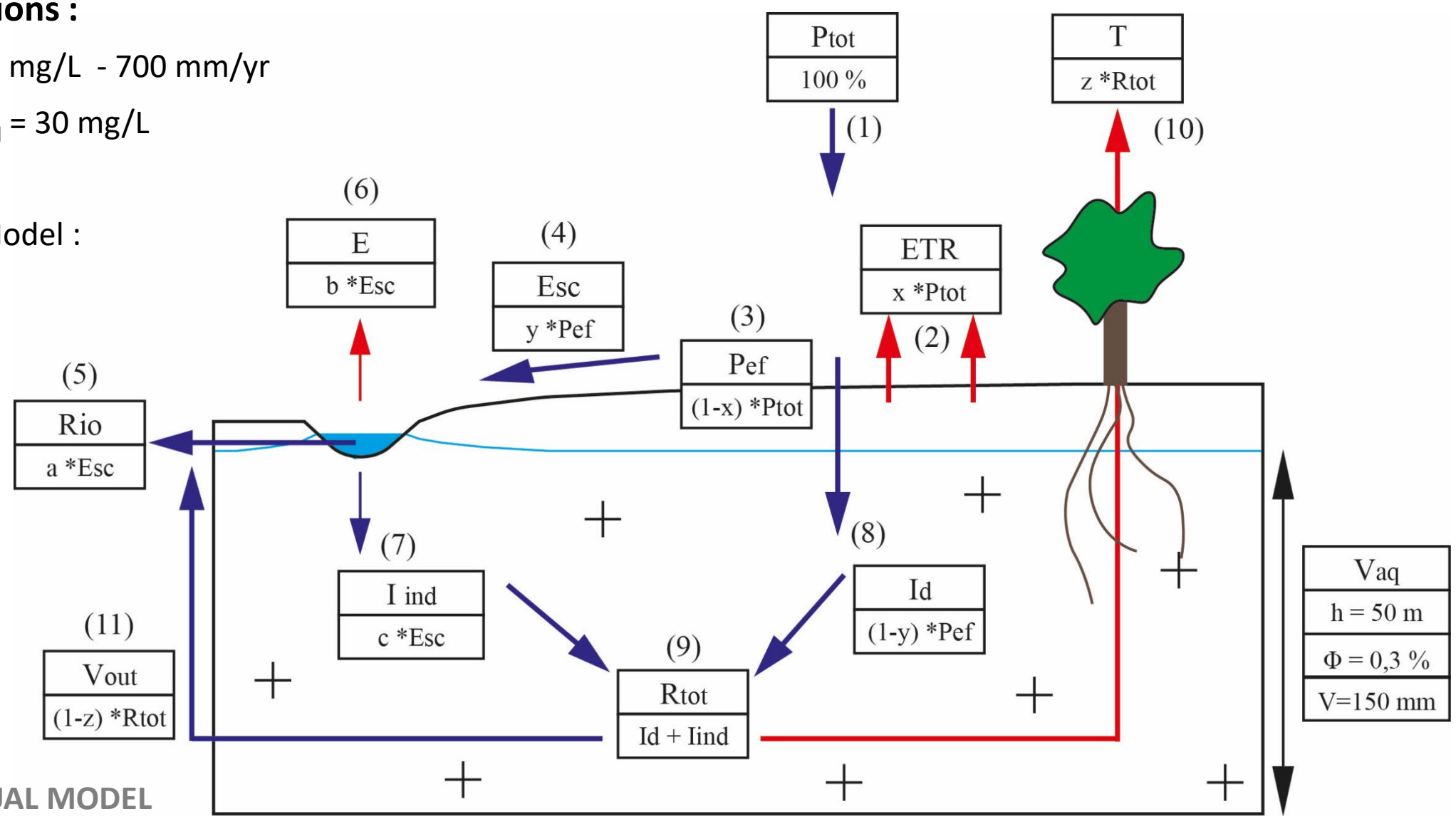
Principal component analysis of Groundwater

Salinization simulations

→ **Initial conditions :**

- Rainfall: [Cl] = 2 mg/L - 700 mm/yr
- Aquifer: $[Cl]_{initial}$ = 30 mg/L

Perfect Mixture Model :

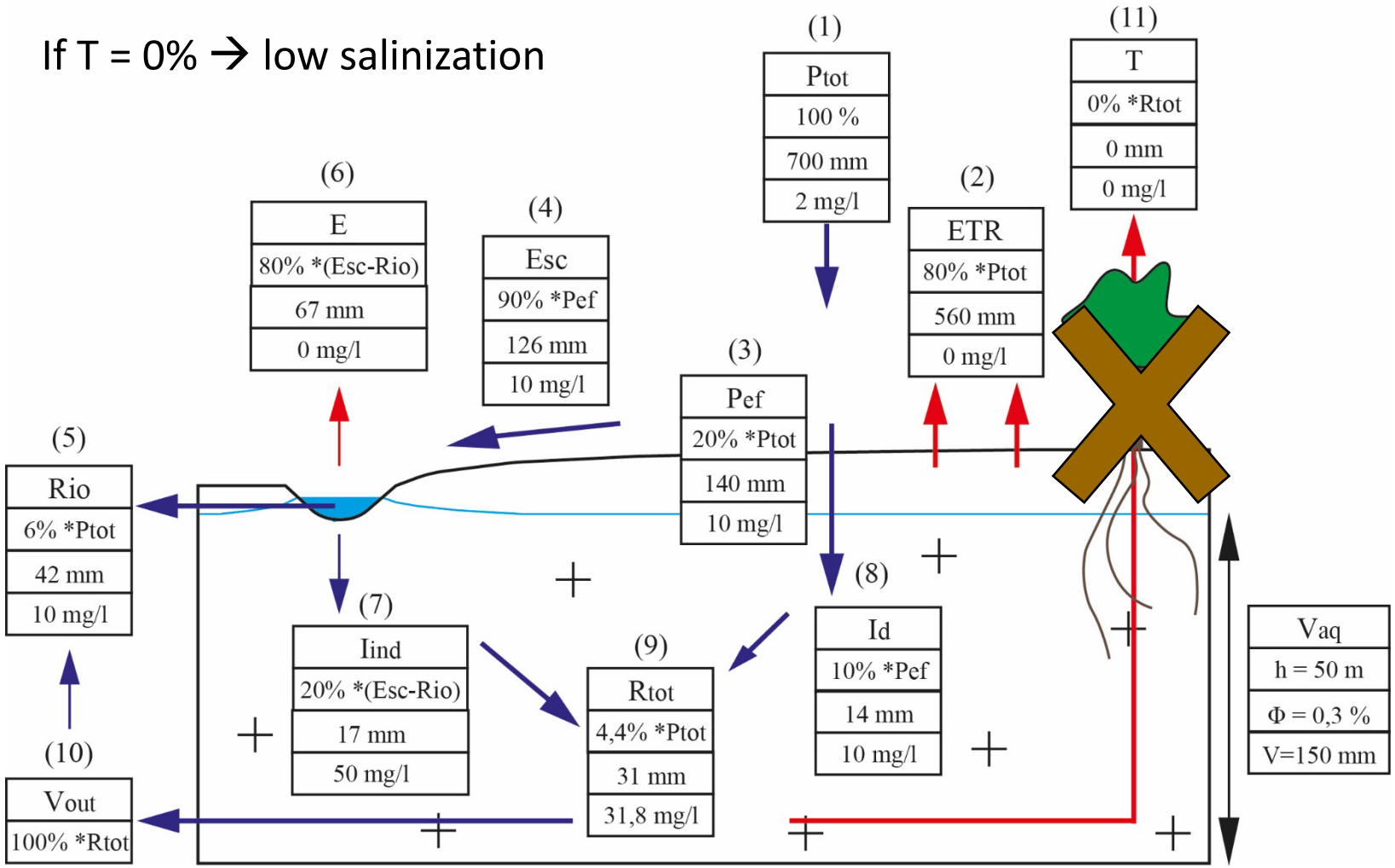


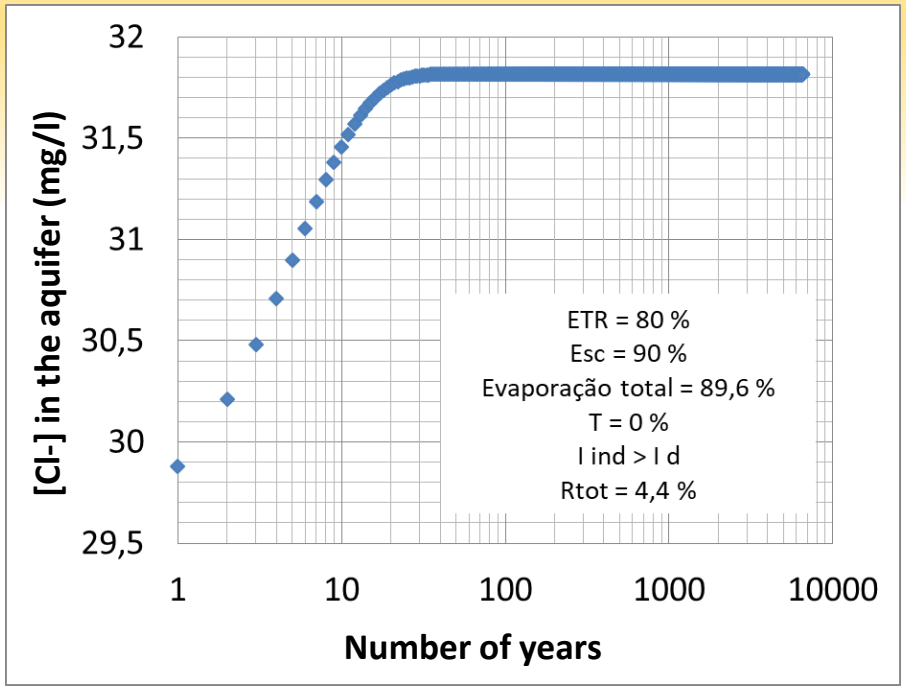
CONCEPTUAL MODEL

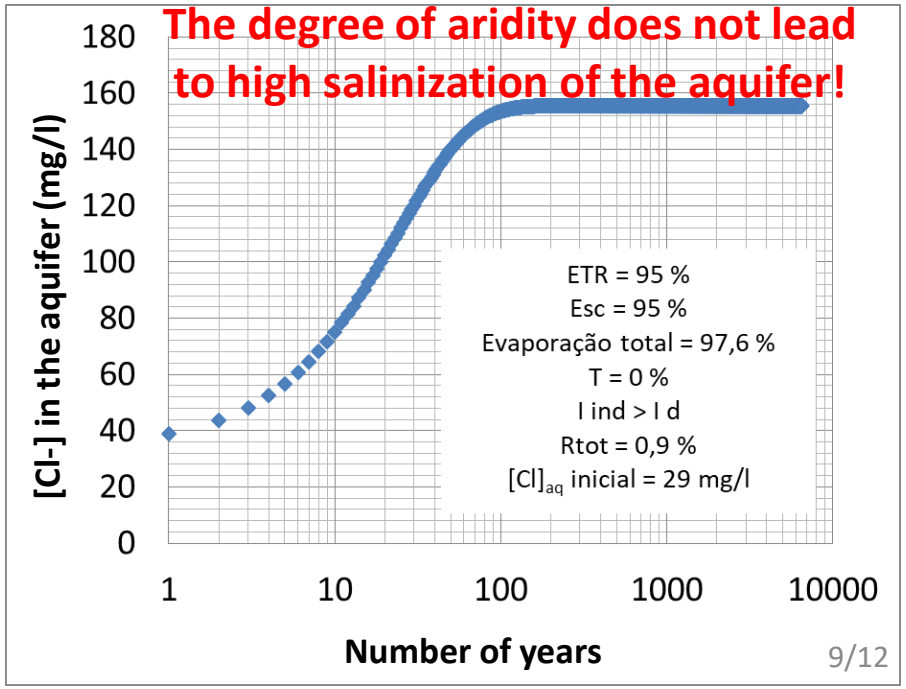
Salinization simulations

→ **If there is NO TRANSPIRATION by the roots of the plants**

If T = 0% → low salinization





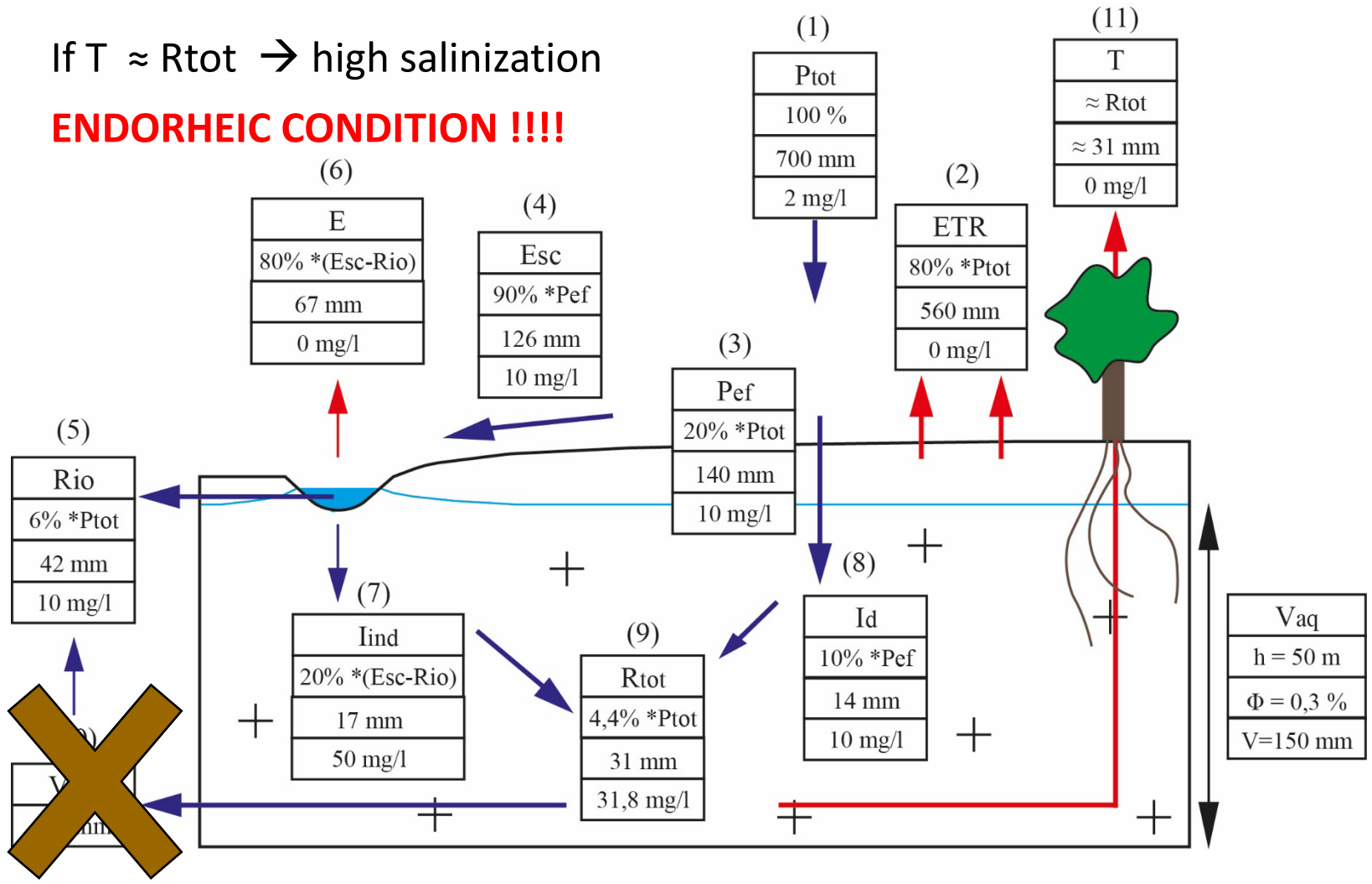


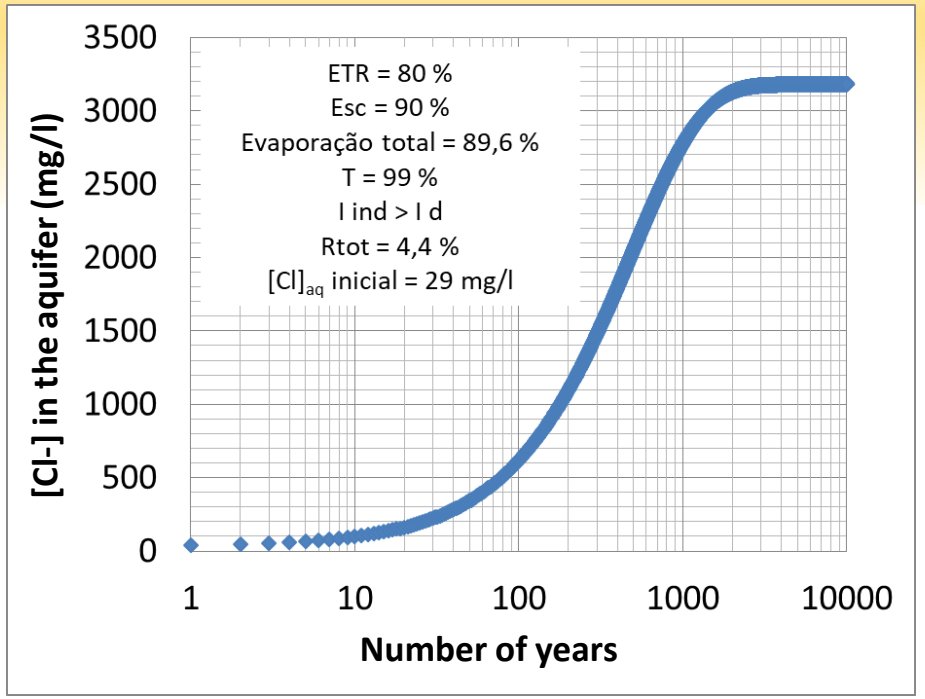
Salinization simulations

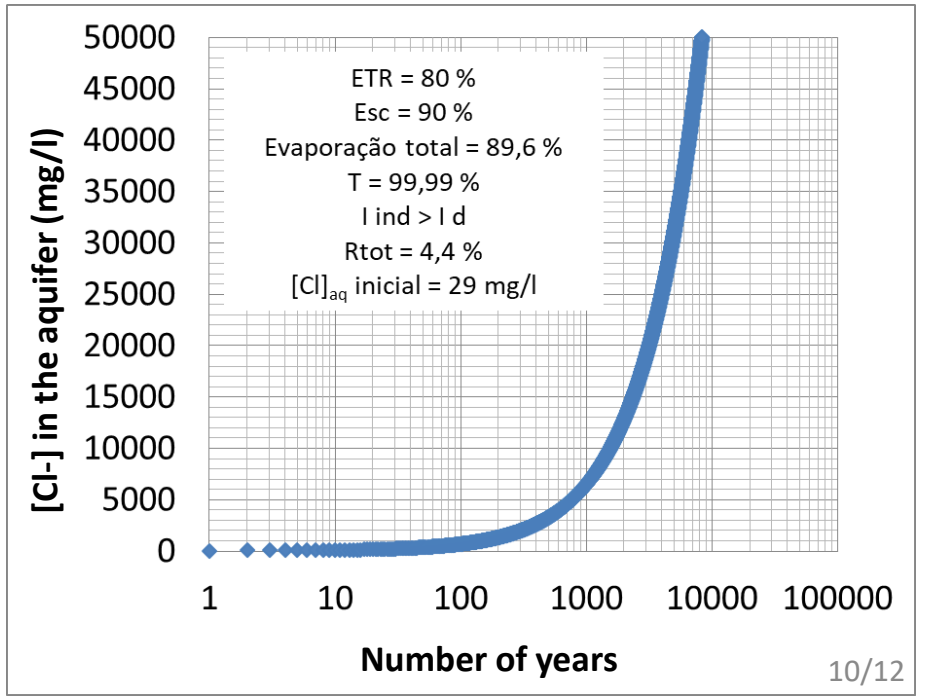
→ **If there is TRANSPIRATION by the roots of the plants**

If T ≈ Rtot → high salinization

ENDORHEIC CONDITION !!!!







Conclusions

HYDRODYNAMIC

- Aquifers reactive to significant rainfall
- Well connected to the surface
- Recharge = direct and indirect infiltration
- Young waters : Actual seasonal vertical flows + longer transit horizontal flows

HYDROCHEMISTRY

High spatiotemporal variability
Signs of dissolution of evaporitic salts
Chlorides of atmospheric origin

→ Lateral compartmentalization
→ Fast circulation processes

Conceptual hydrogeological model

→ **Durable semi-arid climate** that imposes vegetation to pump the groundwater table (metabolism)
+ capacity of vegetation (adaptation) to pump from the water table **=> high salinity**

Thank you for your attention