

# An integrated hydrogeochemical approach to identify multiple salinization sources of a coastal aquifer (Rhodope, Northern Greece)

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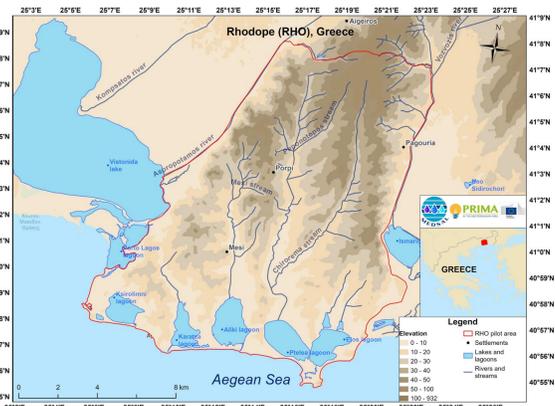
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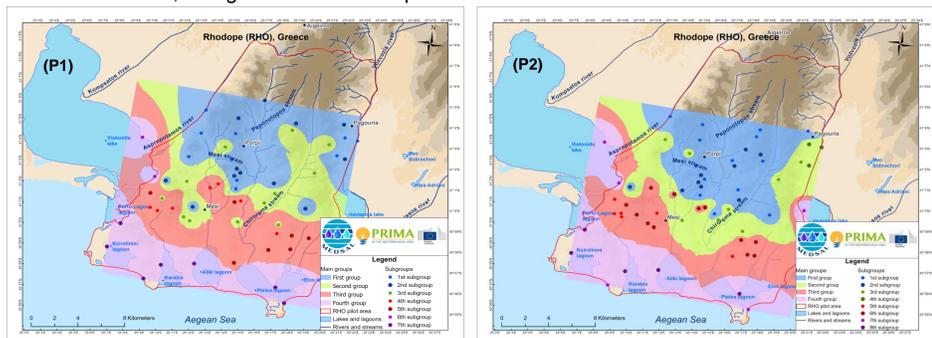
## Introduction

- The coastal aquifer of the Rhodope region (NE Greece) is a complex groundwater system characterized by locally increased salinity.
- Identifying the nature and spatial orientation of the multi-induced salinization sources and their functioning processes is a major step toward sustainable groundwater management.
- An integrated methodology has been employed including a toolbox of methods such as classical hydrogeochemical approaches, multivariate statistics, environmental isotopes, and hydrogeochemical modelling.



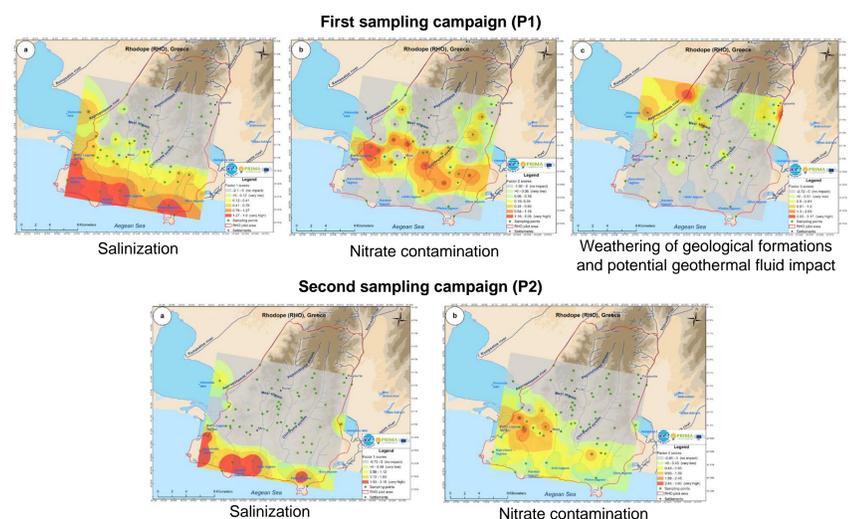
## MVSA methods (HCA and FA)

- Results outlined at least four cascading factors that drive groundwater salinization in the Rhodope aquifer system, including seawater intrusion, upconing of deep brines, irrigation water return, and geothermal fluid impact.



## Methodology

- A set of over 100 samples collected from surface and groundwater resources.
- Corresponding to two periods (beginning and end of the irrigation season).
- A combination of multivariate statistical methods (Q-mode Hierarchical Cluster Analysis – HCA and R-mode Factor Analysis – FA) was performed for the initial classification, grouping and spatial orientation of the samples.
- Data were processed with classical hydrogeochemical molar ratios of major and minor ions to perform a preliminary assessment of the potential salinization sources.
- Outcomes were coupled with a combo multi-isotopic assessment, which included <sup>18</sup>O, <sup>2</sup>H, and <sup>3</sup>H that defined the different salinization sources and processes.
- Hydrogeochemical modelling with the aid of the PHREEQC<sup>1</sup> code further supported assessments and provided an overview of the spatiotemporal variability of factors and processes affecting groundwater chemistry in both periods.



## Hydrogeochemical evaluations and modelling

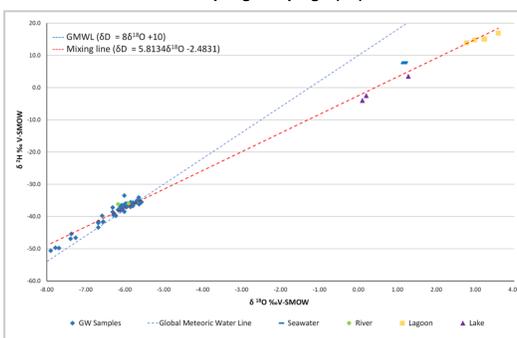
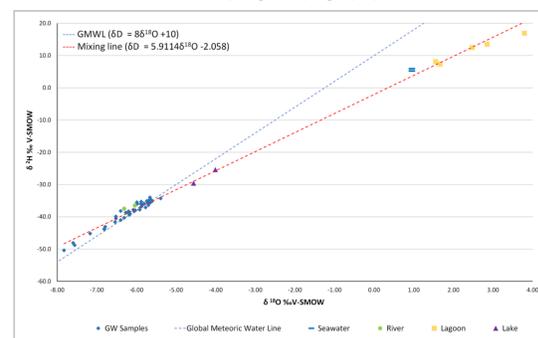
- Performed inverse hydrogeochemical modelling and results explained the mass-balance evolution of the aqueous solutions of the two periods.
- The extent and intensity of the salinization processes are temporally dependent on and affected by the irrigation schemes applied and the local hydrostratigraphic conditions.
- Multiple salinization sources have been identified (seawater intrusion, leaching of old brines, irrigation water return) which often demonstrate a cascading effect

## Environmental Isotopes

- The Global Meteoric Water Line (GMWL)<sup>2</sup> was used to interpret the plotted values.
- Most of the waters attributed to GW wells lie close to the GMWL, suggesting direct infiltration from rainwater, whereas the ones that fall below indicate groundwater of meteoric origin.
- The progressive enrichment in the content of stable isotopes observed in most SW samples is attributed to both evaporation and seawater intrusion (except from the two rivers).
- The isotopic content of the waters obtained from the two lakes (Vistonida and Ismarida) is slightly less enriched due to their recharge from Aspropotamos and Vozvozis Rivers.
- The detected concentrations of tritium in the selected groundwater wells, ranged between <0.5 to 0.6TU, indicating that these GW samples are more than 60-70 years old and can be characterized as premodern<sup>3</sup>.

First sampling campaign (P1)

Second sampling campaign (P2)



## Conclusions

- At least three different salinization processes have been identified with diverse tools and methods combined.
- Seawater intrusion is the dominant process near the coastline, whilst brine leaching and irrigation water return are significant in the inner parts.
- The integrated methodology applied could provide a robust methodological framework for assessing and characterizing coastal aquifers with similar conditions.
- Provide a versatile ensemble of tools that can significantly facilitate integrated groundwater resources management.

## References

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