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"O solo – alvo prioritário do combate à desertificação"

Trends in water quality in the Alqueva irrigation area and its potential effects on soil structure and on crop yields

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Problem framing

- Drought severity in Southern Europe has increased in the last decades, as a consequence of global warming and climate projections for the 21st century point to an increase in the area affected by droughts in the Iberian Peninsula.
- Alentejo is one of the driest regions in Portugal where, presently, about 69% of the water withdrawals are from surface water, hence the importance of reservoirs in the management plan of water resources in the region.
- The Alqueva reservoir constitutes the most important water source in Alentejo providing water for a 120000 ha irrigation plan.
- Monitoring the salinity status of this agricultural water resource is increasingly important to prevent soil salinization processes.
- The aim of this study was to evaluate the temporal and spatial evolution of water quality in the Alqueva reservoir, and its potential effects on soil structure and on crop yields. For this purpose, (i) the physicochemical characteristics of water collected throughout two sampling campaigns in different sampling sites along the Alqueva reservoir, was assessed using the FAO guidelines for interpretation of water quality for irrigation, and (ii) two soil-salinity production functions were used to estimate the relative yield (Yr) for the main crops grown in the Alqueva irrigation area.

Site description

- Climate in the region is predominantly Mediterranean (Csa, in Köppen classification), with a small area of mid-latitude steppe (Bsk).
- Predominant soils are Luvisols, Vertisols, and Cambisols.
- The main crops cultivated in the irrigation are: olive (53%); maize (13%); grapevine (8%); forage crops (8%), cereals other than maize (6%), open field horticultural crops (5%), fruit trees (3%), and oil crops, mostly sunflower (3%) (EDIA, 2017).
- Nine sampling sites along the Alqueva reservoir were assessed: Sra. Ajuda (AJ), Alcarrache (ALC), Álamos-Captação (AL), (Lucefécit (LF), Alqueva-Mourão (MR), Alqueva-Montante (MN), Alqueva-Jusante (JZ), Ardila confluência (AD), Moinho das Barcas (MB).

- 2006-2007 sampling campaign: February, March, May, July, September and November 2006, and in February, March, and May 2007; 2011-2012 sampling campaign: February, April, June, July, September and November, in both 2011 and 2012. The humid period included the months of November, February, and March, and the dry period included the months of May, July, and September (ARHAlentejo 2011).

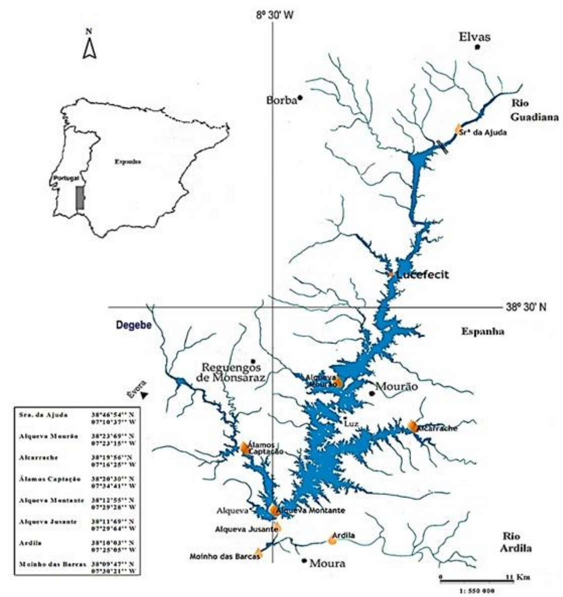

Fig.1 - Map showing the location of the water sampling stations on the Alqueva reservoir

Methodology

- The key inorganic ions and parameters for irrigation water quality evaluation (Ayers and Westcot, 1985) were determined or measured (Na^+, Ca^{2+}, Mg^{2+}, NO_3^-, B (mg L^{-1}); pH, ECw (dS m^{-1})). SAR was calculated using: $\boldsymbol{SAR} = [\boldsymbol{Na}^+]/\sqrt{([\boldsymbol{Ca}^{2+}] + [\boldsymbol{Mg}^{2+}])/2}$.
- Soil salinity estimates (ECe) were obtained, from $\boldsymbol{ECe} = \boldsymbol{ECw} \cdot \boldsymbol{CF}$, using two concentration factors (Ayers and Westcot, 1985): CF = 1.2, corresponding to a leaching fraction of 0.25 (appropriate value for average-efficiency sprinkler irrigation systems); CF = 3.2, corresponding to a leaching fraction of 0.05 (appropriate value for high-efficiency drip irrigation systems).
- Soil-salinity production functions to estimate relative yield (Yr):

❖ Threshold (or breakpoint) model of Maas and Hoffman (1977):

$$\boldsymbol{Yr} = \mathbf{100} + \boldsymbol{b}_{\%} \cdot (\boldsymbol{EC_e} - \boldsymbol{EC_{e100}})$$

❖ S-shaped response model of van Genuchten and Hoffman (1984):

$$\boldsymbol{Yr} = \mathbf{100} \cdot \frac{\mathbf{1}}{\mathbf{1} + \left(\frac{\boldsymbol{EC_e}}{\boldsymbol{EC_{e50}}}\right)^{\boldsymbol{p}}}$$

$b_{\%}$ is the relative slope (% dS^{-1} m); EC_e is the soil salinity; EC_{e100} is the threshold (breakpoint) salinity (Maas and Grattan, 1999); EC_{e50} is the ECe at which the yield has dropped 50% (dS m^{-1}); p is a dimensionless steepness parameter, found to be approximately 3 for several crops.

Results

Meteorological characterization

- The hydrological year **2006-2007**, especially the **winter period**, was characterized by **values of precipitation much lower than normal**, being classified as **very dry** (IPMA, 2007).
- **2012** was characterized by a **meteorological drought** situation, which began at the end of 2011 and remained for most of the year 2012, with almost all of the territory in the **severe and extreme drought** classes of the PDSI index (Palmer drought severity Index, PDSI) in the months of **February and March** (IPMA, 2013).

Main meteorological data of the study period and climatological normals for Beja:

Year	T (ºC)	P (mm)
2006	16.9	646
2007	16.4	349
2011	16.8	621
2012	16.0	484
Long term mean (1981-2010)	**16.9**	**558**

Results

Water physicochemical characteristics

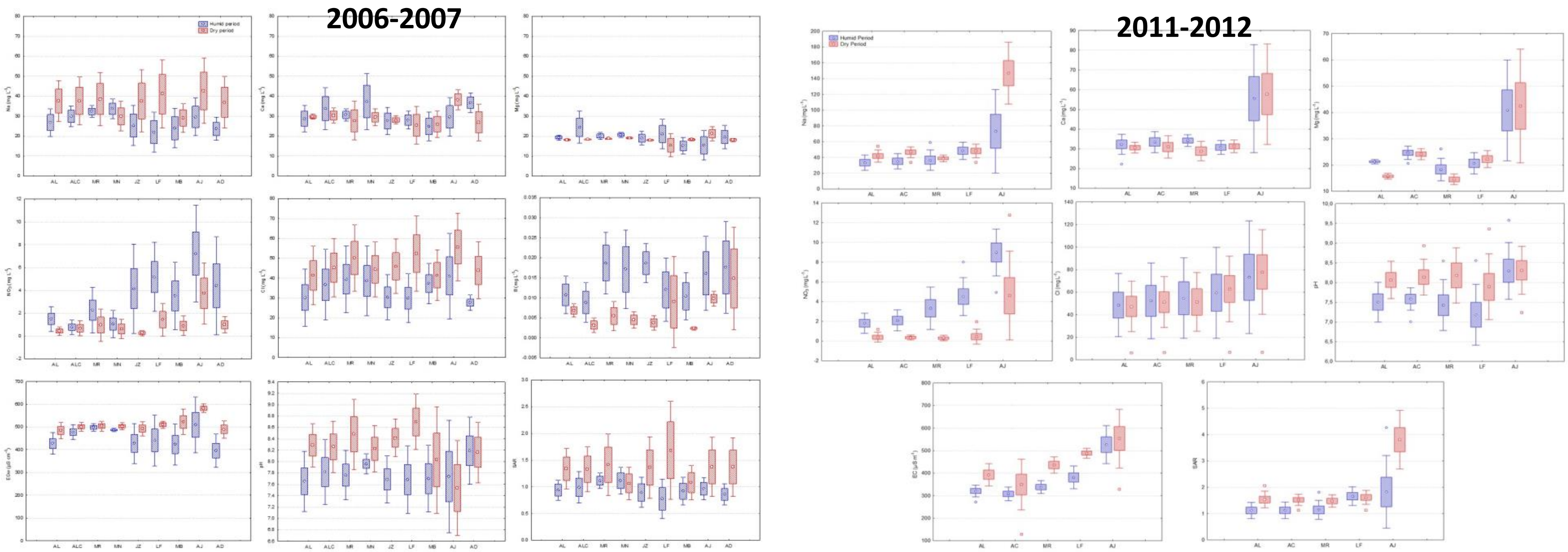

Fig. 2 - Spatial and temporal variation of chemical parameters in the humid and dry periods, during 2006-2007 and 2011-2012, at the Alqueva reservoir

From 2006-2007 to 2011-2012 there was an **increment of the ionic concentrations at the water body** more significant for **Na^{+} (+55%)**, **Cl^{-} (+44%)**, and **Mg^{2+} (+30%)**. Average pH at all sites and dates was near 8.0. The **SAR** values showed an **average increase of 36%**. The annual temporal patterns were similar in both campaigns, with an **increase of ionic concentrations of Na, of pH, EC_w, and SAR in the dry period**, and a **humid period with higher concentrations of NO_3^{-}, Cl^{-}, and Mg^{2+}**. Spatial analysis indicated that **AJ and LF** were the sites where **ion concentrations were higher**, in both campaigns.

Results

	2006-2007	2011-2012
Water quality for irrigation	• **Slight to moderate risk of reduced infiltration** rates in every site and date. • **pH > 8.4**, especially in the dry months. Specifically: ❖ at all sites in Sep 2006; ❖ at AL, JZ, LF, MB, and AD, in May 2006; ❖ at AD, in Mar 2007. These last values, however recorded in a humid month can be due to the dry conditions felt during the previous winter months	• **Slight to moderate risk of reduced infiltration** rates in every site and date. • **pH > 8.4** in dry months: ❖ at AL and AJ, in Jun 2011; ❖ at AJ, in Jul 2011; ❖ at AL, ALC, and AJ, in Sep 2006 • Characteristics consistent with a **slight to moderate risk of Na^+ and Cl^- toxicity** when using **sprinkler irrigation**. Specifically: ❖ at LF (Sep and Nov 2006); ❖ At AJ (Feb and Apr 2006).
Soil salinity	• **Maximum ECe** estimated using CF=1.2 and CF=3.2 was **0.8 dS m^{-1}**.	• **Maximum ECe** estimated using CF=1.2 and CF=3.2 was **2.2 dS m^{-1}**.

Results

Relative yields

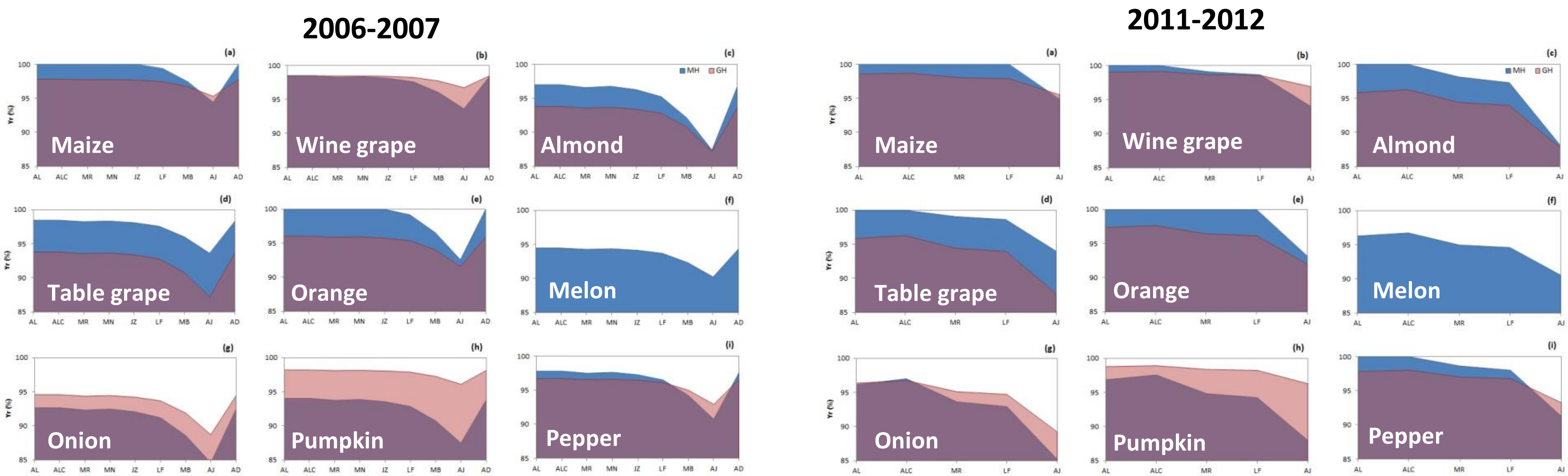

Fig. 3 - Minimum relative yield for some crops grown in the Alqueva irrigation area in 2006-2007 and 2011-2012, using the Maas and Hoffman model (MH) and the van Genuchten and Hoffman (GH) model

- Minimum **Yr > 85%.**
- The lower Yr using the **MH model** occurred for **almond, onion, and pumpkin**. In the case of the **GH model**, the lower Yr values were also found for **almond, onion** and **table grape**.
- In horticultural crops (onion, pumpkin), Yr estimates were higher using the GH model
- In fruit crops (almond, table grape and orange), Yr estimates were higher using the MH model

Conclusions

- Overall, these evaluations performed in campaigns separated by 5 years, point to a degradation in water quality for irrigation that could be attributed, on one hand, to the expansion of the irrigation area with the intensification of agriculture, and, in the other hand, to the increase in drier conditions resulting from climate change.
- The slight to moderate risk of reduced infiltration rates in every site and date means that low-salt water can reduce infiltration even for low SAR, since the effect of increasing SAR grows as the salinity of the water decreases. This is especially important in fine textured soils, and whenever sprinkler irrigation systems are used, as the energy of water droplets impacting soil surface add a supplementary energy to the dispersing effect of Na^+ in this types of soils.
- Attention should be given to sensitive and moderately sensitive crops cultivated in the Alqueva irrigation area (like almond, table grape, onion, melon), especially in drought years, and at periods with high atmosphere evaporative demands.

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Acknowledgments

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