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Assessing water quality for irrigation and soil salinization risk under drought: the case of the Alqueva reservoir (Guadiana river basin)

Alexandra Tomaz, Sofia Fialho, Ana Lima, Paula Alvarenga, Miguel Potes, Rui Salgado, Patrícia Palma

ALOP Alentejo Observation and Prediction systems

Instituto Escola Superior Politécnico de Beja Agrária

geobiotec Geobiociências, Geoengenharias e Geotecnologias

LEAF Linking Landscape, Environment, Agriculture and Food

ICT Instituto de Ciências da Terra

Universidade de Évora

Alentejo 2020

Portugal 2020

União Europeia Fundo Europeu de Desenvolvimento Regional

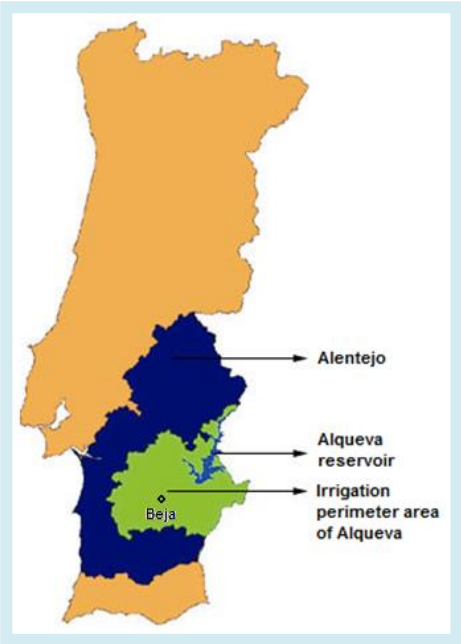
Introduction

- **Drought** years are becoming more frequent in Portugal, a country in the Mediterranean climate zone, where climate change is leading to an increase in **water limitation** **for crops** and **higher demand for irrigation water**.
- During **2017** Portugal experienced a drought that extended throughout almost the entire territory of **mainland Portugal**, reaching the level of severe drought in 81% of the territory.
  - ✓The **Baixo Alentejo region** (South Portugal) was one of the most affected areas.

Baixo Alentejo

Introduction

- **Traditionally**, in Baixo Alentejo, rainfed, extensive farming systems **were predominant**.
- **Presently**, **agriculture in large areas of the region is changing thanks** to the **availability of water provided** by the **Alqueva reservoir** (Guadiana river basin) part of the **Multi Purpose Development of Alqueva:**
  - Public water supply;
  - **Agriculture;**
  - Industry;
  - Energy production;
  - Tourism.

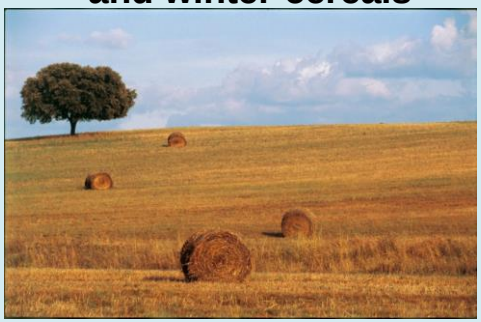


Alqueva dam and reservoir

Introduction

- Crops already practiced in the region are now grown in **more intensive** farming systems and there has been an increase of **new crops and cultivars** adapted to environmental conditions and water availability.

Traditional Alentejo agricultural system: holmoak and winter cereals



Super intensive olive grove with drip irrigation

Maize and Opium poppy with sprinkler irrigation (center-pivot)

- This has brought a **positive economic impact** in the region, with a large number of new farmers and new companies.

Introduction

- However, **water scarcity** conditions and **high atmosphere evaporative demand** increase the **risk of land salinization**.
- The maintenance of **long-term salt balance** at a crop, farm or regional scale is critical for sustainable crop production in irrigated agriculture.
- For this purpose, in this study we focused on:

  i. **assessing the quality of the Alqueva reservoir water for irrigation;**

  ii. **estimating risks of yield losses of the most representative crops grown in the area due to salinity.**

Methods

Study area

- The Alqueva irrigation area has a total area of 120000 ha, of which about **70000 ha were in operation in 2017**.
- The dominant climate in the region is **Mediterranean** (**Csa)**.

- 2017 land occupation:
  - ✓**Olive**; **maize**; **grapevine**; **forages and pastures; barley; wheat; sunflower** ; **horticultural crops** (almond ; melon; tomato; pepper; garlic; onion; etc).

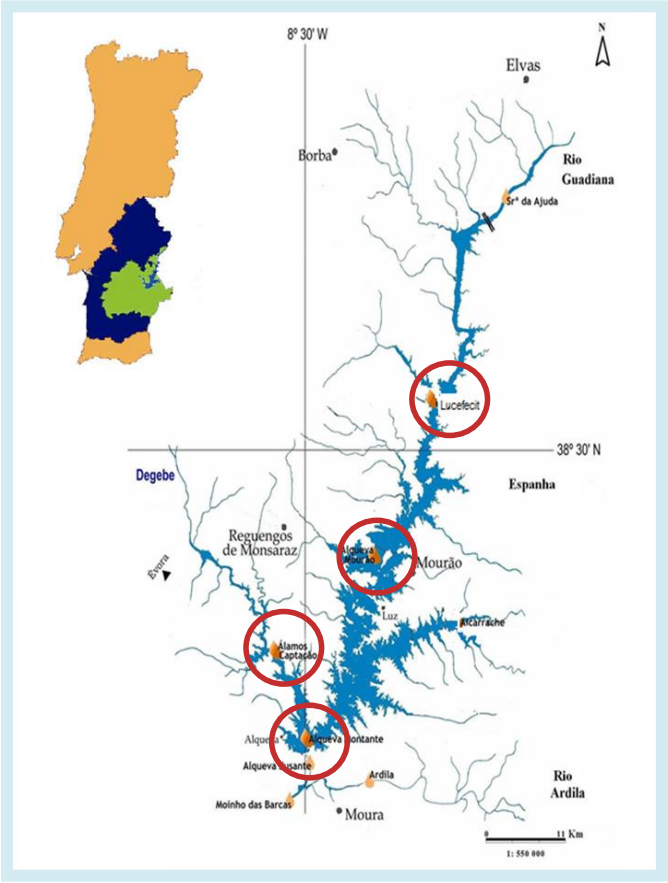
Adapted from http://www.alqueva.com.pt/pt/#/regadio/ocupacao-cultural/11

Methods

Water chemical characterization

- Performed every two months. **pH**, electrical conductivity (**ECw**,), and the **major inorganic ions**, decisive in evaluating the quality of water for irrigation, were analyzed in water samples collected at **4 platforms** (Montante, Mourão, Álamos, Lucefécit) located in the reservoir.
- Sodium Adsortion Rate (SAR) was calculated:

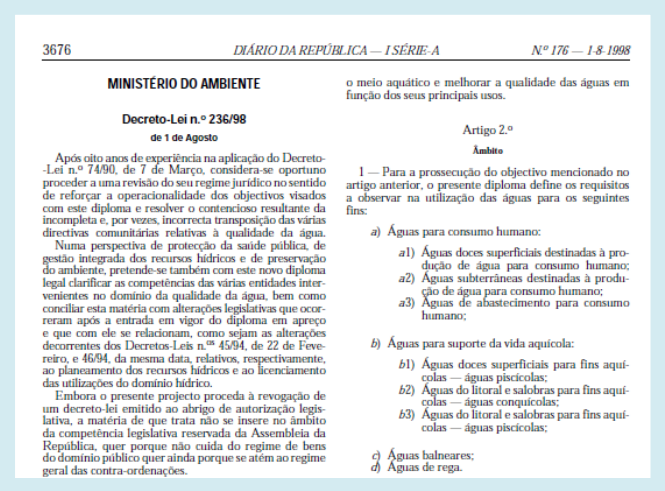
$$SAR = \frac{[Na]}{\sqrt{\frac{[Ca] + [Mg]}{2}}}$$



Methods

Irrigation water quality

- Evaluated using both the **Portuguese regulations** (DL 236/98) and the **FAO guidelines** (Ayers and Westcot, 1985), comparing parameters that are common to both standards.



3676 DIÁRIO DA REPÚBLICA — I SÉRIE-A N.º 176 — 1-8-1998

MINISTÉRIO DO AMBIENTE

Decreto-Lei n.º 236/98

de 1 de Agosto

Após oito anos de experiência na aplicação do Decreto-Lei n.º 74/90, de 7 de Março, considera-se oportuno proceder a uma revisão do seu regime jurídico no sentido de reforçar a operacionalidade dos objectivos visados com este diploma e resolver o contencioso resultante da incompleta e, por vezes, incorrecta transposição das várias directivas comunitárias relativas à qualidade da água.

Numa perspectiva de protecção da saúde pública, de gestão integrada dos recursos hídricos e de preservação do ambiente, pretende-se também com este novo diploma legal clarificar as competências das várias entidades intervenientes no domínio da qualidade da água, bem como conciliar esta matéria com alterações legislativas que ocorreram após a entrada em vigor do diploma em apreço e que com ele se relacionam, como sejam as alterações decorrentes dos Decretos-Leis n.os 45/94, de 22 de Fevereiro, e 46/94, da mesma data, relativos, respectivamente, ao planeamento dos recursos hídricos e ao licenciamento das utilizações do domínio hídrico.

Embora o presente projecto proceda à revogação de um decreto-lei emitido ao abrigo de autorização legislativa, a matéria de que trata não se insere no âmbito da competência legislativa reservada da Assembleia da República, quer porque não cuida do regime de bens do domínio público quer ainda porque se atém ao regime geral das contra-ordenações.

o meio aquático e melhorar a qualidade das águas em função dos seus principais usos.

Artigo 2.º

Âmbito

1 — Para a prossecução do objectivo mencionado no artigo anterior, o presente diploma define os requisitos a observar na utilização das águas para os seguintes fins:

a) Águas para consumo humano:

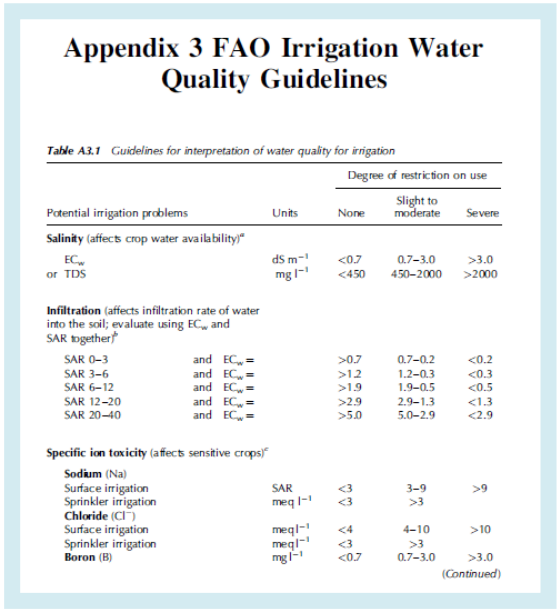
a1) Águas doces superficiais destinadas à produção de água para consumo humano;
a2) Águas subterrâneas destinadas à produção de água para consumo humano;
a3) Águas de abastecimento para consumo humano;

b) Águas para suporte da vida aquícola:

b1) Águas doces superficiais para fins aquícolas — águas piscícolas;
b2) Águas do litoral e salobras para fins aquícolas — águas conquícolas;
b3) Águas do litoral e salobras para fins aquícolas — águas piscícolas;

c) Águas balneares;
d) Águas de rega.

DL 236/98 excerp



Appendix 3 FAO Irrigation Water Quality Guidelines

Table A3.1 Guidelines for interpretation of water quality for irrigation

Potential irrigation problems	Units	Degree of restriction on use: None	Slight to moderate	Severe
Salinity (affects crop water availability)[a]				
EC_w	dS m^{-1}	<0.7	0.7–3.0	>3.0
or TDS	mg l^{-1}	<450	450–2000	>2000
Infiltration (affects infiltration rate of water into the soil; evaluate using EC_w and SAR together)[b]				
SAR 0–3 and EC_w =		>0.7	0.7–0.2	<0.2
SAR 3–6 and EC_w =		>1.2	1.2–0.3	<0.3
SAR 6–12 and EC_w =		>1.9	1.9–0.5	<0.5
SAR 12–20 and EC_w =		>2.9	2.9–1.3	<1.3
SAR 20–40 and EC_w =		>5.0	5.0–2.9	<2.9
Specific ion toxicity (affects sensitive crops)[c]				
Sodium (Na)				
Surface irrigation	SAR	<3	3–9	>9
Sprinkler irrigation	meq l^{-1}	<3	>3	
Chloride (Cl^-)				
Surface irrigation	meq l^{-1}	<4	4–10	>10
Sprinkler irrigation	meq l^{-1}	<3	>3	
Boron (B)	mg l^{-1}	<0.7	0.7–3.0	>3.0

(*Continued*)

FAO paper nº 29 excerp

Methods

Soil salinity

- Soil salinity (*ECe*) estimates were obtained according to Ayers and Westcot (1985), with $ECe = ECw \cdot X$

  considering two **salt concentration factors**:

  - **X = 1.5**, a standard value for leaching fractions (LF) of 0.15, representing a medium-high irrigation efficiency and;
  - **X = 3.2**, for LF = 0.05, corresponding to high irrigation efficiency with low percolation losses.

Potential yield

- Relative crop yield (Yr) of the most representative crops was assessed using the linear function (Maas and Hoffman, 1977):

$$Yr = 100 - b \cdot (ECe - a)$$

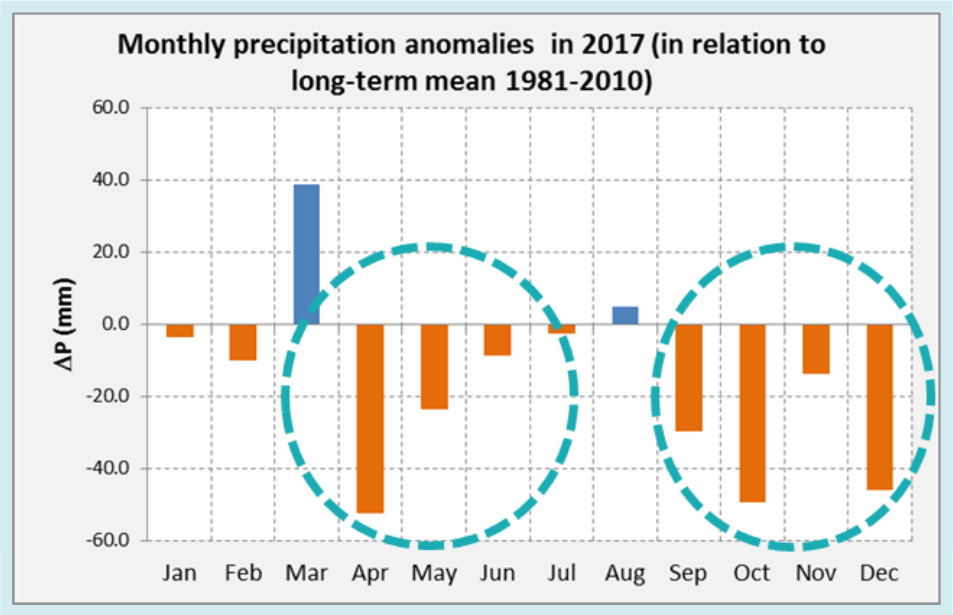
Where: b - is the slope of the function; a - is the threshold salinity of the crop.

Results

Drought characterization

- 2017 was an **extremely hot and dry** year (among the 4 driest years since 1931). Total **annual precipitation** was about **35% below the normal value** in the region (long-term mean of 558 mm for the 1981-2010 period).

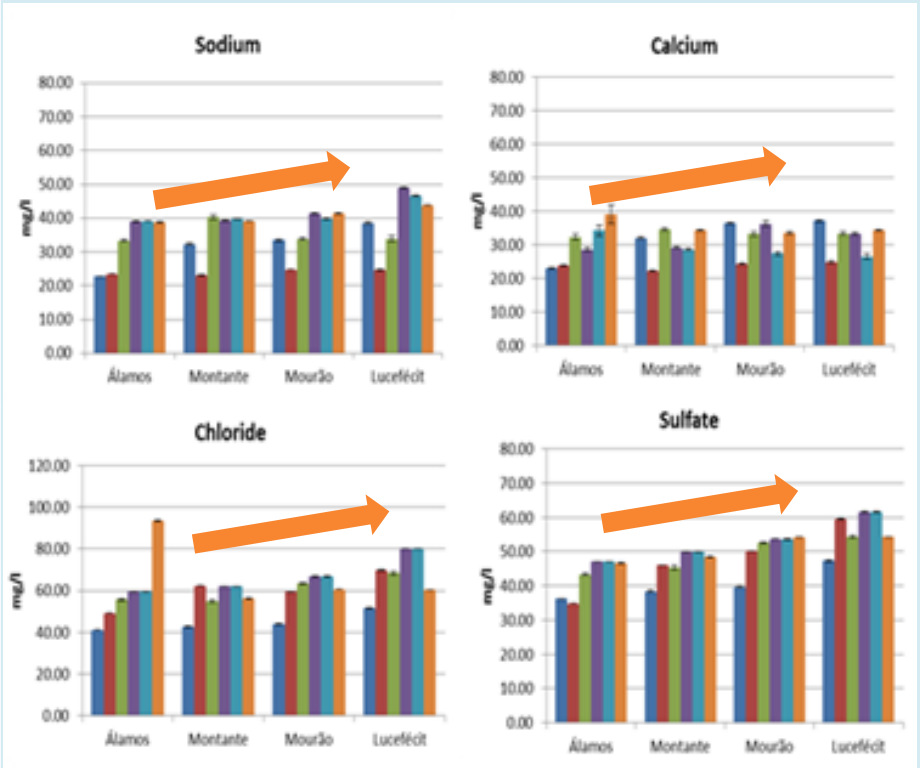
- The period from April to December, had **persistently negative precipitation anomalies**: two periods with **four consecutive months precipitation values below normal**.
- The first dry period (**April to July**) overlaps the growing season of **Spring-Summer crops**, further increasing their water requirements.

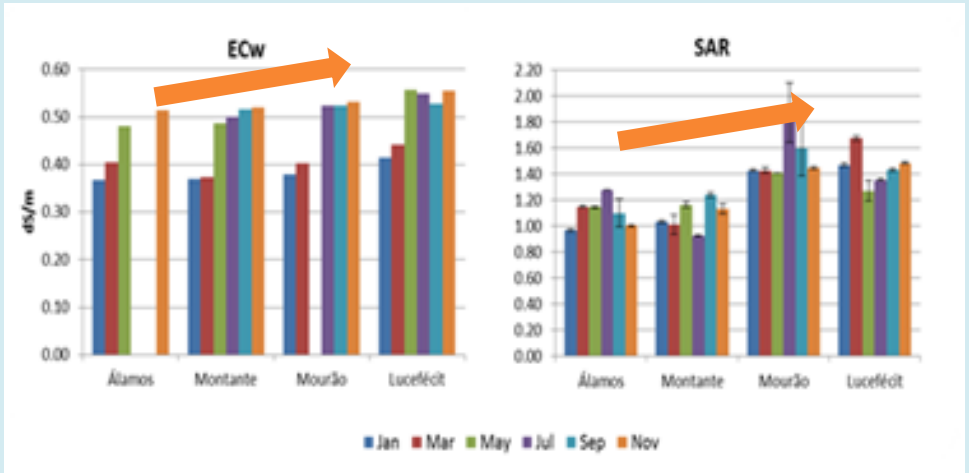


Results

Chemical parameters

- Over the year, there was a **slight upward trend** in **Sodium, Calcium**, **Chloride**, **Sulfate, ECw** and **SAR**.

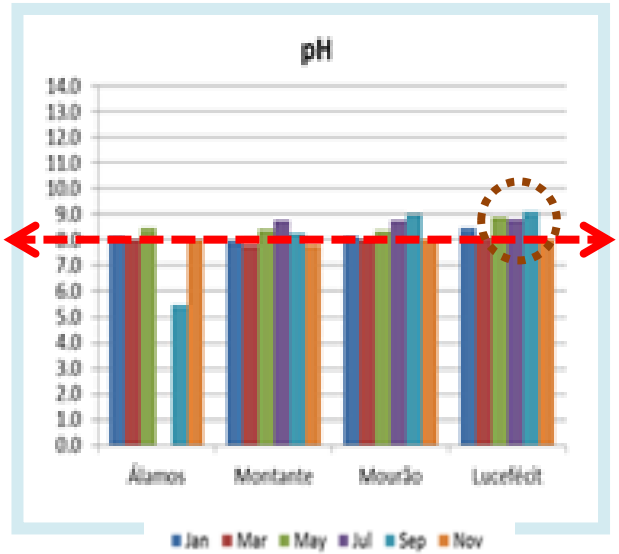


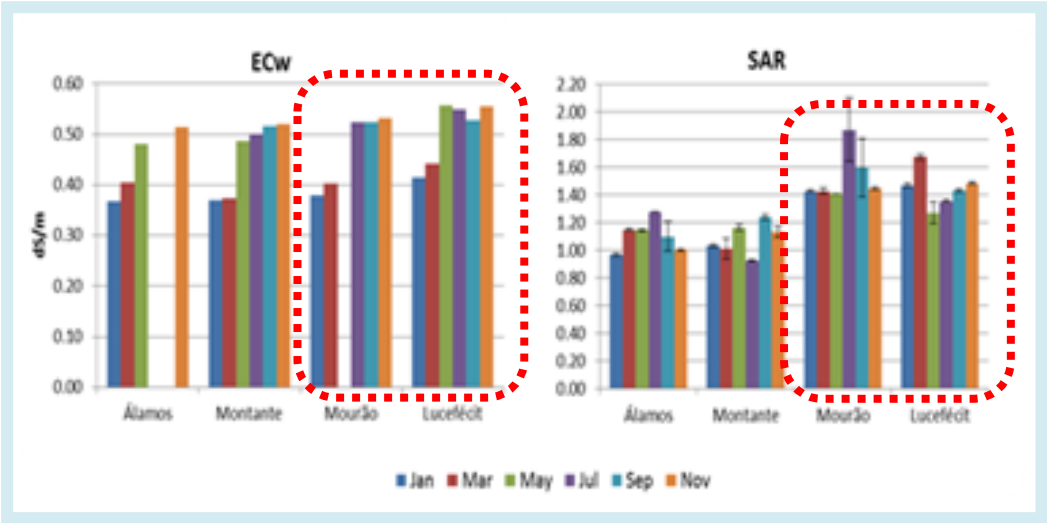


Results

Chemical parameters

- **pH** remained **stable around 8.0**, with the maximum value (**9.1**) recorded in September in Lucefécit.





- In general, highest concentrations and values occured in samples collected in the **Mourão** and **Lucefécit** (most upstream platforms).

Results

Irrigation water quality

Parameter	Site	Degree of restriction on use according to FAO29						Conpliance with DL 236/98					
		Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov
ECw	Plat Alamos	N	N	N			N	C	C	C			C
	Plat Montante	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Mourão	N	N		N	N	N	C	C		C	C	C
	Plat Lucefecit	N	N	N	N	N	N	C	C	C	C	C	C
SAR	Plat Alamos	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Montante	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Mourão	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Lucefecit	N	N	N	N	N	N	C	C	C	C	C	C
Soil infiltration rate	Plat Alamos	SM	SM	SM	SM	SM	SM						
	Plat Montante	SM	SM	SM	SM	SM	SM						
	Plat Mourão	SM	SM	SM	SM	SM	SM						
	Plat Lucefecit	SM	SM	SM	SM	SM	SM						
Cl^-	Plat Alamos	N	N	N	N	N	N	C	C	C	C	C	NC
	Plat Montante	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Mourão	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Lucefecit	N	N	N	N	N	N	C	NC	C	NC	NC	C
NO_3^-	Plat Alamos	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Montante	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Mourão	N	N	N	N	N	N	C	C	C	C	C	C
	Plat Lucefecit	N	N	N	N	N	N	C	C	C	C	C	C
pH	Plat Alamos	C	C	NC		C	C	C	C	NC		C	C
	Plat Montante	C	C	NC	NC	C	C	C	C	NC	NC	C	C
	Plat Mourão	C	C	C	NC	NC	C	C	C	C	NC	NC	C
	Plat Lucefecit	NC	C	NC	NC	NC	C	NC	C	NC	NC	NC	C

Results

Potential yield reductions

Crop		Potential yield reduction (%)
	Sunflower, Barley , Wheat, Olive , Tomato, Broccoli, Garlic	None
	Maize, Grape, Almond, Pepper	1 - 5
	Melon, Onion, Pumpkin	6 - 10
	Strawberry	11 - 15

- Risk of yield reductions **for salt concentrations factor X = 3.2,** representing the most common irrigation systems found in the Alqueva area - **drip and center-pivot systems**.
- The **main crops in the perimeter (olive, maize or grapevine) would not be salt affected** or else the potential yield reductions would be **below 5%**.
- Potential yield reductions from **6 to 10% were estimated** for sensitive or moderately sensitive, open-field, horticultural crops, such as **melon**, **onion** or **pumpkin**
- The highest potential yield loss (resulting from water samples collected between May and November) was estimated in **strawberry**, one of the most sensitive crops relatively to salinity tolerance scale. Nonetheless, strawberries are a **greenhouse hydroponic cultivation occupying a residual area in the region**.

Conclusions

- ECW and SAR values were in compliance at all sites and dates.
- In the Spring-Summer season, water presented pH values outside the recommended range.
- Water quality assessment regarding soil infiltration rate decline and surface crust formation problems showed a slight to moderate degree of restriction of use. This result should be taken into account when surface or sprinkler irrigation systems are used, particularly in fine textured and poorly structured soils.
- Yield reductions estimates for the main crops in the perimeter (olive, maize and grapevine) were none or below 5%. In open-field horticultural crops like melon, onion and pumpkin, salt sensible, estimates were in the range of 6 to 10%, so appropriate agronomic management practices, such as the addition of leaching fractions to irrigation, should be taken into account.

Thank you!

atomaz@ipbeja.pt