A D(R)YING RIVER: the Upper Paiva

V. Sousa
IST, University of Lisbon

I. Meireles
University of Aveiro

A. Gonçalves
IST, University of Lisbon

A. P. Flores
IST, University of Lisbon

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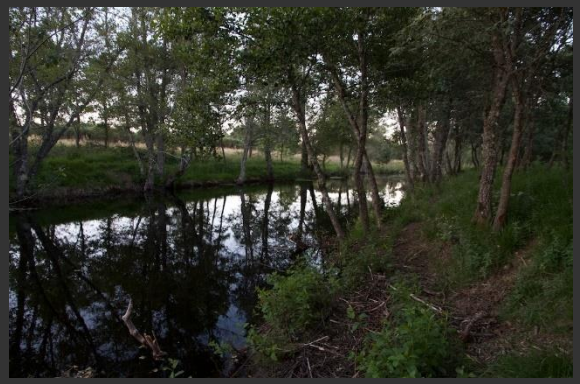
1. INTRODUCTION

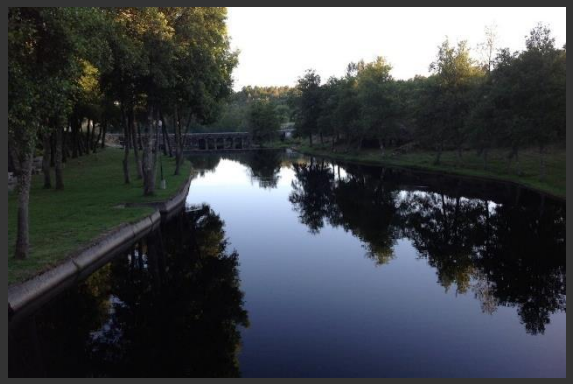
Based on several macro-scale hydrological modelling studies at continental (Arnell 1999a; Lehner et al. 2006) and global scales (Arnell 1999b; Döll and Zhang 2010; Sperna et al. 2012; van Vliet et al. 2013; Vörösmarty et al. 2000), climate change is expected to impact the hydrological regime of rivers and lakes. Along with studies focusing on Mainland Portugal, these general models estimate either an increase in seasonality, with higher winter flows compensating lower summer flows (Corte-Real et al. 1998, 1999; Trigo and Palutikof 2001), or even an annual flow decrease (APA 2010; Kilsby et al. 2007; Santos et al. 2002).

Based on the collective memory of the population in the communities along the upper Paiva River section, there has been a dramatic change in the hydraulic regime that became visible over the last two decades. According to interviews carried out during the study of EGSP (2015), there was a consistent report that the complete dry out of the river by the end of the summer months (end of August and beginning of September) began during late 1990s/early 2000s and has been regular ever since. Climate changes were considered a possible explanation considering that (EGSP 2015):

- the population has been decreasing since the early 2000s;
- there was a shift from agriculture to other, in principle, less water intensive economic activities;
- in addition to the decline of agriculture, the only major land covering changes have been due to numerous wildfires that occur every summer.

1. INTRODUCTION





2. METHODOLOGY

The methods used were statistical tests and involved:

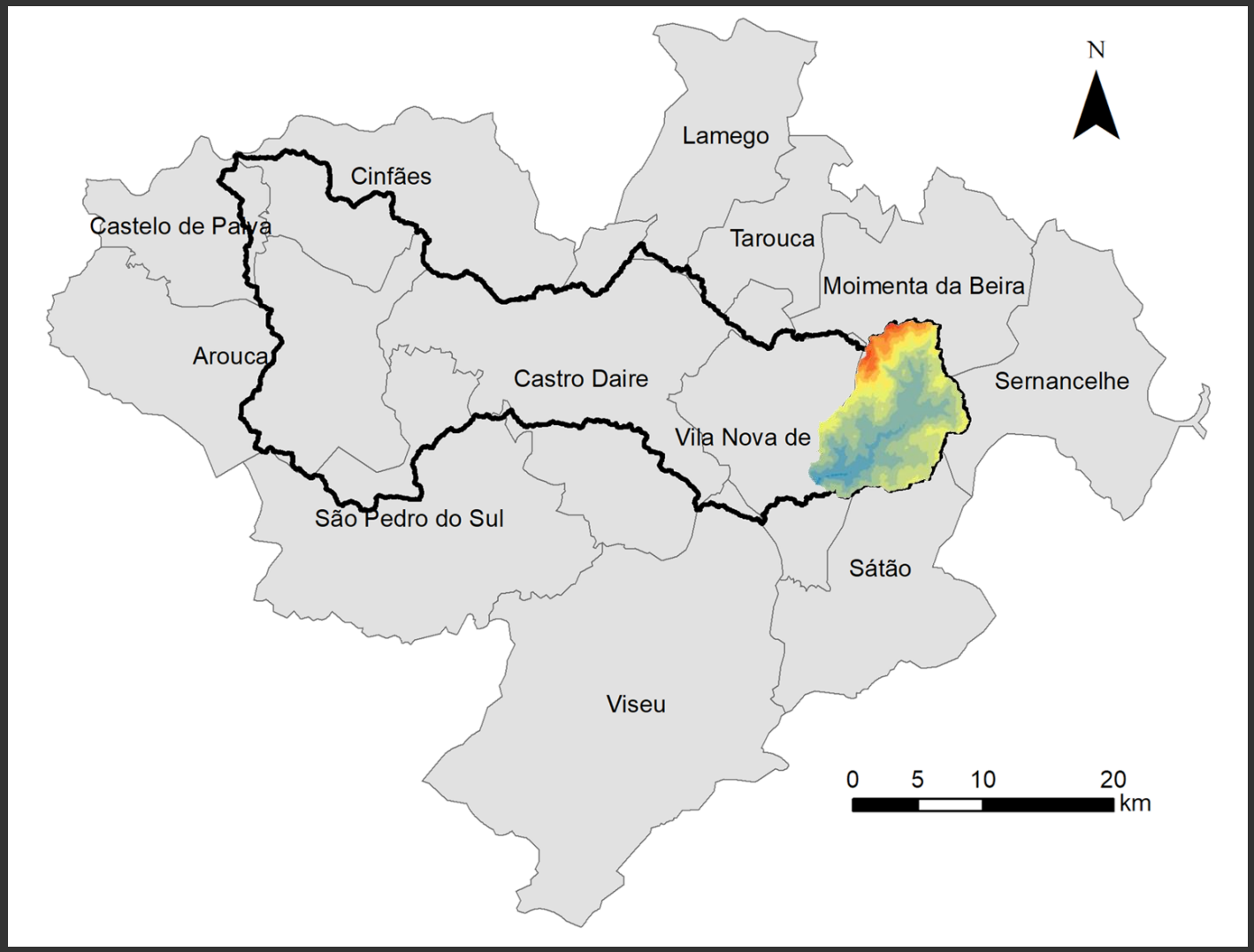
- analysis of the runoff data;
- analysis of the rainfall data.

The analyses were carried out at a yearly and a monthly time scales using basic statistics (average, maximum, minimum, standard deviation) and a set of statistical test to identify:

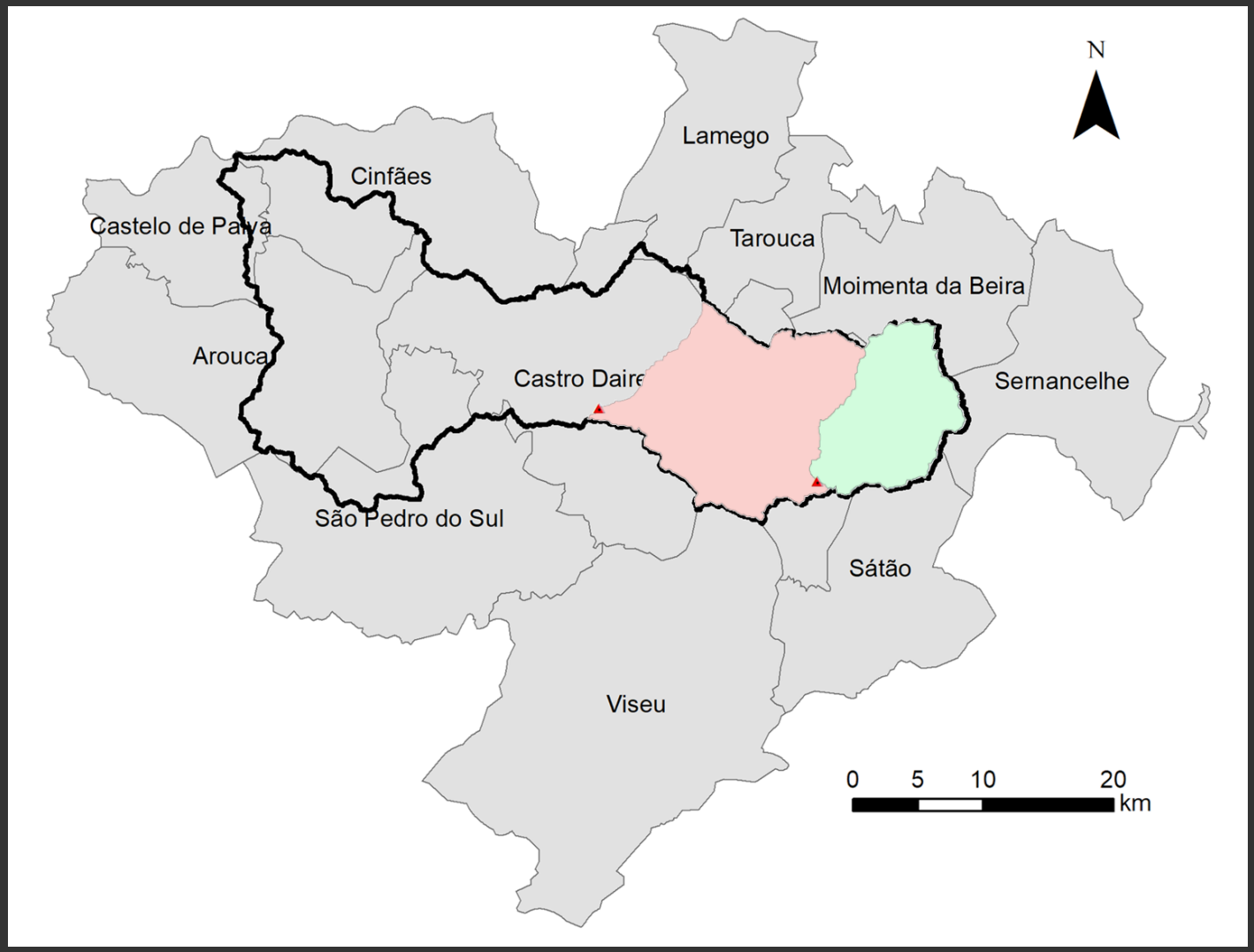
- trends (Mann-Kendall, Spearman's R, Linear Regression);
- jump in mean (Distribution free CUSUM, Cumulative Deviation, Worsley Likelihood Ratio);
- difference in mean/median (Wilcoxon Rank Sum, Student's t).

3. PAIVA RIVER

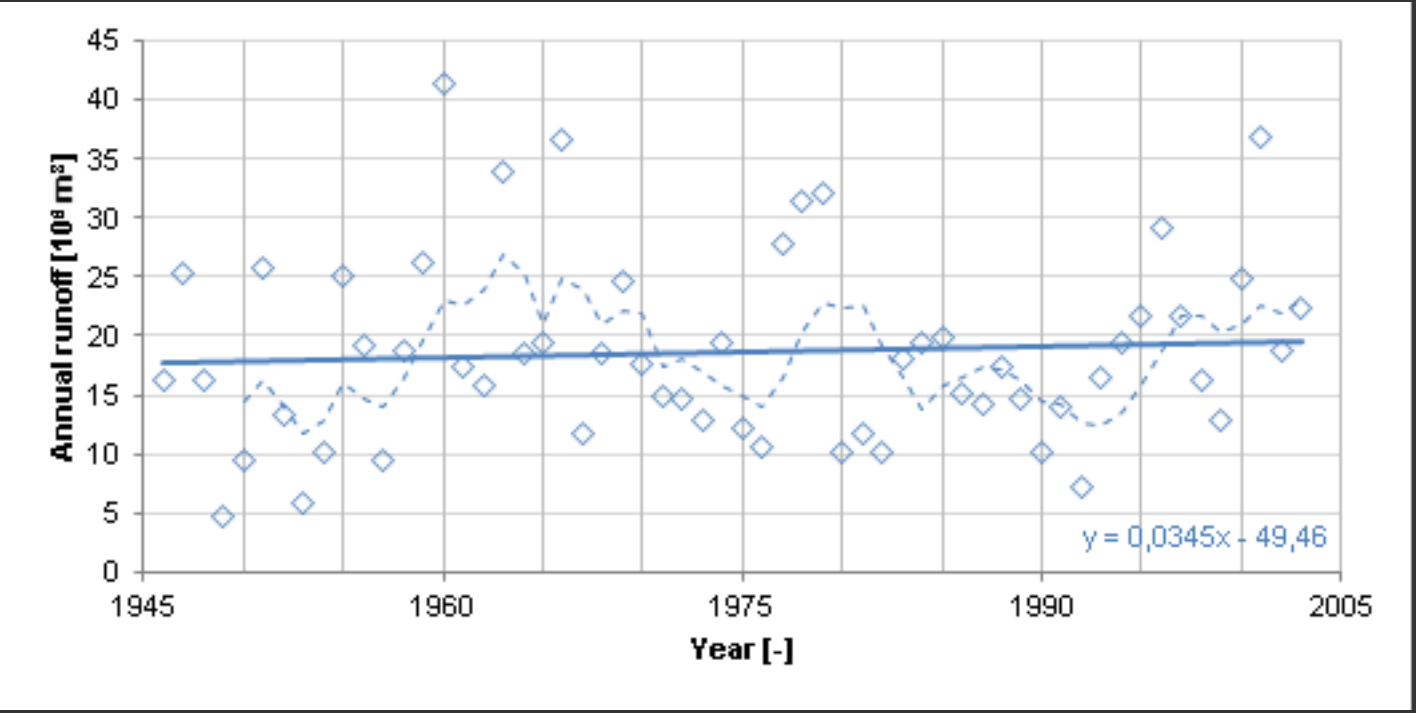
3. PAIVA RIVER



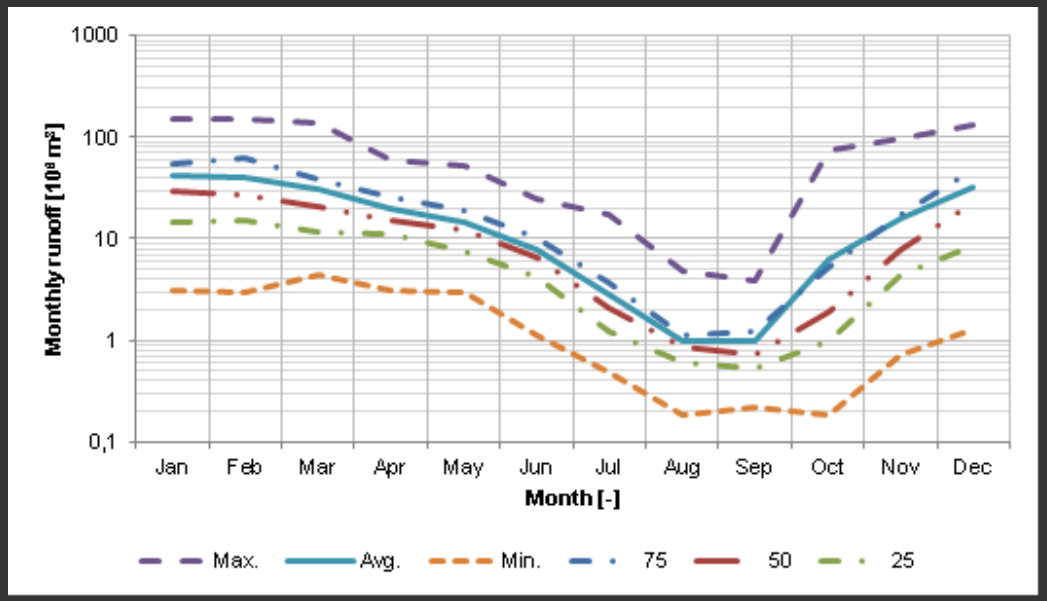
3.1. Runoff

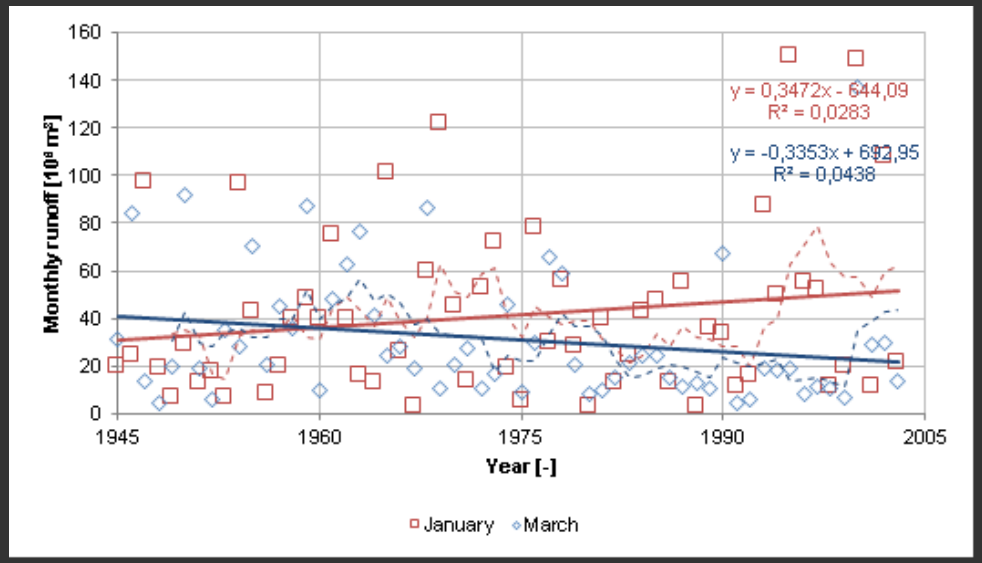

N
Lamego
Cinfães
Castelo de Paiva
Tarouca
Moimenta da Beira
Arouca
Castro Daire
Sernancelhe
São Pedro do Sul
Sátão
Viseu
0 5 10 20
km

3.1. Runoff

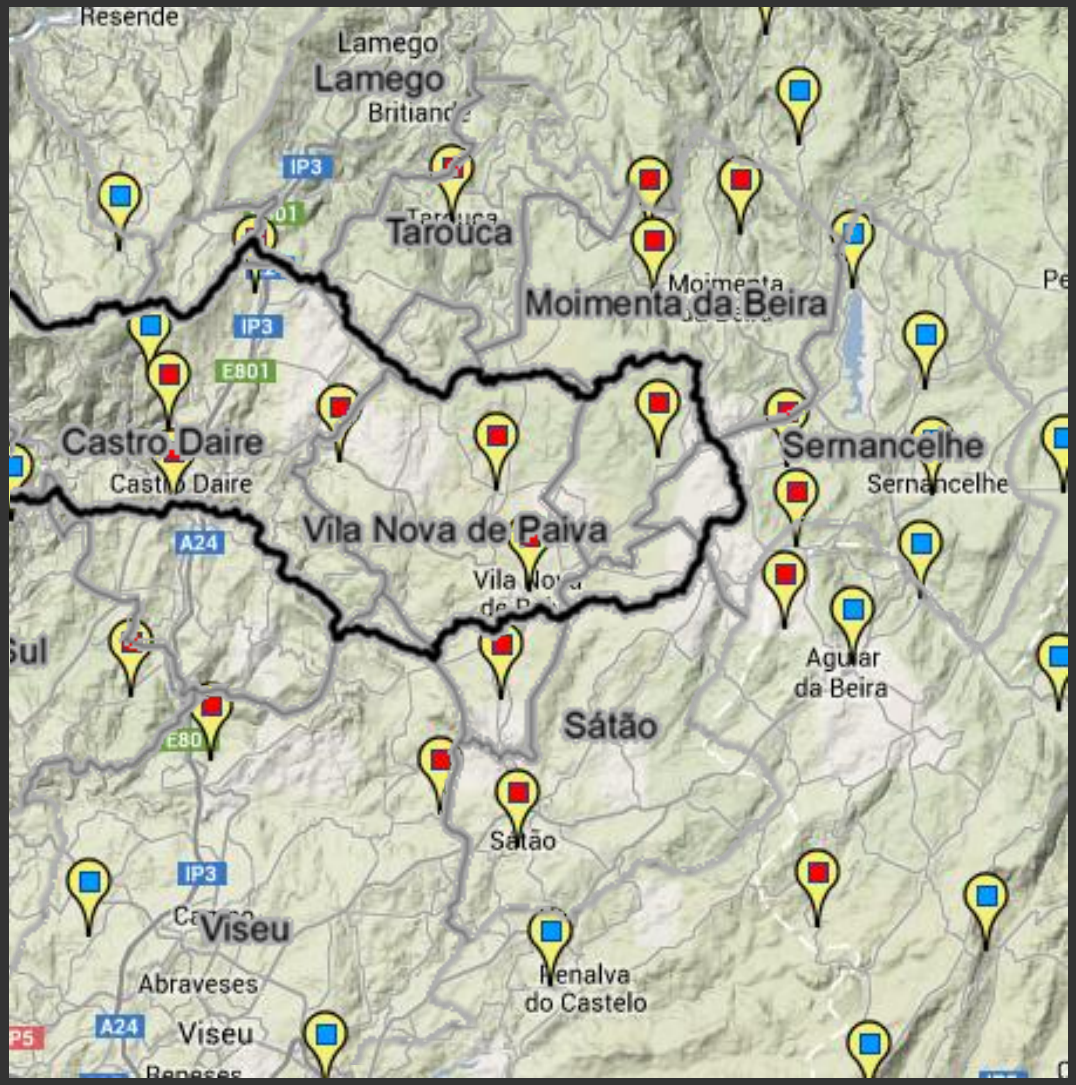

45
40
35
30
25
20
15
10
5
0
Annual runoff [10⁶ m³]
1945
1960
1975
1990
2005
Year [-]
y = 0,0345x - 49,46

3.1. Runoff

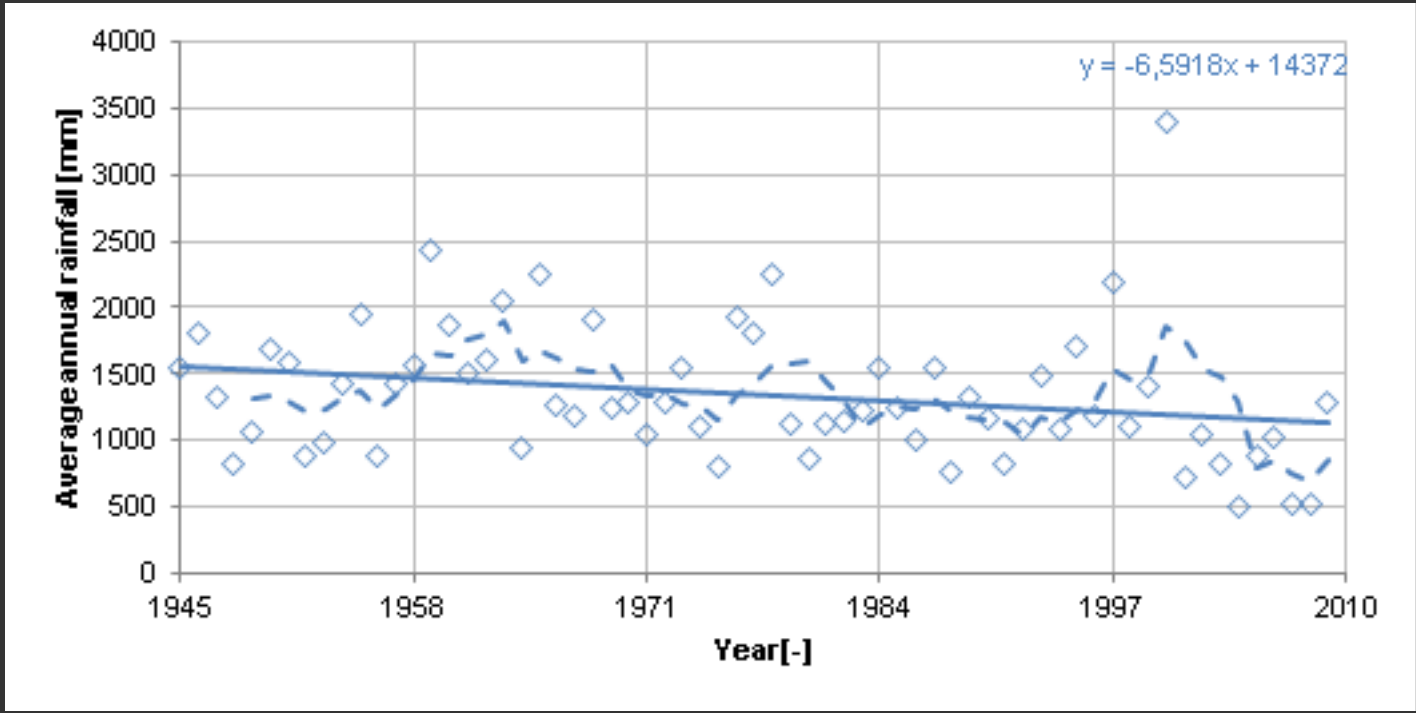

1000
100
10
1
0,1
Monthly runoff [10⁹ m³]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month [-]
Max.
Avg.
Min.
75
50
25


160
140
120
100
80
60
40
20
0
Monthly runoff [10⁹ m³]
y = 0,3472x - 644,09
R² = 0,0283
y = -0,3353x + 692,95
R² = 0,0438
1945
1960
1975
1990
2005
Year [-]
January
March

3.2. Rainfall


Resende
Lamego
Lamego
IP3
Tarouca
Moimenta da Beira
IP3
E801
Castro Daire
Castro Daire
Sernancelhe
Sernancelhe
Vila Nova de Paiva
A24
Aguiar
da Beira
Sátão
Sátão
IP3
Viseu
Abraveses
Viseu
A24
Penalva
do Castelo

3.2. Rainfall

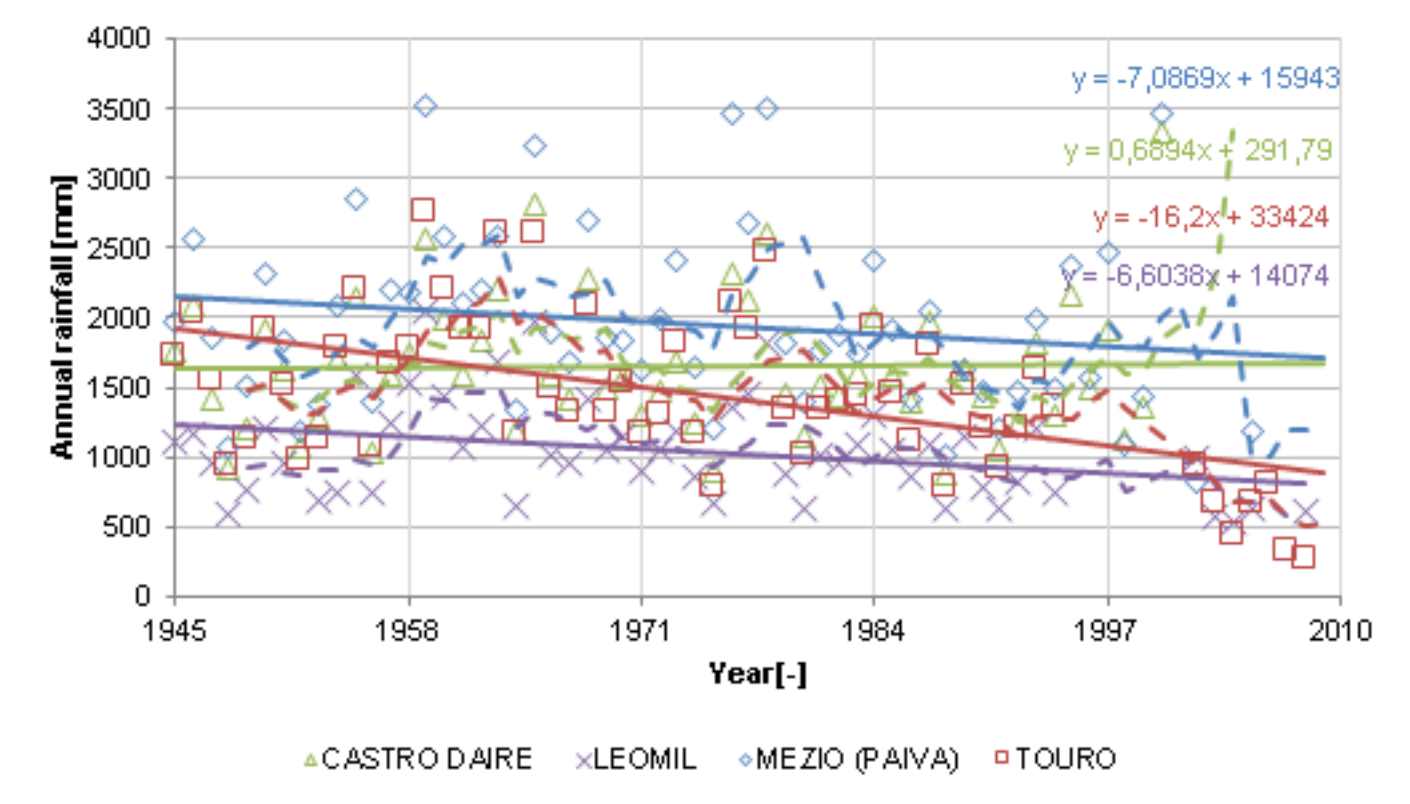

y = -6,5918x + 14372
Average annual rainfall [mm]
4000
3500
3000
2500
2000
1500
1000
500
0
1945
1958
1971
1984
1997
2010
Year[-]

3.2. Rainfall

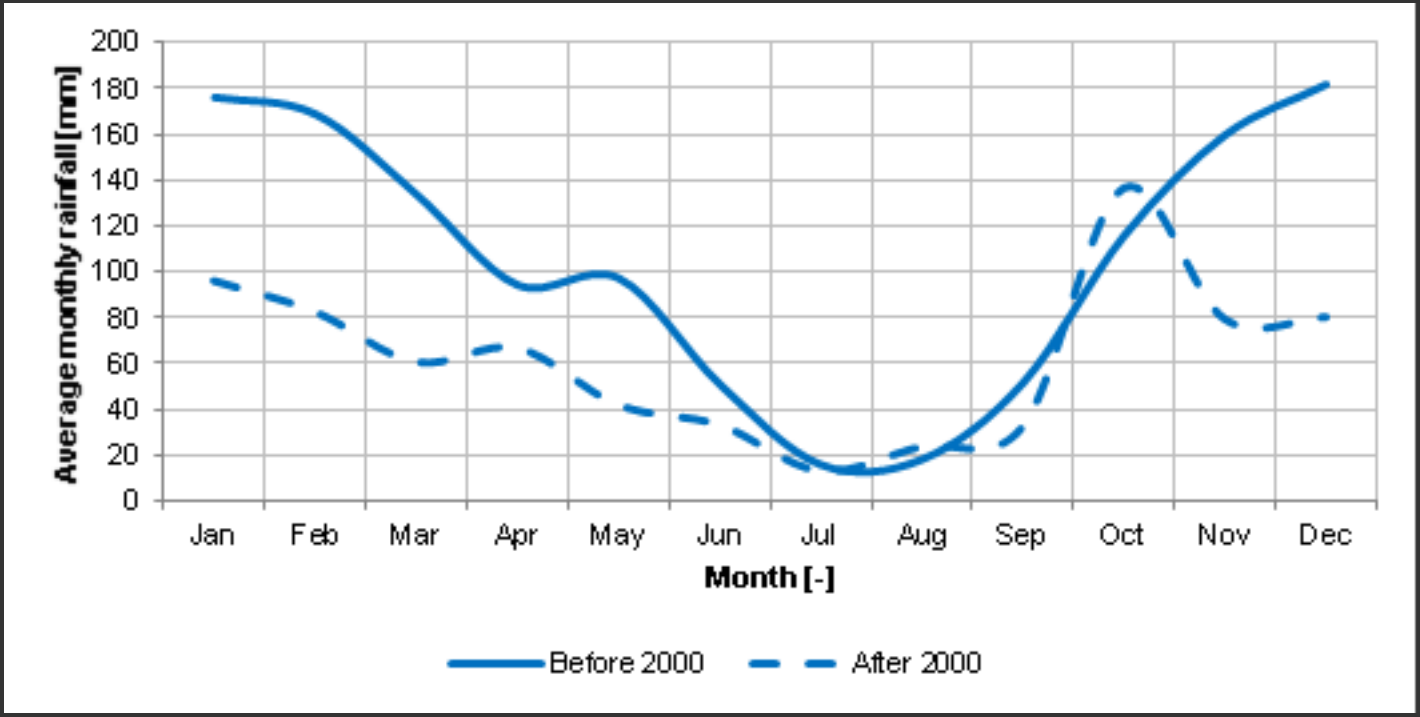
Test	Statistics	Critical values (α)			Turning year
		0.01	0.05	0.10	
Trend					
Mann-Kendall	3.070	*2.576*	*1.960*	*1.645*	-
Spearman's R	3.002	*2.576*	*1.960*	*1.645*	-
Linear Regression	-2.211	2.690	2.010	1.680	-
Jump in Mean					
Distribution free CUSUM	9.000	11.526	9.617	*8.627*	1978
Cumulative Deviations	1.223	1.520	1.270	*1.140*	2000
Worsley Likelihood Ratio	3.492	3.790	*3.160*	*2.870*	2000
Difference in Mean/Median					
Wilcoxon Rank Sum	2.168	2.576	*1.960*	*1.645*	-
Student t	1.294	2.690	2.010	1.680	-
Randomness					
Median Crossing	0.143	2.576	1.960	1.645	-
Turning Points	0.342	2.576	1.960	1.645	-
Rank Difference	1.077	2.576	1.960	1.645	-
Autocorrelation	0.476	2.576	1.960	1.645	-

Italic value indicates statistically significant results

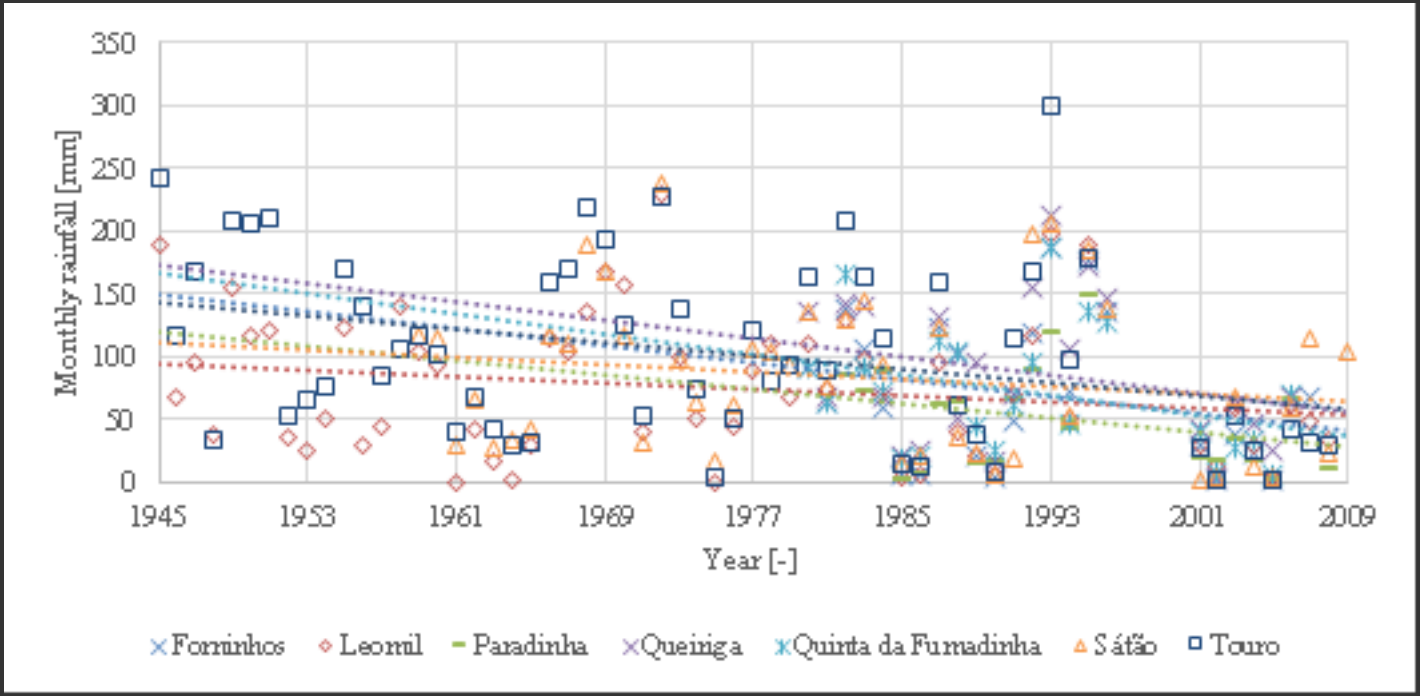
3.2. Rainfall


4000
3500
3000
2500
2000
1500
1000
500
0
Annual rainfall [mm]
1945
1958
1971
1984
1997
2010
Year[-]
y = -7,0869x + 15943
y = 0,6694x + 291,79
y = -16,2x + 33424
y = -6,6038x + 14074
CASTRO DAIRE
LEOMIL
MEZIO (PAIVA)
TOURO

3.2. Rainfall


Average monthly rainfall [mm]
200
180
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month [-]
Before 2000
After 2000

3.2. Rainfall


350
300
250
200
150
100
50
0
Monthly rainfall [mm]
1945
1953
1961
1969
1977
1985
1993
2001
2009
Year [-]
Forninhos
Leonil
Paradinha
Queiriga
Quinta da Furnadinha
Sátão
Touro

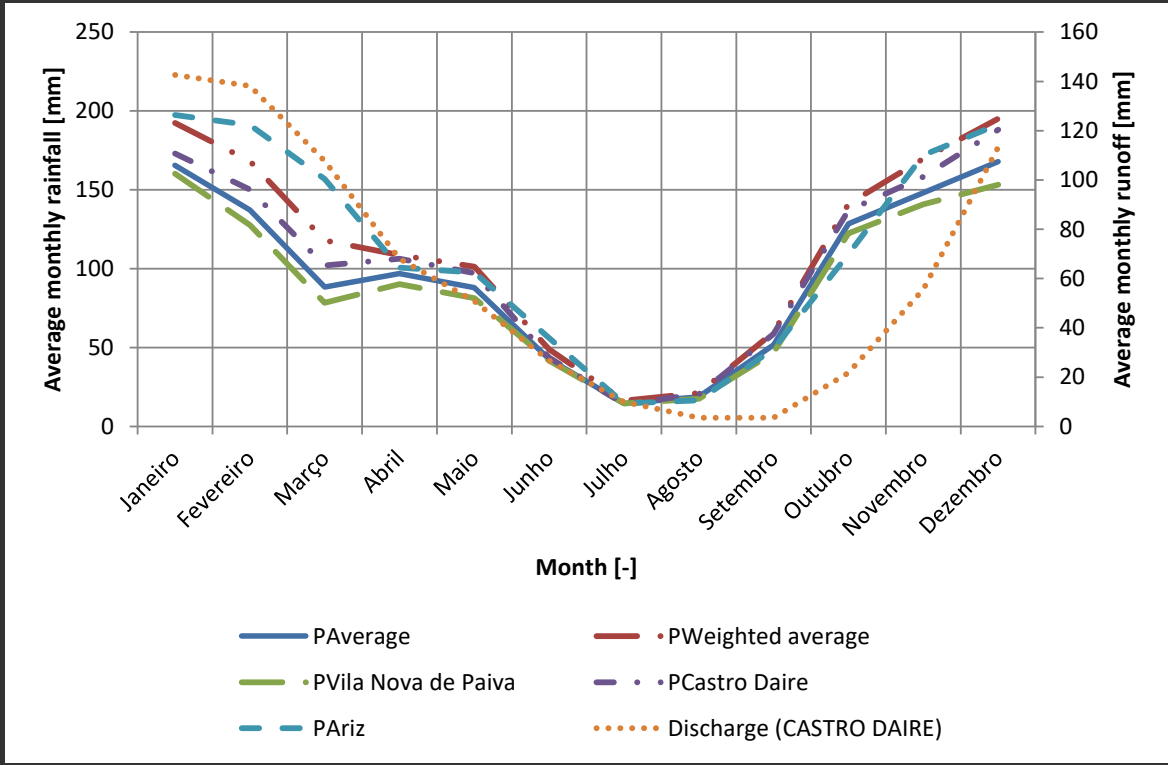
3.2. Rainfall

Test	Statistics	Critical values (α)			Turning year
		0.01	0.05	0.10	
Trend					
Mann-Kendall	2.710	*2.576*	*1.960*	*1.645*	-
Spearman's R	2.708	*2.576*	*1.960*	*1.645*	-
Linear Regression	2.809	*2.690*	*2.010*	*1.680*	-
Jump in Mean					
Distribution free CUSUM	10.000	11.526	*9.617*	*8.627*	1975
Cumulative Deviations	1.745	*1.520*	*1.270*	*1.140*	1975
Worsley Likelihood Ratio	3.969	*3.790*	*3.160*	*2.870*	1975
Difference in Mean/Median					
Wilcoxon Rank Sum	2.624	*2.576*	*1.960*	*1.645*	-
Student t	2.468	2.690	*2.010*	*1.680*	-
Randomness					
Median Crossing	0.714	2.576	1.960	1.645	-
Turning Points	1.025	2.576	1.960	1.645	-
Rank Difference	1.077	2.576	1.960	1.645	-
Autocorrelation	1.707	2.576	1.960	*1.645*	-

Italic value indicates statistically significant results

4. FINAL REMARKS

A statistically significant change in the rainfall amount and the number of consecutive days without precipitation was found within the Paiva River basin for the analyzed period. The available data does not allow concluding if the rainfall amount explains the drying of the upper Paiva River, but the number of consecutive days without rain is consistent with the time to deplete the upper Paiva river groundwater supply.



5. ACKNOWLEGMENTS

This study was possible with the financial support of EGSP – Sistemas de Energia e Potência and is part of a more extensive study on the upper Paiva River natural and human interaction.

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