DROUGHT AND WATER SCARCITY MANAGEMENT PLAN FOR THE PELOPONNESE RIVER BASIN DISTRICTS

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INTRODUCTION

The drought & water scarcity management plan was drafted for the Peloponnese River Basin Districts (RBD) as outlined by the implementation of the Water Framework Directive 2000/60/EC in Greece. This plan is formed according to:

- ✓ EC Guidance Documents (G.D. 24)
- ✓ EC Working Documents (Addressing the challenge of water scarcity and droughts in the EU, 18/7/07)
- ✓ EC Reports (Drought management plan & Med. water scarcity & drought report)
- ✓ Publications and literature
- ✓ Other Mediterranean countries experiences

PROJECT SUBJECTS

1. Record extreme past drought and scarcity events.
2. Risk and impact assessment of future drought and scarcity events.
3. Possible impact assessment on the environmental objectives of WFD 2000/60/EC.
4. Determination of a proper drought index as a predictor of such phenomena
5. Determination of basic, supplementary and additional measures
6. Identify strategic water reserves that may be used in case of drought – scarcity
7. Suggestions of creating a flexible and effective early warning system

DEFINITIONS RELATED TO DROUGHT

DROUGHT represents relevant temporary decrease of the average water availability refer to important deviations from the average levels of natural water availability and are considered natural phenomena.

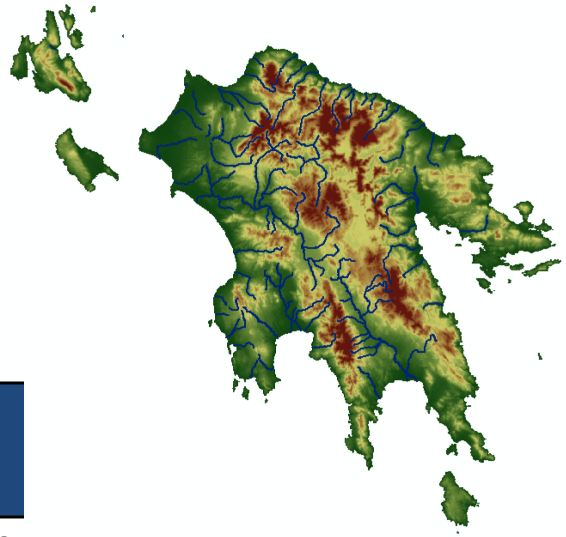
WATER SCARCITY is defined as a situation where insufficient water resources are available to satisfy long-term average requirements. The water demand exceeds the water resources exploitable under sustainable conditions

TYPES OF DROUGHT

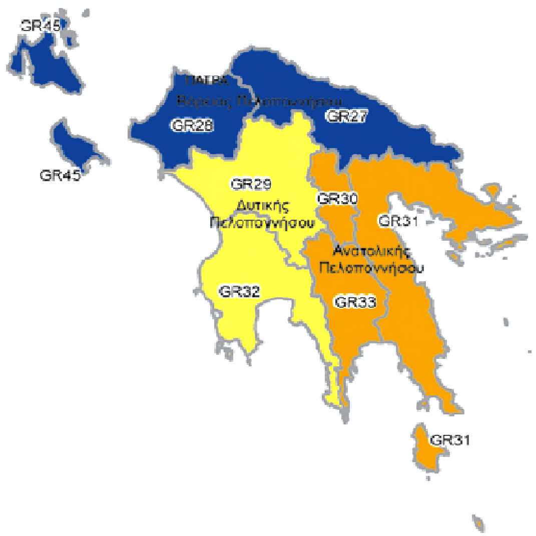
- ✓ Meteorological
- ✓ Agricultural
- ✓ Hydrological (Groundwater and surface water bodies)
- ✓ Socioeconomic (Society Vulnerability due to lack of water)

STUDY AREA

The area under study in this project covers the 3 River Basin Districts (RBD) of Western (GR01), Northern (GR02) and Eastern Peloponnese (GR03) of ~23.100km^2 in total area.
Each RBD is consisted of two or more River Basins

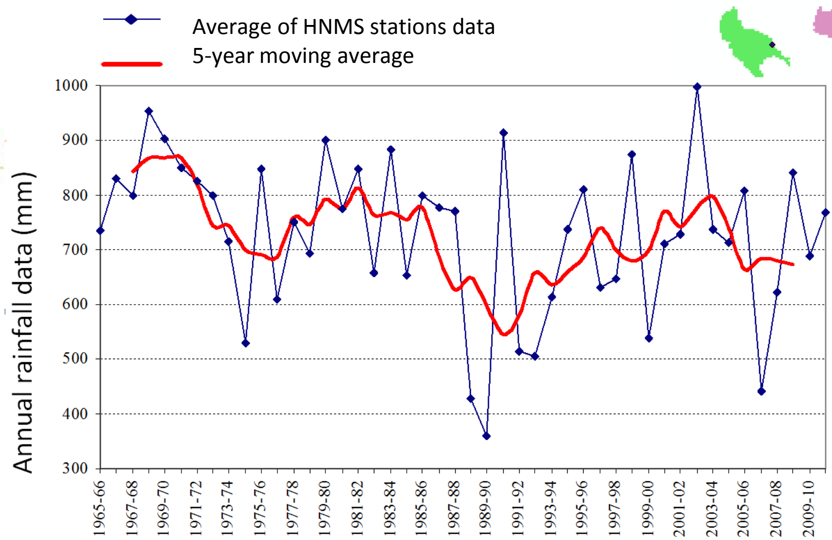


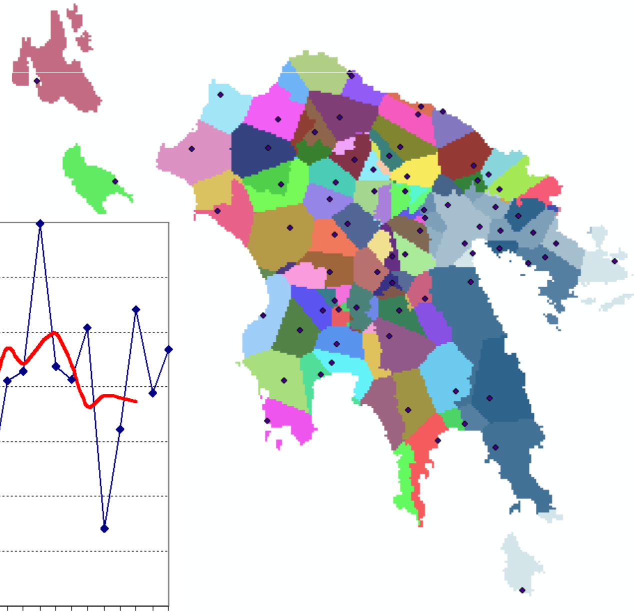
River Basin District	River Basin	Name	Area (km^2)
GR01	29	Alpheus	3.810
GR01	32	Pamisos-Nedondas-Neda	3.425
GR02	27	North Peloponnese Str.	3.685
GR02	28	Piros-Vergas-Pinios	2.423
GR02	45	Kefalonia-Ithaca-Zante	1.289
GR03	30	Tripoli's plateau	907
GR03	31	Argolikos bay streams	5.296
GR03	33	Eurotas	2.239
		Total Area:	**23.074**



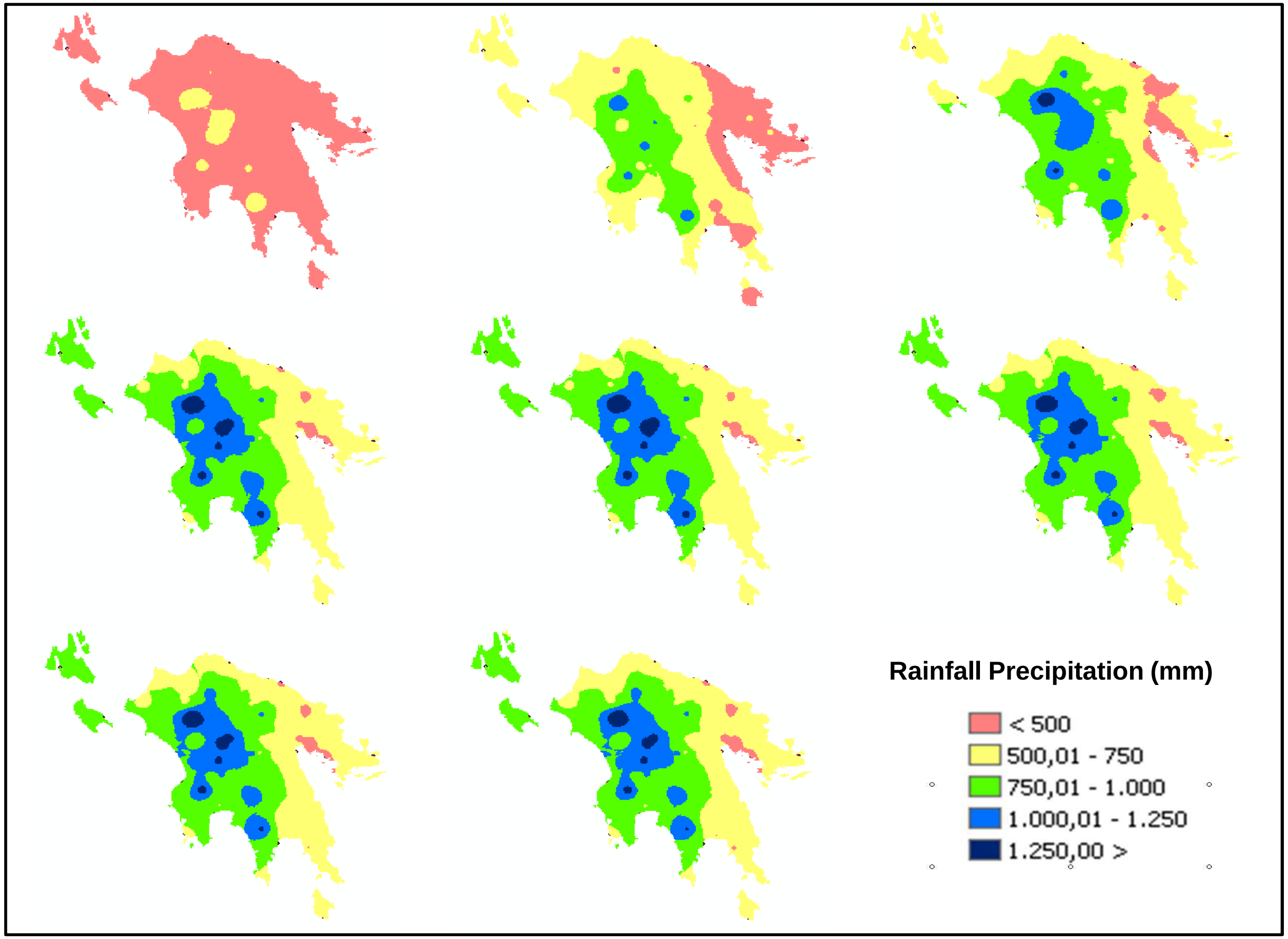
RAINFALL STATIONS DATA

- ✓ **74** independent stations (**7** of them from Hellenic National Meteorological Service)
- ✓ Time period is from 1980-81 to 2001-2002 (22 hydrological years)
- ✓ 7 time series were extended by newer available data (up to 2010-2011 HNMS).





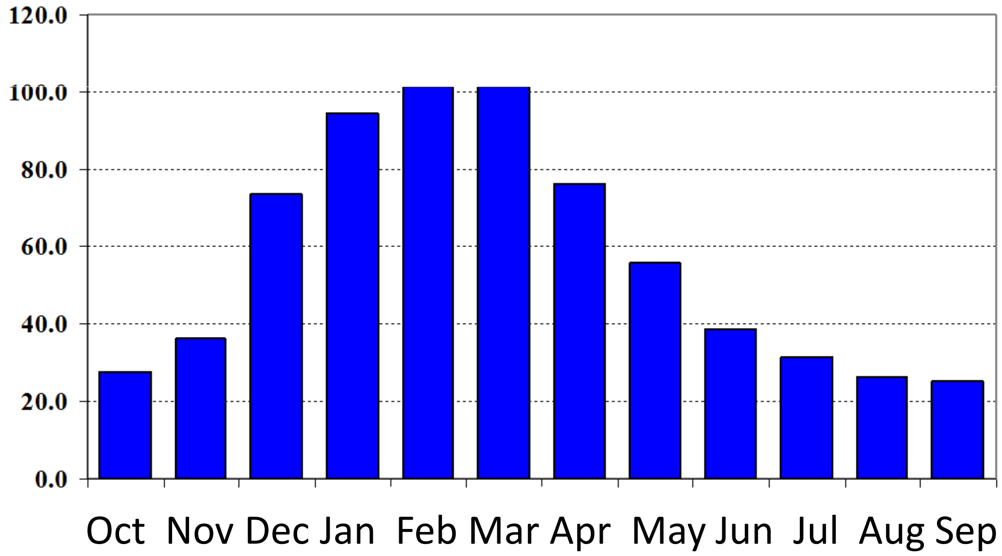
GEOGRAPHICAL DISTRIBUTION OF MEAN RAINFALL



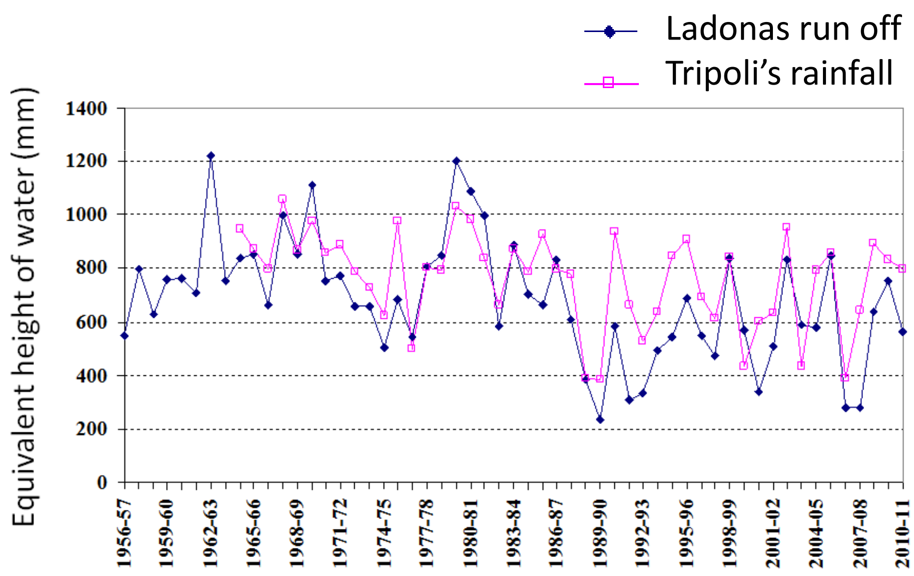
Geographical distribution of mean rainfall for various timescales.
From upper left to down right: 3, 6, 9 months, 1, 2, 3, 4 and 5 years

HYDROMETRIC DATA

- ✓ The study area is poor in hydrometric data due to infrequent surface measurements
- ✓ **Ladonas** is the exception with a great number of runoff data 1956-57 to 2010-11
- ✓ Data from Public Power Corporation SA.



Mean monthly heights of run off at the sub basin of Ladonas upstream the dam

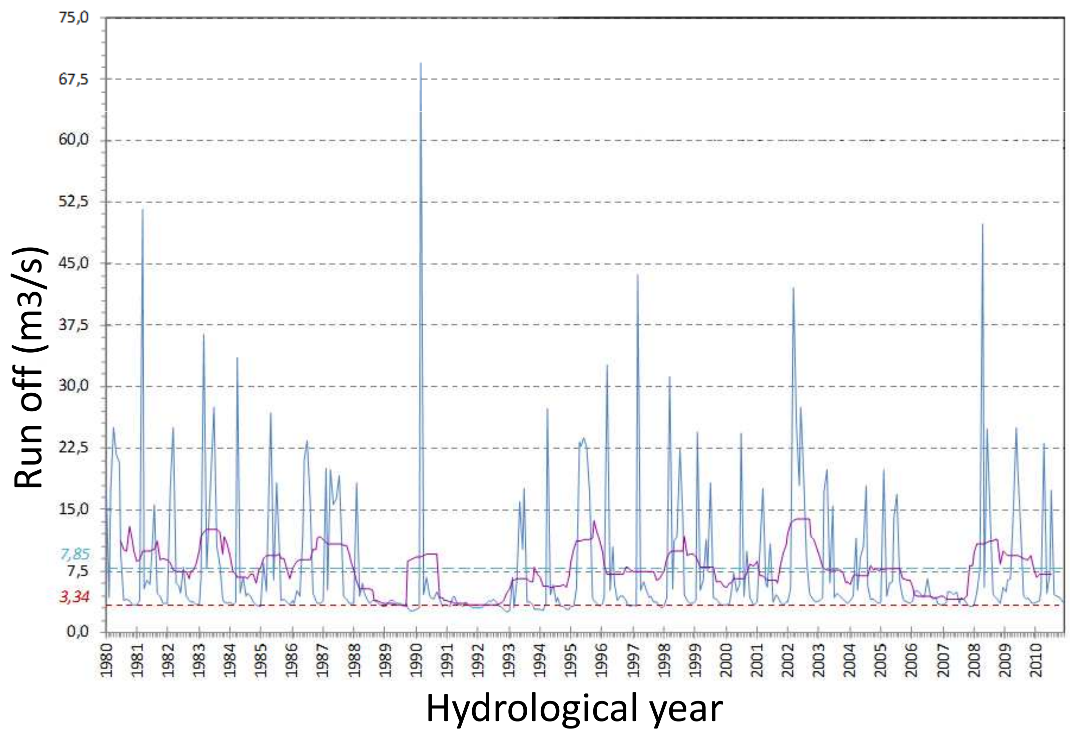


Ladonas annual run off height time series and Tripoli's annual rainfall data

HYDROMETRIC DATA

- ✓ Due to the lack of surface water measures, the use of monthly run off time series (1980-2002) has adopted, produced by means of hydrological simulation models (Sacramento) at specific locations of river water bodies (**14**). “Development of systems and tools for water resources management of Peloponnese BD“, Ministry of Development, 2008.
- ✓ The hydrometric time series have been extended based on newer data of precipitation up to 2011.

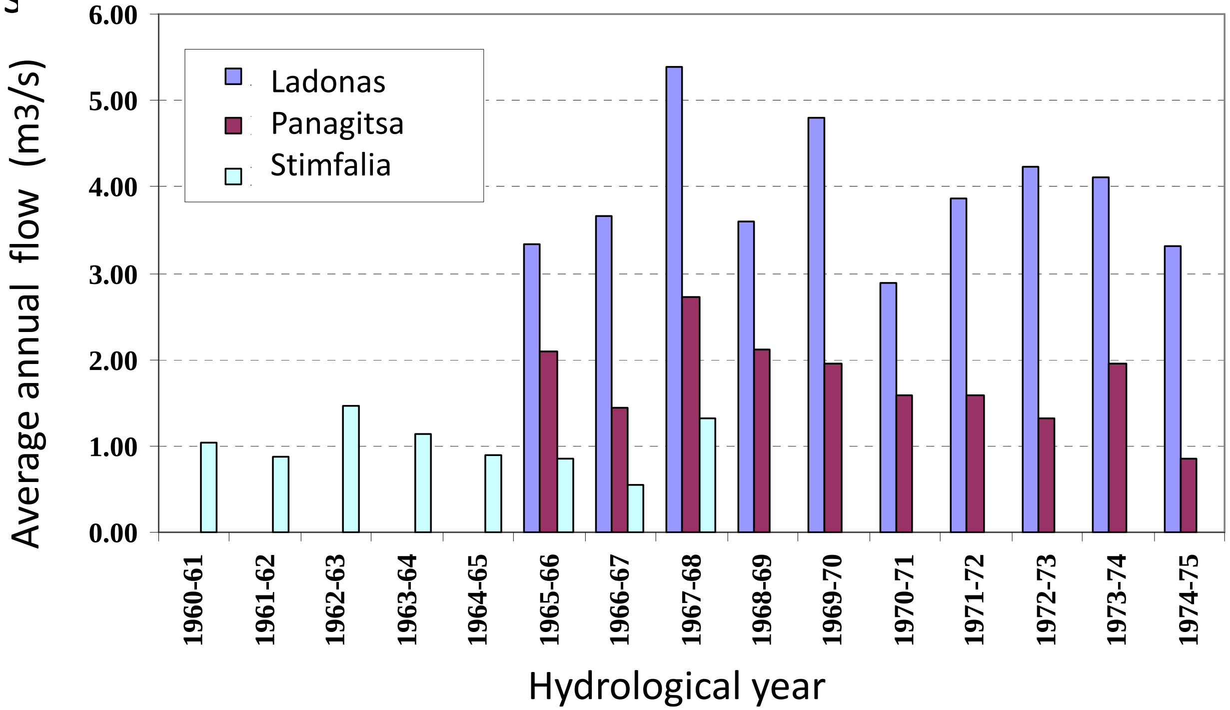
ex. River Pamissos, RBD 01 Peloponnese



SPRINGS FLOW TIME SERIES

✓ The data of monthly flow rates were recovered especially for the decades of 1960 and 1970 by **24** important springs of the Peloponnese area (PPC, IGME, Ministry of Development, Ministry of Infrastructure, Transport and Networks).

✓ New measurements for the years 2004-2008 were taken by IGME which supplement the past time series

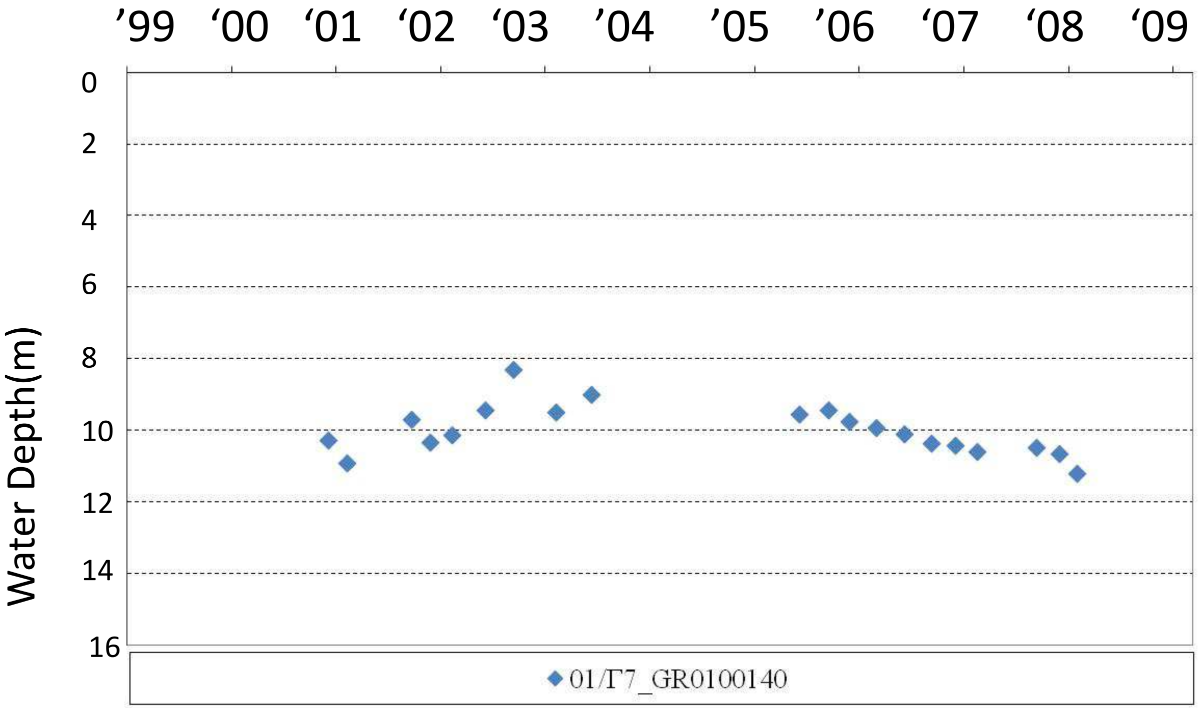


DATA MEASURING WELLS WATER LEVEL

✓ The well's data are based on evidence provided by measurements of the underground level that were collected during older studies and also provided by measurements taken by the IGME during the period from the years 2000 to 2008.

✓ The correlation between water supply and groundwater runoff cannot be evaluated from the existing few data of level measurements especially during dry periods.

Water depth of groundwater body GR0100140 (Data from IGME 2001-2008)



CALCULATIONS OF METEOROLOGICAL DROUGHT INDICATORS

The study implemented a new drought index, called the Return Period Precipitation Index, RPPI. This improved version of the SPI (Standardized Precipitation Index) as to:

(a) The theoretical distribution functions (Lognormal & Weibull) applied to historical rainfall data

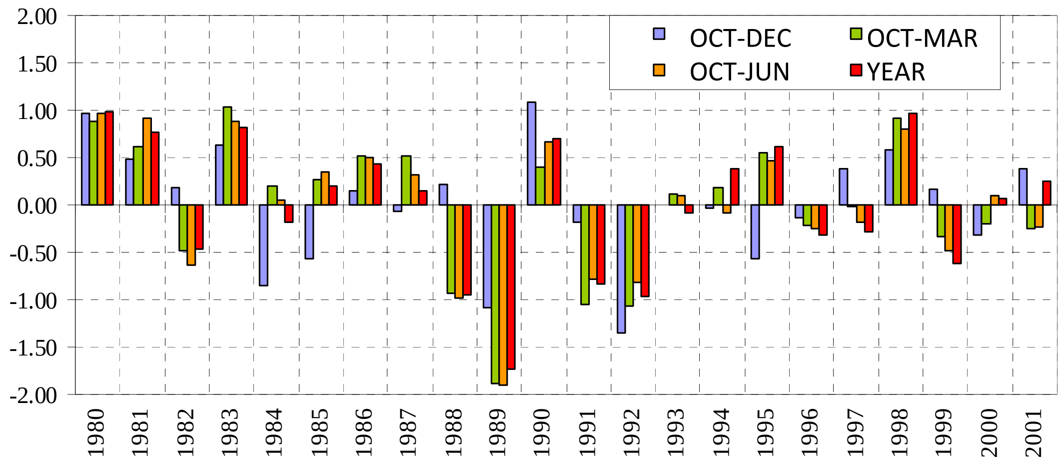
(b) The prices received, referring to a return period of drought episode and, therefore, are immediately apparent.

Symbol	Range Indicator Drought, SPI	Range Function Distribution, F_Z	Range return period (RPPI index, years)	Drought level
A-	**0.0 ≥ SPI > –1.0**	$0.500 \geq F_Z > 0.159$	$2.0 \geq T > 6.3$	Mild
B-	**–1.0 ≥ SPI > –1.5**	$0.159 \geq F_Z > 0.067$	$6.3 \geq T > 15.0$	Moderate
Γ-	**–1.5 ≥ SPI > –2.0**	$0.067 \geq F_Z > 0.023$	$15.0 \geq T > 44.0$	Severe
Δ-	**–2.0 ≥ SPI**	$0.023 \geq F_Z$	$44.0 \geq T$	Extreme

$F_Z = 1 - 1 / \text{RPPI}$, If RPPI suggests a return period of maximum

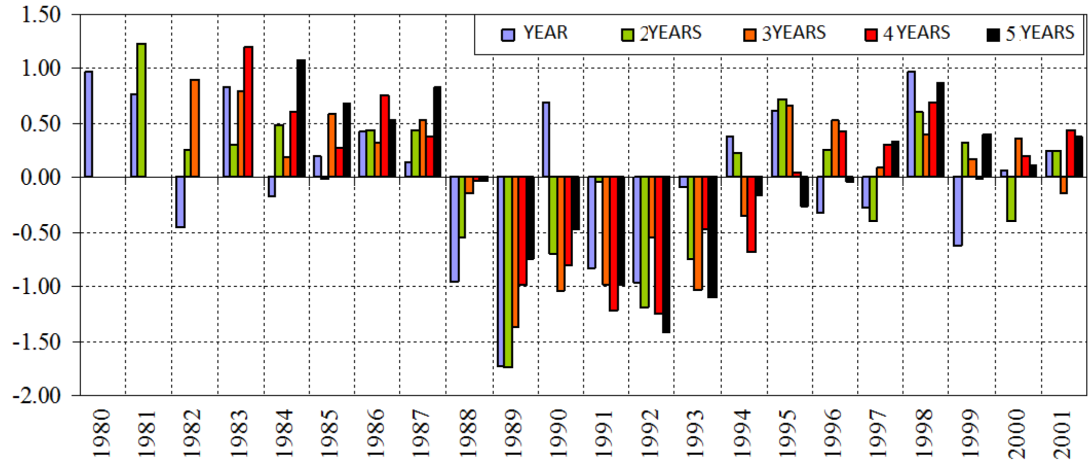
$F_Z = 1 / \text{RPPI}$, If RPPI suggests a return period of minimum

CALCULATIONS OF METEOROLOGICAL DROUGHT INDICATORS

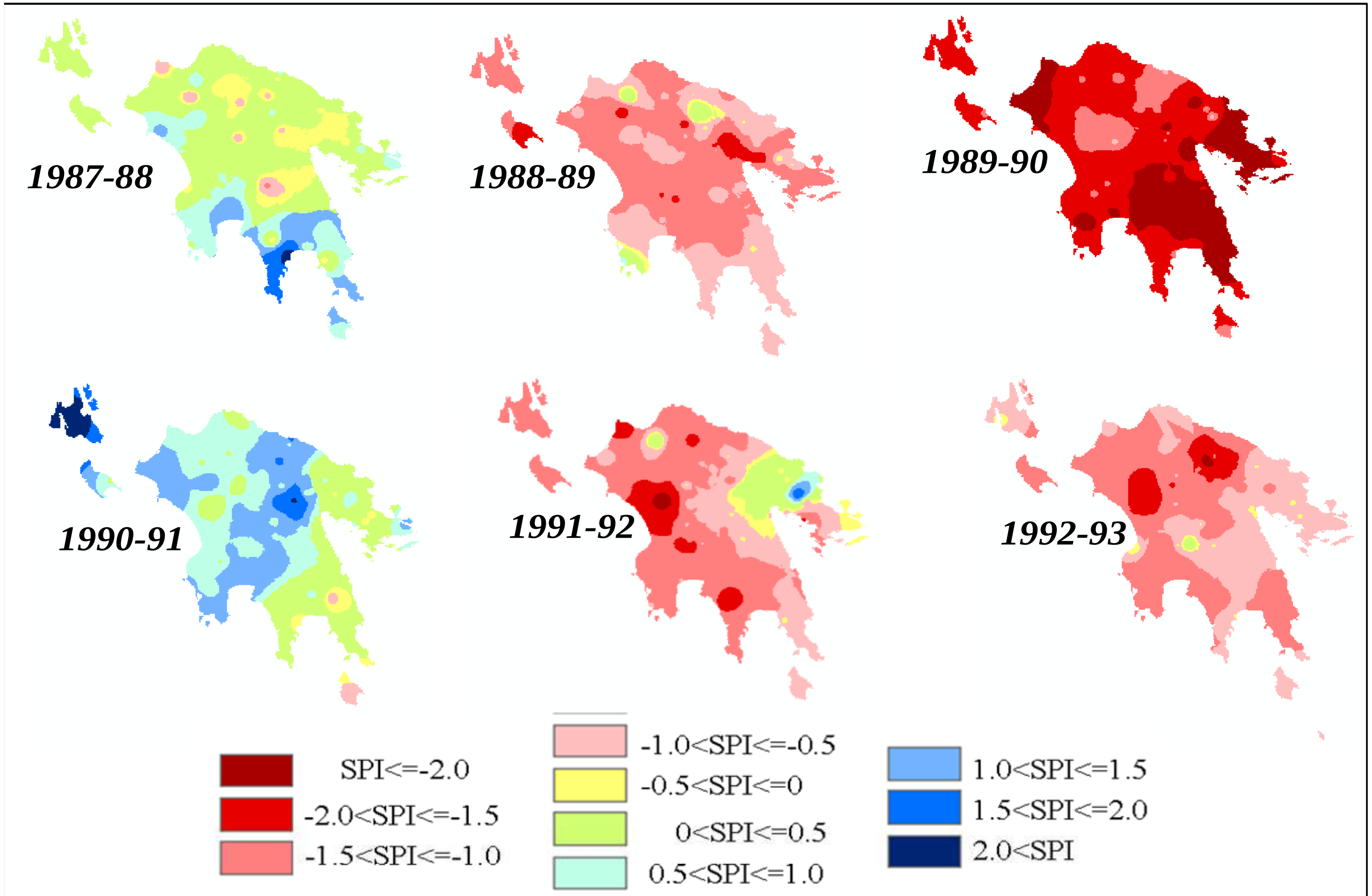


Meteorological drought index (SPI) of Peloponnese. Time scale from quarterly to annual.

Meteorological drought index (SPI) of Peloponnese. Time scale from annual to five years.

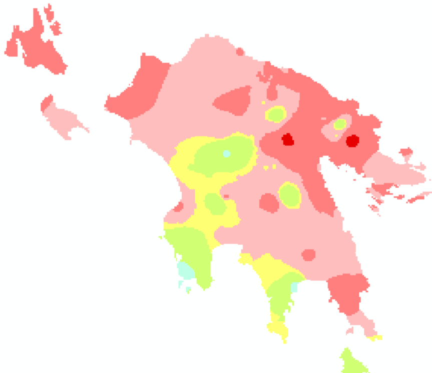


CALCULATIONS OF METEOROLOGICAL DROUGHT INDICATORS

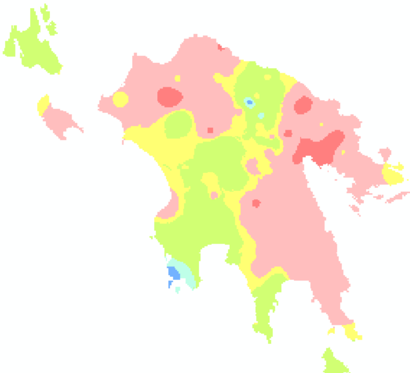


Spatial distribution of drought through 1-year average drought index during the period 1987-1993

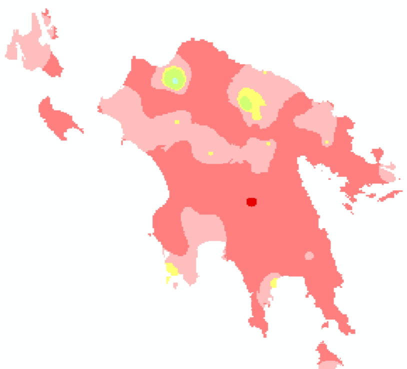
CALCULATIONS OF METEOROLOGICAL DROUGHT INDICATORS



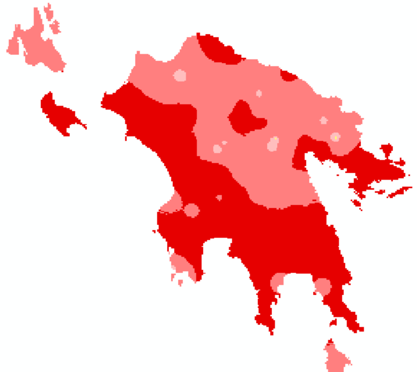
Oct ‘85 – Sep ‘90



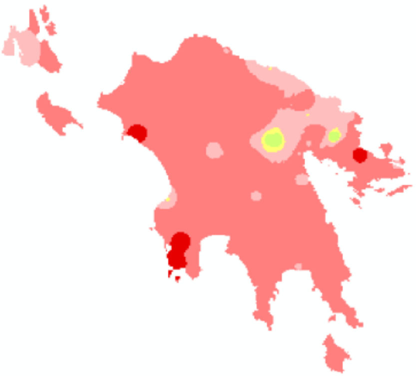
Oct ‘86 – Sep ‘91



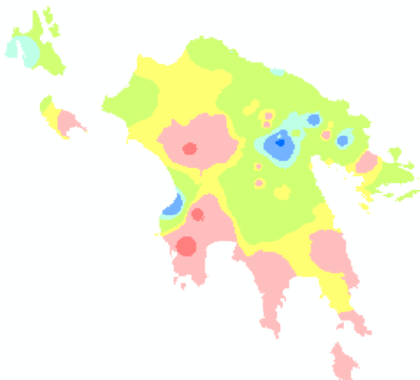
Oct ‘87 – Sep ‘92



Oct ‘88 – Sep ‘93

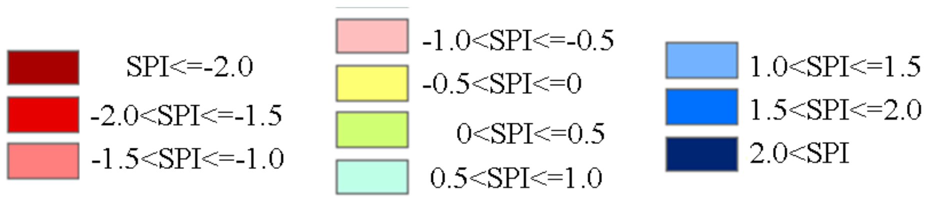


Oct ‘89 – Sep ‘94



Oct ‘90 – Sep ‘95

Spatial distribution of drought through 5-year average drought index during the period 1988-1995



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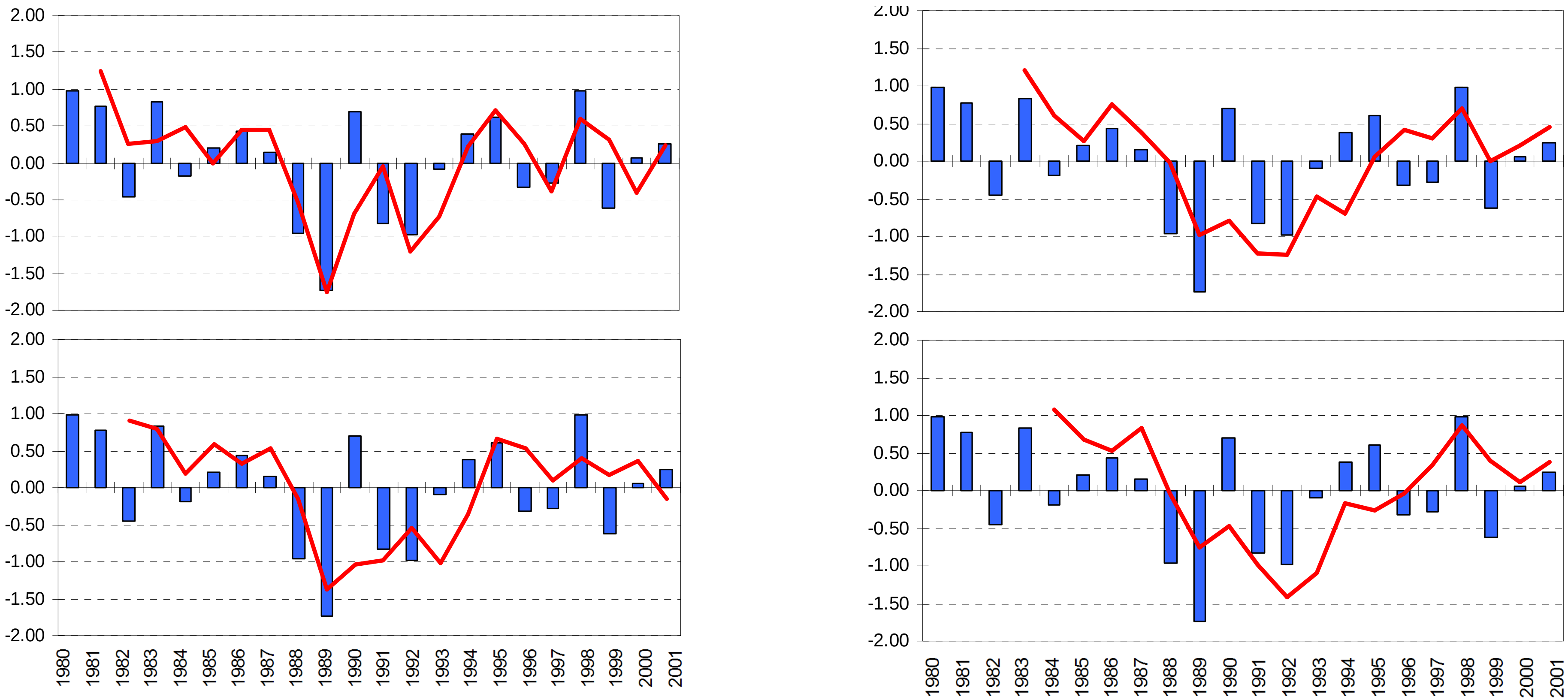
CALCULATIONS OF METEOROLOGICAL DROUGHT INDICATORS



Time Evolution of annual SPI (columns) and 2,3,4 and 5 year (lines) SPI for the whole area of Peloponnese

PAST SEVERE DROUGHT EVENTS AT PELOPONNESE

1. **<u>Drought Event 1988-1994</u>**

- Prolonged extreme drought
- Rainfall was far below the mean average
- Problems with the springs discharge of Messenia, Anavalos (Argolida)
- Requests of drilling deeper wells in the regions of Achaia, Corinthia and Messenia

2. **<u>Drought Event 2000</u>**

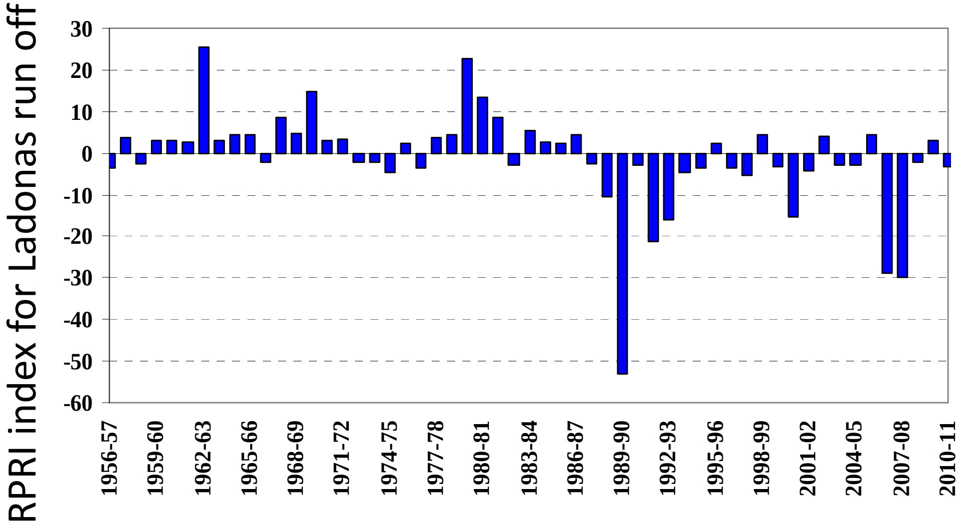
- Water supply problems at Corinthia
- Requests of drilling deeper wells
- Additional funding to the local areas to deal with water supply problems

3. **<u>Drought Event 2006-2008</u>**

- Serious problems with the water supply at Nafplio and Argos. Use of lower quality water from spring Anavalos.
- Pineios dam emptied
- Springs discharge were reduced (ex. Springs of Messenia, Eurotas area)

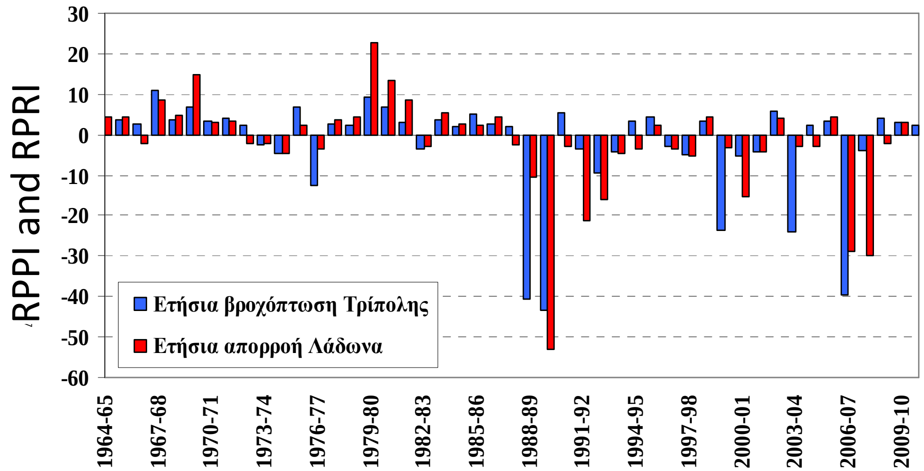
CALCULATIONS OF HYDROLOGICAL DROUGHT INDICATORS

Subsequently and in line with the RPPI (improved SPI), the Return Period Run off Index RPRI was estimated (improved SRI).



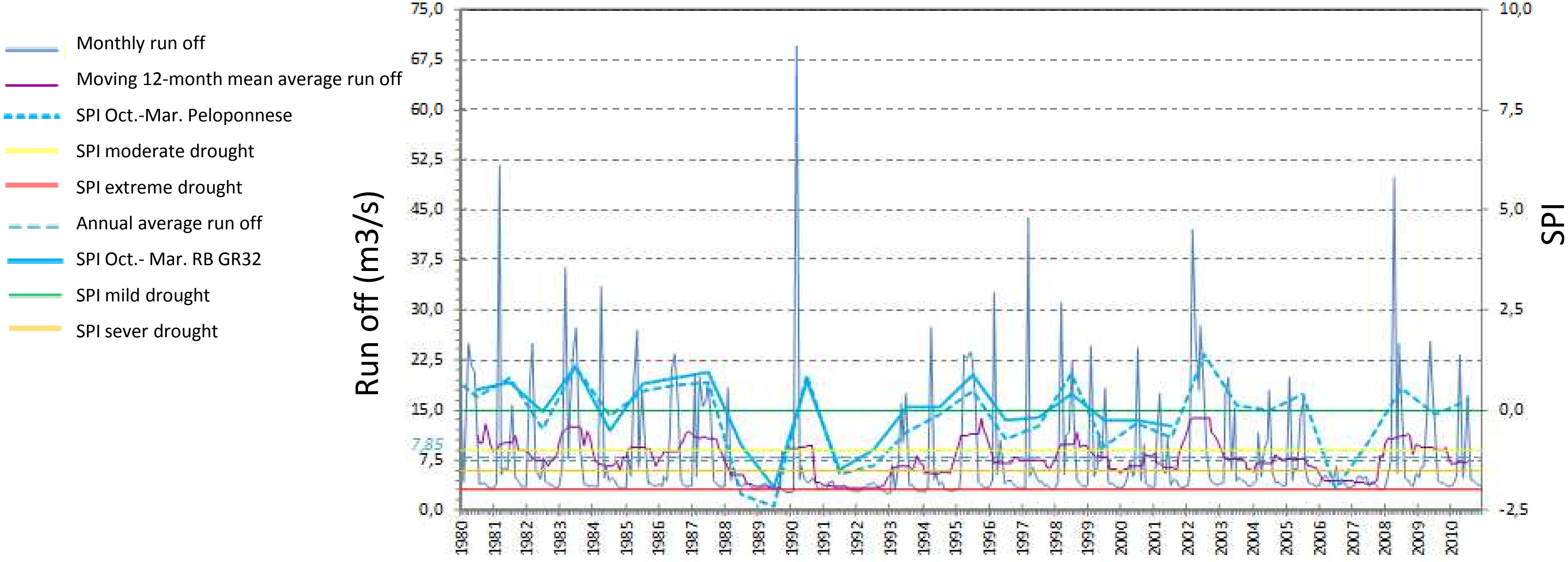
Time evolution RPRI index for Ladonas annual run off

Comparison of temporal evolution index RPRI of Ladonas run off to RPPI annual rainfall at Tripoli



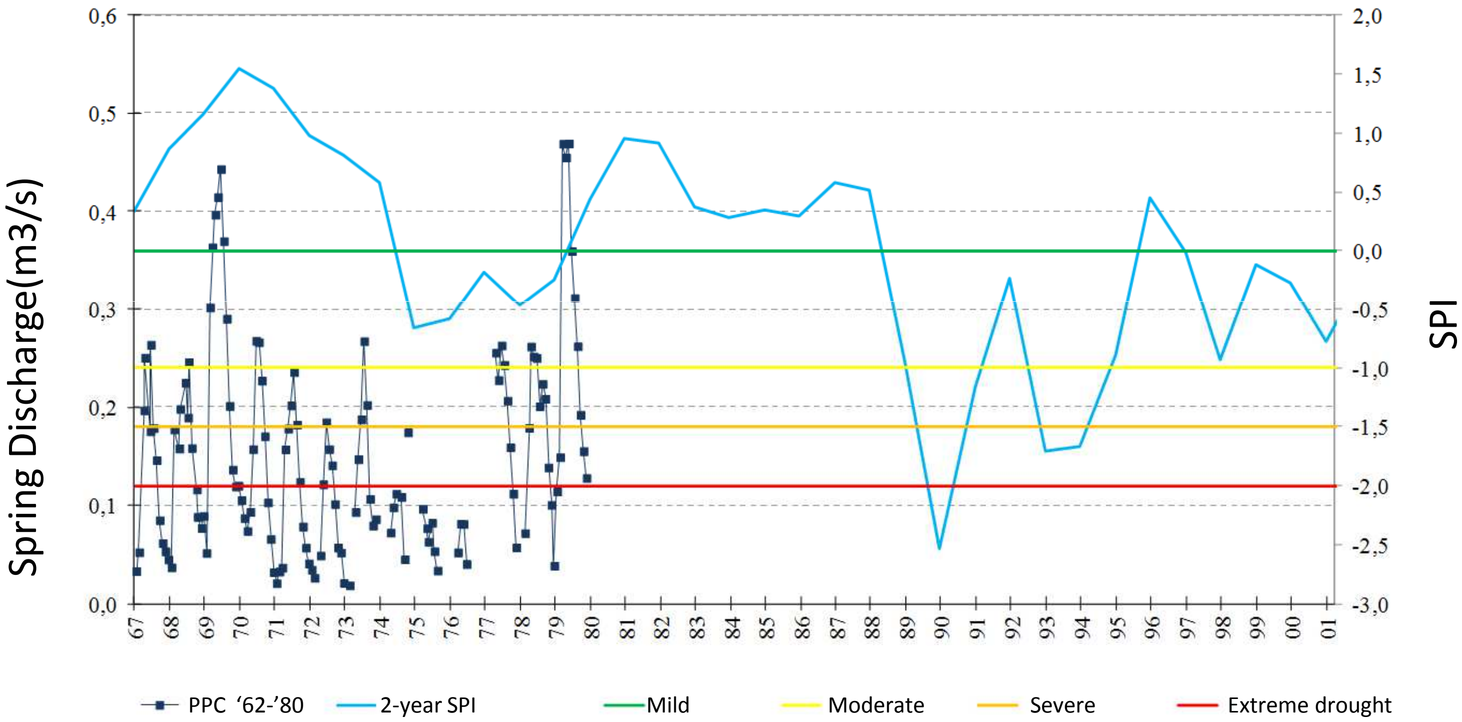
CORRELATION BETWEEN SPI LIMITS AND SACRAMENTO MODEL RUNOFF TIME SERIES

In addition to the calculation of RPRI, the run off time series of Sacramento model were correlated with the SPI index.



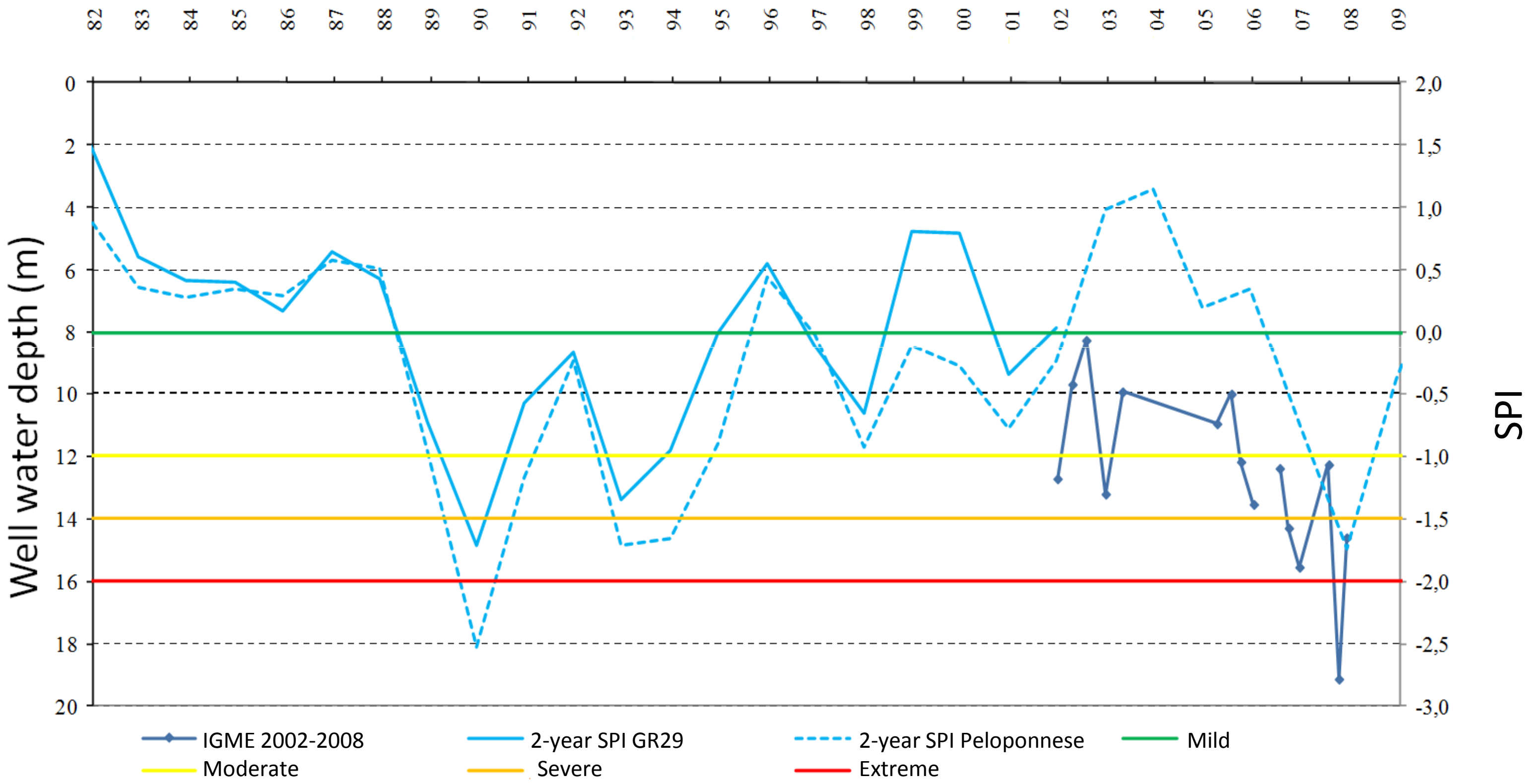
Correlation between SPI limits and Sacramento model runoff time series for river Pamissos

CORRELATION BETWEEN SPI LIMITS AND SPRINGS DISCHARGE TIME SERIES



Correlation between 2-year SPI limits and Spring Panagia (Ladonas) discharge.

CORRELATION BETWEEN SPI LIMITS AND WELLS WATER LEVEL



Correlation between 2-year SPI limits and water depth of a well at GWB GR0100250

ESTIMATION OF WATER EXPLOITATION INDEX PLUS (WEI+)

The Water Exploitation Index Plus (WEI+) is applied to a particular hydrological district and time period. It is calculated as the ratio of the volume of water available for uses (Total Water Abstraction, TWA) divided by the available amount of renewable water resources (Renewable Water Availability, RWA):

$$WEI+ = TWA / RWA$$

AVERAGE ANNUAL WATER BALANCE FOR EACH RIVER BASIN

River Basin District	River Basin	Name	Water Supply (10^6 m^3)	Irrigation (10^6 m3)	Industry (10^6 m3)	Livestock (10^6 m^3)
GR01	29	Alpheus	14,4	89,3	15,0	1,7
GR01	32	Pamisos-Nedondas-Neda	20,6	90,9	1,4	1,1
GR02	27	North Peloponnese streams	40,3	157,4	2,0	2,0
GR02	28	Piros-Vergas-Pinios	18,8	253,5	5,9	3,3
GR02	45	Kefalonia-Ithaca-Zakynthos	10,7	5,2	0,4	1,2
GR03	30	Tripoli's plateau	4,7	13,7	0,1	0,6
GR03	31	Argolikos bay streams	20,1	233,2	6,3	2,8
GR03	33	Eurotas	6,6	82,9	1,3	1,1
		Total	**136.2**	**926,1**	**32,4**	**13,9**

DROUGHT PREDICTION

$$RWA = P - ET + AEI - WR + RW$$

P: the surface precipitation
ET: the losses due to the evaporation
AEI: the inflows from neighboring river basins
RW: the amount of the water that returns to the system from several consumptive uses
WR: the water demands for the environment use. In the present study, the water requirements for environmental use, WR are estimated as a percentage of 50% of the total runoff

$$WR = 0.50\,(P - ET + AEI)$$

The amount of water that is returned to the system, RW, estimated as a percentage of 30% of the total demand.

$$RW = 0.30\,WR$$

So, it is considered that a percentage of 70% from the water that is being consumed for various uses is converted into losses due to the evaporation and transpiration effects or it discharges into the sea, through the sewer systems.

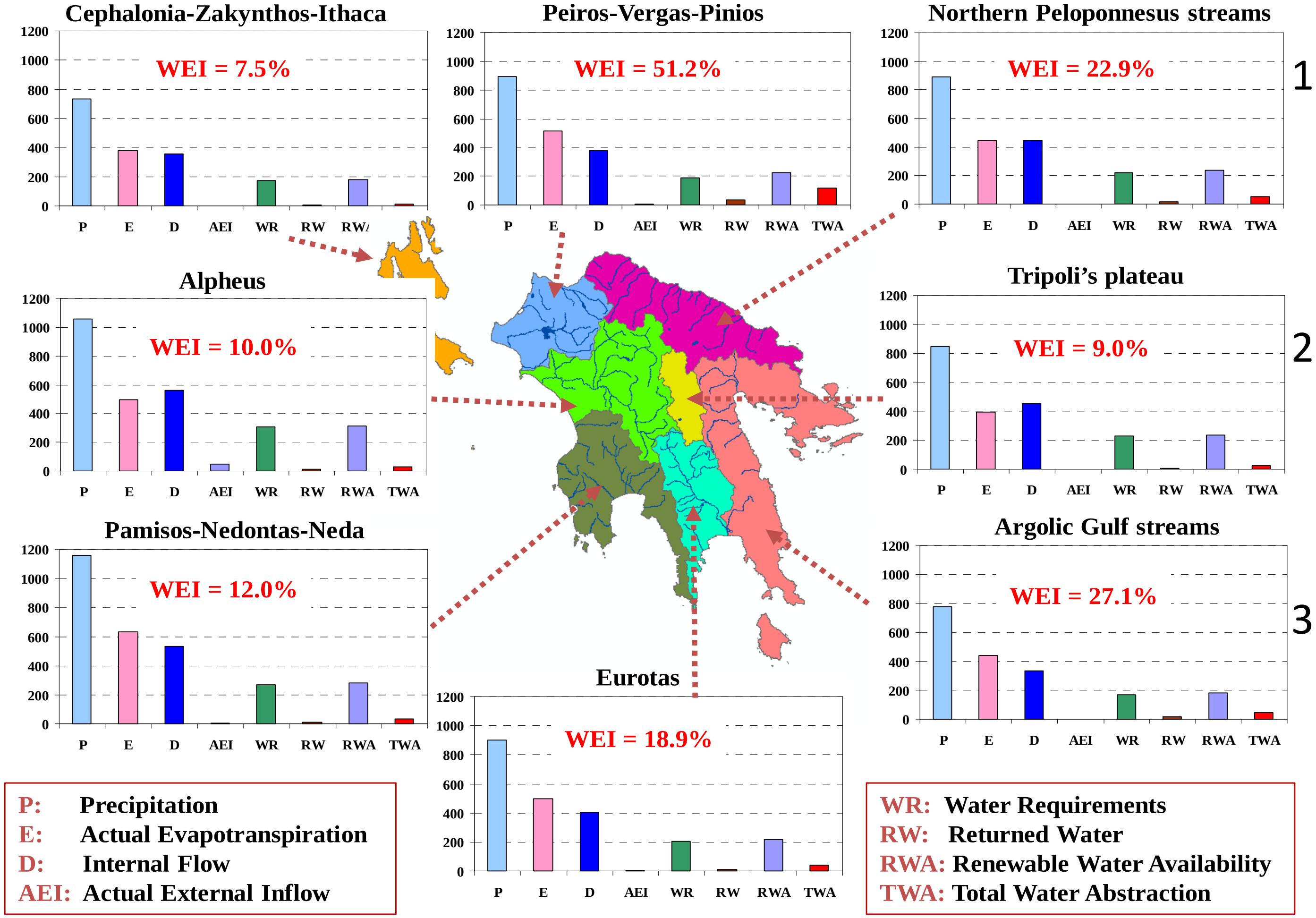
AVERAGE ANNUAL WATER BALANCE FOR EACH RIVER BASIN OF PELOPONNESE

River Basin District	River Basin	Name	Rainfall, P (mm)	Evaporation, E (mm)	External inputs, AEI (mm)	Environmental Demand, WR (mm)	Returned Water, RW (mm)
GR01	29	Alpheus	1.059,6	496,3	48,7	306,0	9,5
GR01	32	Pamisos-Nedondas-Neda	1.159,4	629,3	7,0	268,5	10,0
GR02	27	North Peloponnese streams	888,4	443,7	0,8	222,7	16,4
GR02	28	Piros-Vergas-Pinios	895,2	515,5	4,2	191,9	34,8
GR02	45	Kefalonia - Ithaca - Zakynthos	734,0	380,0	0,0	177,0	4,1
GR03	30	Tripoli’s plateau	850,0	396,0	0,0	227,0	6,3
GR03	31	Argolikos bay streams	778,5	443,0	0,0	167,7	14,9
GR03	33	Eurotas	902,7	497,1	4,5	205,0	12,3
		Total	**7.267,8**	**3.800,9**	**65,2**	**1.765,8**	**108,3**

CALCULATION OF WEI + FOR EACH RIVER BASIN OF PELOPONNESE

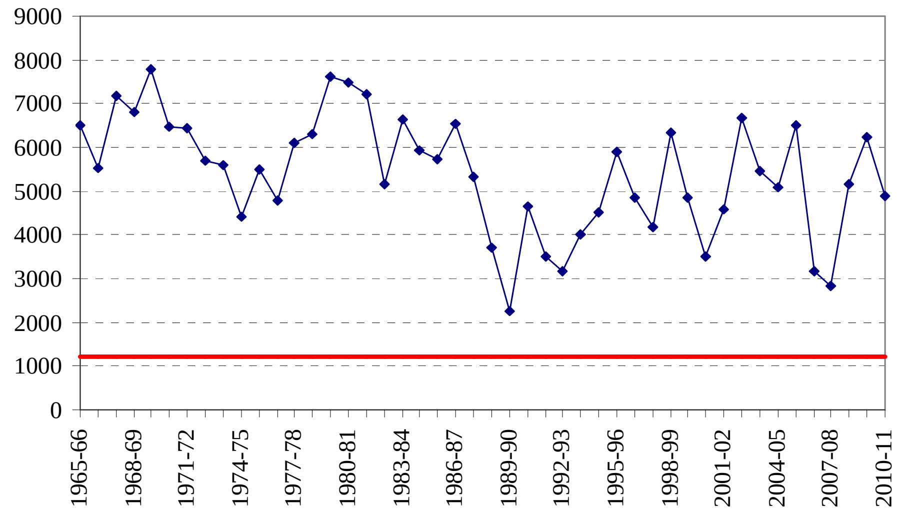
River Basin District	River Basin	Name	Renewable Water Availability, RWA (hm3)	Total Water Abstraction, TWA (hm3)	WEI+ (%)	Vulnerability
GR01	29	Alpheus	1202	121	10.0	Low
GR01	32	Pamisos-Nedondas-Neda	954	114	12.0	Low
GR02	27	North Peloponnese streams	881	202	22.9	Moderate
GR02	28	Piros-Vergas-Pinios	550	282	51.2	High
GR02	45	Kefalonia - Ithaca - Zakynthos	233	17	7.5	Low
GR03	30	Tripoli's plateau	212	19	9.0	Low
GR03	31	Argolikos bay streams	967	263	27.1	Moderate
GR03	33	Eurotas	487	92	18.9	Low
		Total	**5.485**	**1.109**	**20.2**	**Moderate**

ESTIMATION OF WATER EXPLOITATION INDEX PLUS (WEI+)

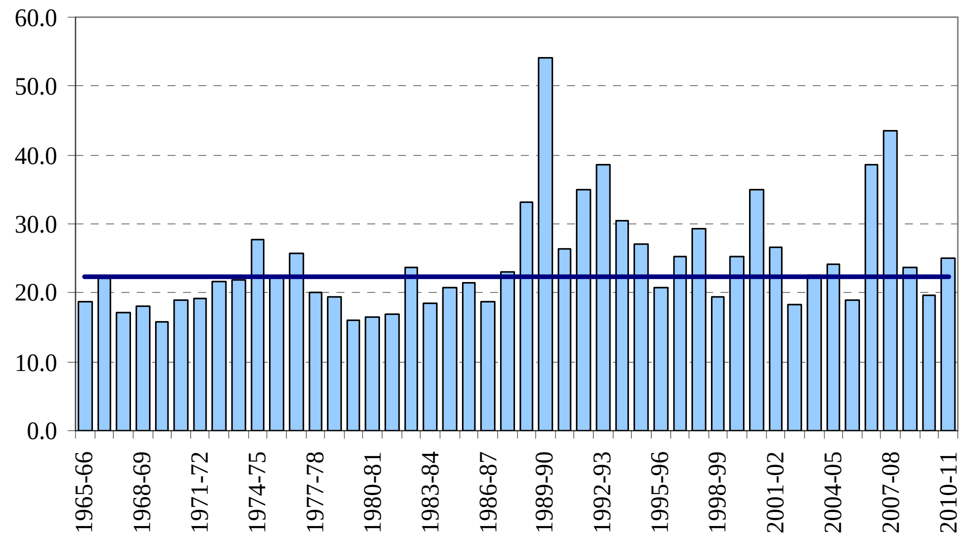


1. WEI + <20%
   No water stress
   Low vulnerability
2. 20% <= WEI + <40%
   Low water stress
   Moderate vulnerability
3. WEI +> = 40%
   Significant water stress
   Severe water stress and great vulnerability

ESTIMATION OF WATER EXPLOITATION INDEX PLUS (WEI+)



Annual time availability of water resources and water demand (red line) for the whole area of Peloponnese.



Annual WEI index change at the whole area of Peloponnese (blue line shows the mean average value of WEI+)

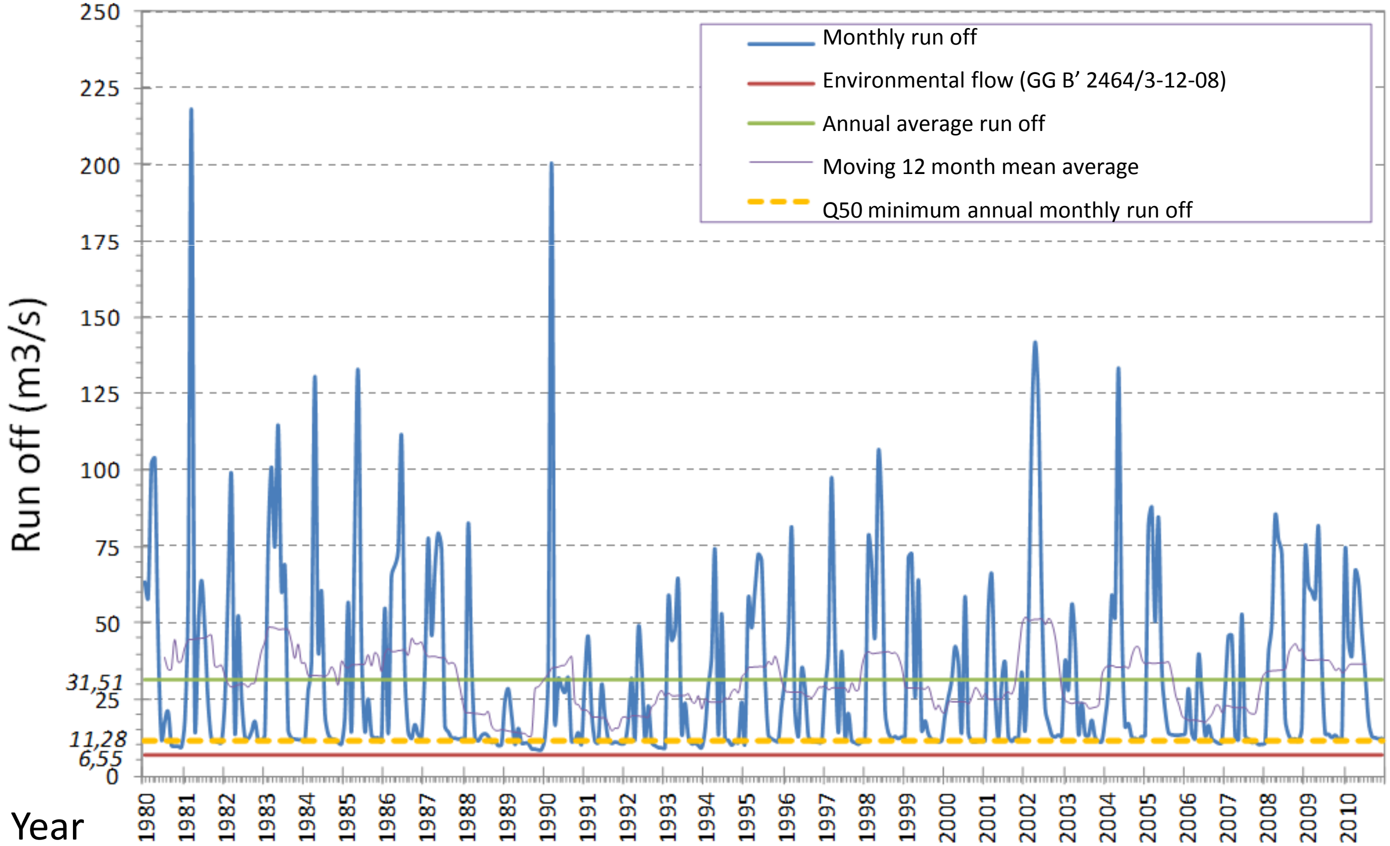
DROUGHT-SCARCITY EFFECT IN ACHIEVING THE ENVIRONMENTAL OBJECTIVES OF WFD

The environmental objectives of WFD 2000/60/EC for WB is to achieve good status/potential and to prevent the deterioration of WB status. In order not to affect certain desirable features of ecosystems and to achieve the desired ecological objectives, a certain minimum amount of flow in aquatic systems must be maintained which is called “Environmental flow”. According to 49828 Decision, GG. B’ 2464/3-12-2008 (Special Framework for Spatial Planning and Sustainable Development for Renewable Energy), the environmental flow must be the maximum of :

- 30% of the average flow at the summer months (June – July – August)
- 50% of the average supply of September
- 30lt/s in each case

DROUGHT-SCARCITY EFFECT IN ACHIEVING THE ENVIRONMENTAL OBJECTIVES OF WFD

Correlation between SPI limits – Sacramento model run off – Environmental flow



DROUGHT PREDICTION

The early forecast or recognition of incoming drought event, based on current hydrologic data is of major importance for the preparation of competent authorities and the local community. Drought prediction is also very important in taking water management measures.

DROUGHT CHARACTIRIZATION BASED SPI INDEX (McKee et al, 1993)

Symbolism	range of SPI	Characterization
A-	$0.0 \geq SPI > -1.0$	Mild
B-	$-1.0 \geq SPI > -1.5$	Moderate
Γ-	$-1.5 \geq SPI > -2.0$	Severe
Δ-	$-2.0 \geq SPI$	Extreme

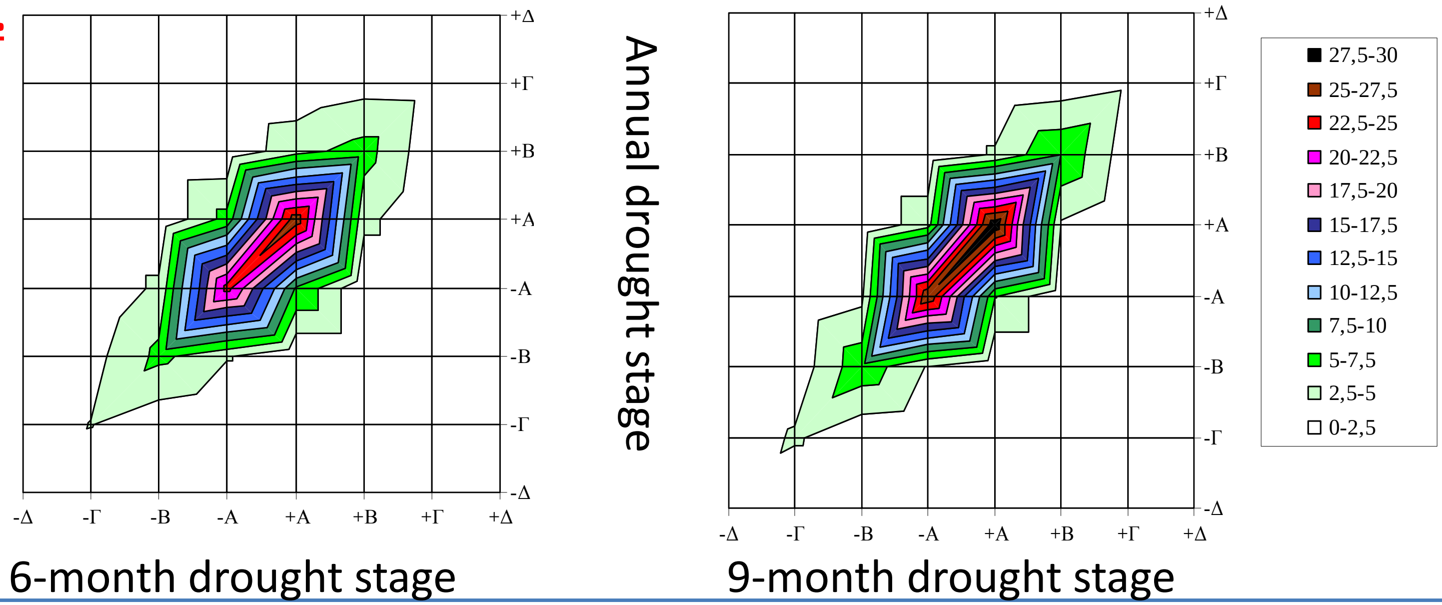
Symbolism	range of SPI
A+	$0.0 < SPI \leq 1.0$
B+	$1.0 < SPI \leq 1.5$
Γ+	$1.5 < SPI \leq 2.0$
Δ+	$2.0 < SPI$

The drought indicators that have been used in this study are the rainfall SPI and the hydrological SRI predictive models as a medium-term evolution of the drought phenomenon in the coming time periods.

DROUGHT PREDICTION

The treatment is based on the time series rainfall of 22 hydrological years. These data have been measured and collected by 74 rainfall stations. The linear correlation coefficient of 3, 6 and 9 months drought indices is also calculated and compared with the hydrological year's index. The correlation coefficient of annual drought index is compared also with the 2-3-4 or 5 years index. **The confirmation of a drought event is finally occurred at a half of a year, when the forecast of annual hydrological sizes is much more reliable.**

Transition probabilities (%) between drought categories from 6 and 9 months to 1 year



DROUGHT MANAGEMENT OPERATIONAL STEPS FOR THE COMPETENT AUTHORITIES

DATA COLLECTION

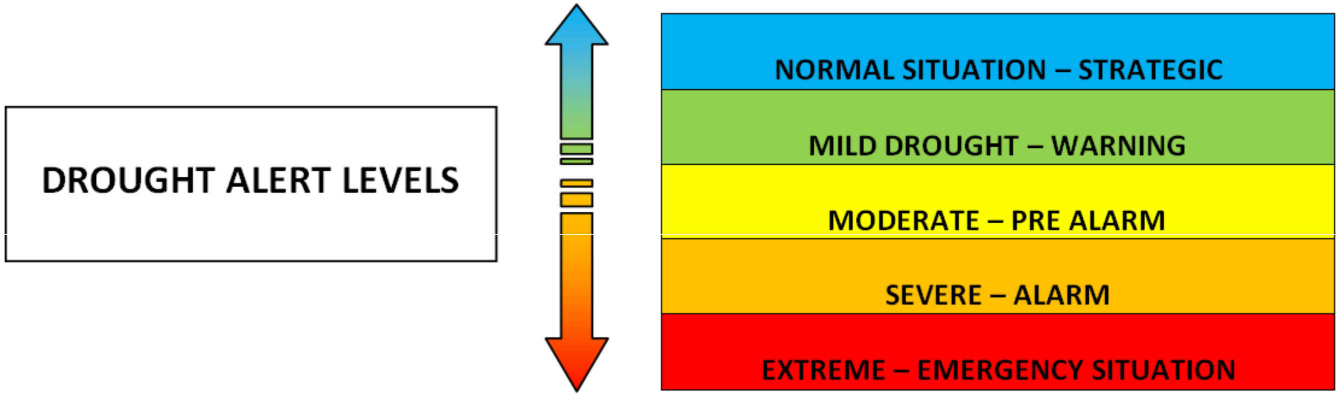
1. Meteorological and hydrometric stations selection and determination
2. Meteorological and hydrometric data (water levels, flows, precipitation)

CALCULATION OF SPI INDICATORS – TAKING MEASURES

3. October: 1-year SPI calculation from 2-year data as a first view of the expected situation
4. February: 3-month SPI calculation (Oct.-Jan.). If the year seems to be dry from the 3-month SPI preliminary calculation, the competent authorities must be prepared to take measures and other water use management restrictions.
5. Confirmation of a drought event with the calculation of 6-month SPI (Oct.-Mar.) that is more reliable. Competent authorities must take measures depending on the level of drought.
6. 2-year SPI calculation.
7. Correlation coefficient calculations of rainfall and run off.
8. Prediction of SPI (optional SRI). Υπολογισμός πιθανοτήτων μετάβασης
9. Taking measures depending on the drought event level

DROUGHT LEVELS – DROUGHT PROGRAM OF MEASURES

From the above indicators four levels of drought alert are defined. The drought alert levels are as follows:



ALERT LEVEL	DROUGHT LEVEL	SPI
STRATEGIC	NORMAL SITUATION	$SPI > 0.0$
WARNING	MILD	$0.0 \geq SPI > -1.0$
PRE ALARM	MODERATE	$-1.0 \geq SPI > -1.5$
ALARM	SEVERE	$-1.5 \geq SPI > -2.0$
EMERGENCY	EXTREME	$-2.0 \geq SPI$

DROUGHT LEVELS – DROUGHT PROGRAM OF MEASURES

1. Some of the RBMP's basic measures
2. Some of the RBMP's supplementary measures
3. Additional and specific measures depending on the drought level

- ✓Educational measures
- ✓Reducing irrigation water abstraction
- ✓Increasing control checks in water abstraction
- ✓Operation of Desalination plants
- ✓Reducing some water use
- ✓Water transfer

CONCLUSIONS

1. The vulnerability index (WEI+) in the River Basin Districts of Eastern and Northern Peloponnese is higher than the Western Peloponnese, showing greater vulnerability to this area and the reduced rainfall.
2. There is lack of continuous and reliable measurements of SW run off and precipitation.
2. A drought event is confirmed in the half of the year
3. The 2-year period SPI indicator is suggested to calculate only for the Groundwater bodies.
4. The main objective of the drought – scarcity management plan is the creation of a practical and reliable operational system of indicators
5. Competent authorities are the responsible of the usage, maintenance and the benefits exploitation of this tool.
6. Based on this operational system, competent authorities may assess and predict the severity of drought events and they can proactively respond by taking measures to mitigate the effects.