# Greek experiences in Drought Monitoring and Management

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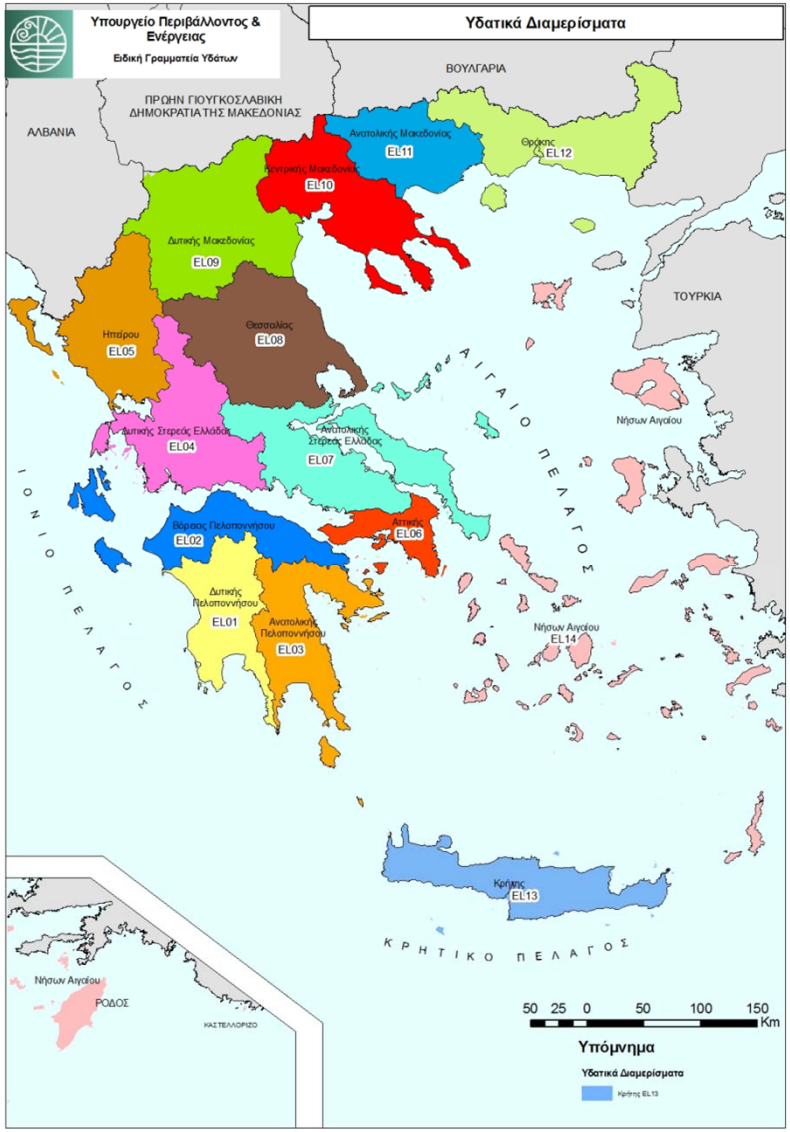
Solutions for the Environment
Sustainable Engineering

**EDO User Meeting, JRC, ISPRA, 09-10.11.2017**

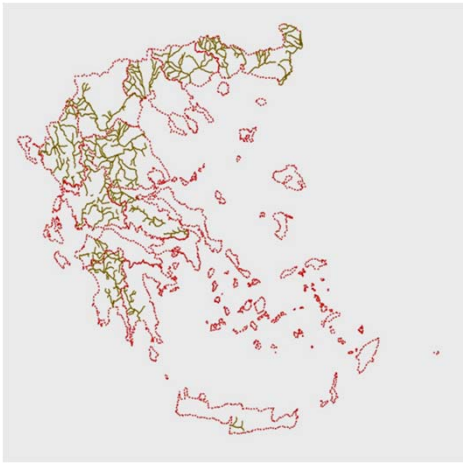
# Presentation Outline

- Drought Facts
- Drought Risk Management: The policy context
- Some examples from the GR DWSMPs
- The Crete case study
- Conclusions

# Drought Facts…

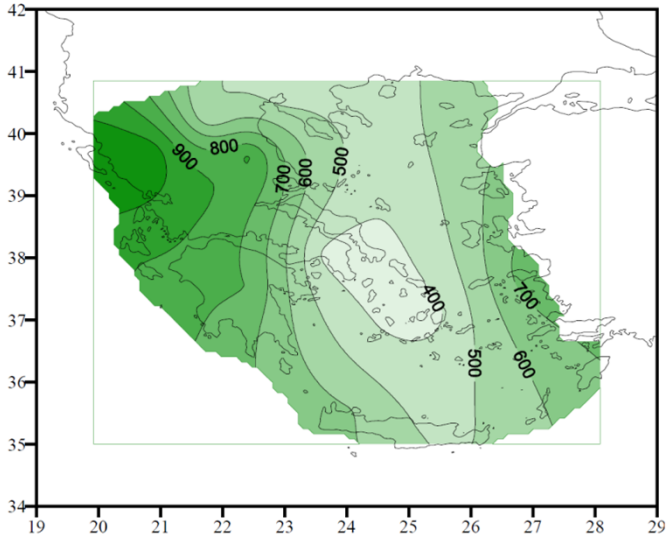


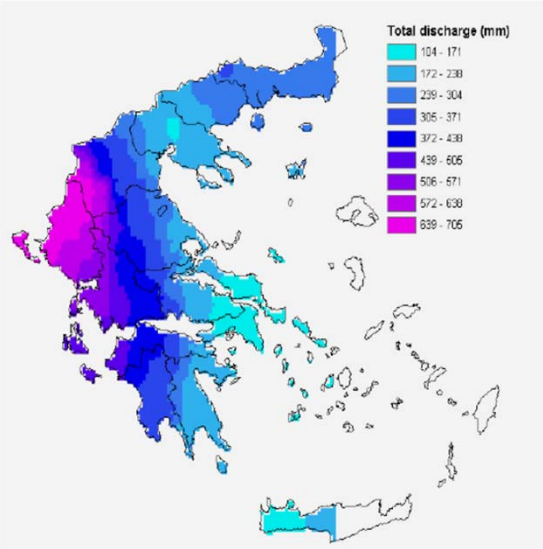

- 14 RBDs according to the WFD
- Large number of river basins (46) compared to the total surface area of the country
- Diverse geomorphological setting, contributing to the spatiotemporal diversity of water resources (regions with great water reserves vs. others with intense deficiencies)
- Significant quantities of groundwater are discharged straight into the sea
- Many rivers with torrential and ephemeral flow



# Drought Facts…

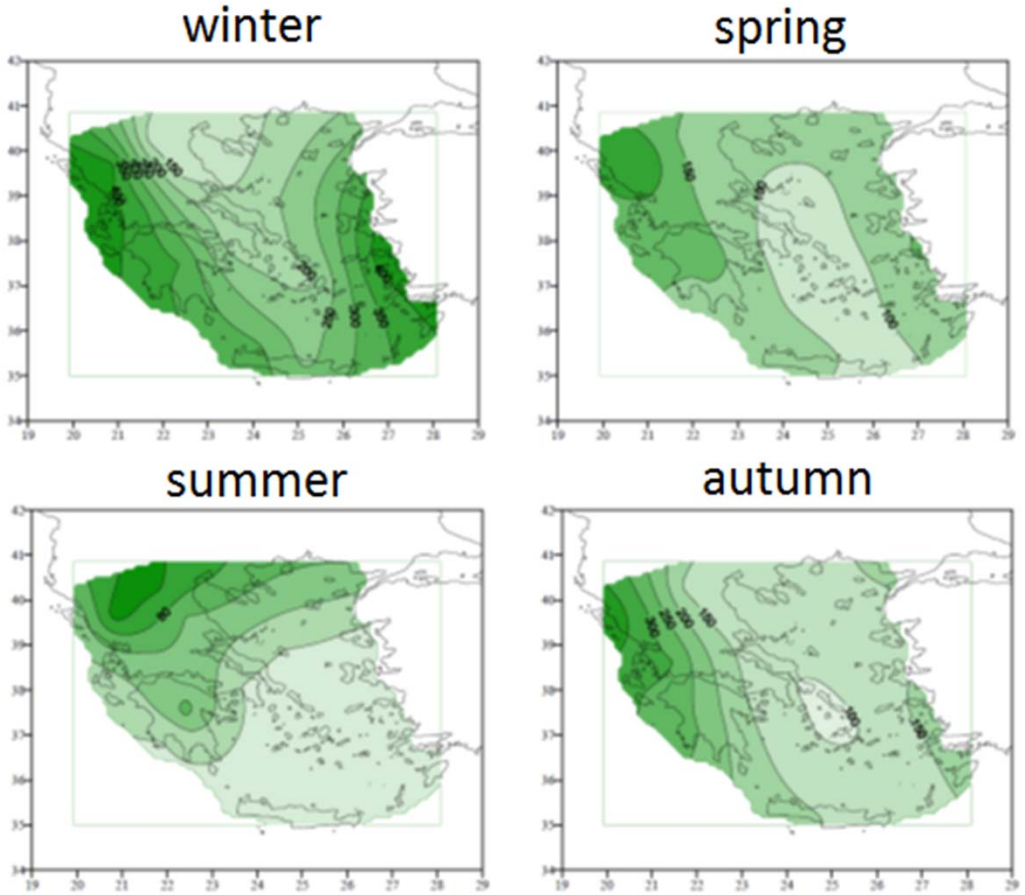
**Precipitation distribution (annual)**




**Precipitation distribution (seasonal)**

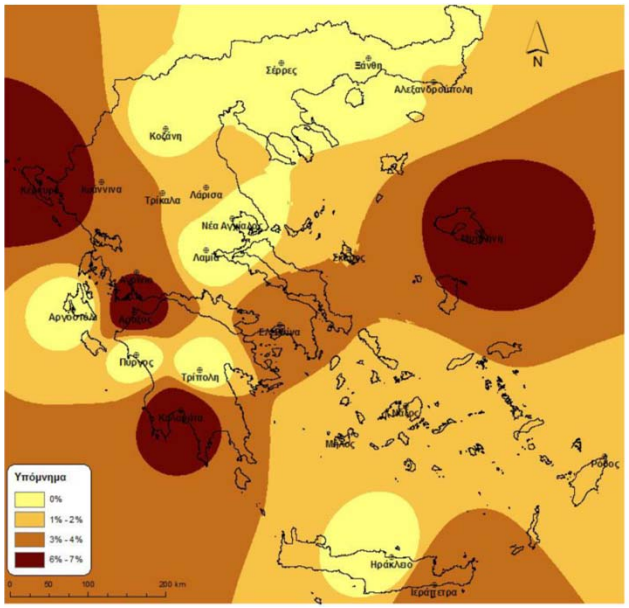
*[Anagnostopoulou, 2003]*



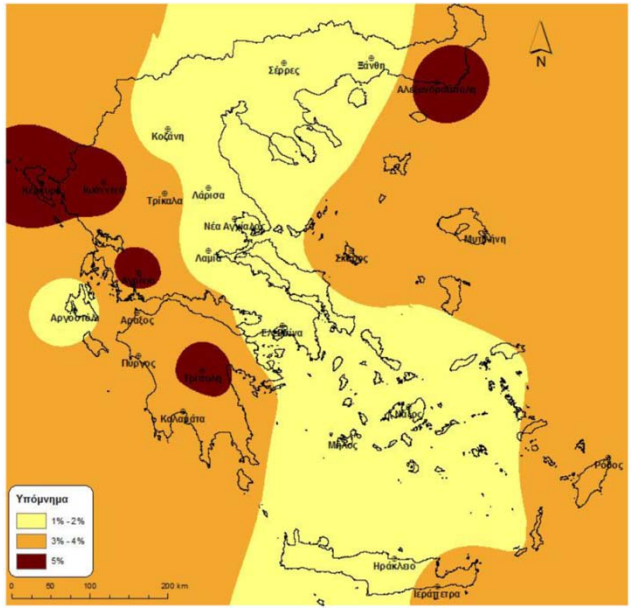
# Drought Facts…

Data from 24 stations from ~1950-2006 (~50yrs = 600months) *[Papantou, 2011]*

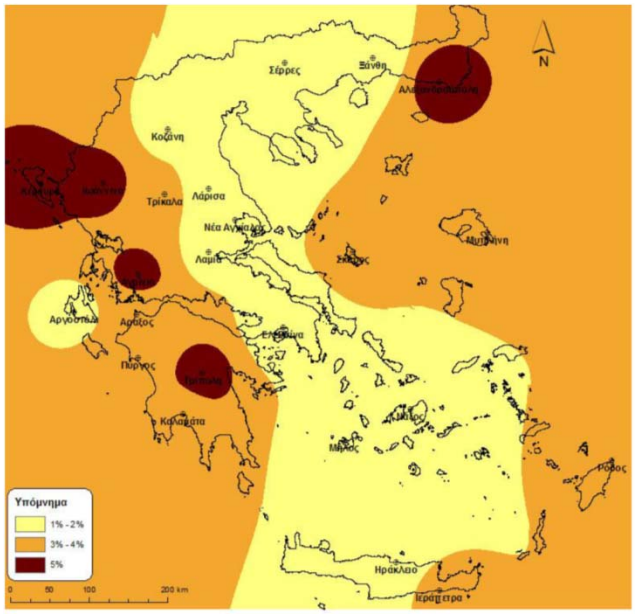
% of months with SPI-48 <-2




% of months with SPI-24 <-2




% of months with SPI-12 <-2




Main drought events in the since 1980:

- 04/1989 – 07/1991
- 12/1992 – 09/ 1994
- 11/2000 – 08/2002
- 2007-2008

# Drought Risk Management: The policy context

- Drought AND Water Scarcity
- Drought & Water Scarcity Management Plans (DWSMPs) have been developed as complimentary to the WFD RBMPs
- During the 1st WFD cycle → 1st version of DWSMPs for 12/14 RBMPs, 2 more ongoing
- In the review of the RBMPs (2nd cycle) a measure is included (in the PoMs), to review, update, harmonize and extend the DWSMPs
- In case of prolonged drought, the General Secretariat for Water (EGY) issues a Regulatory Decision to activate a Response Mechanism

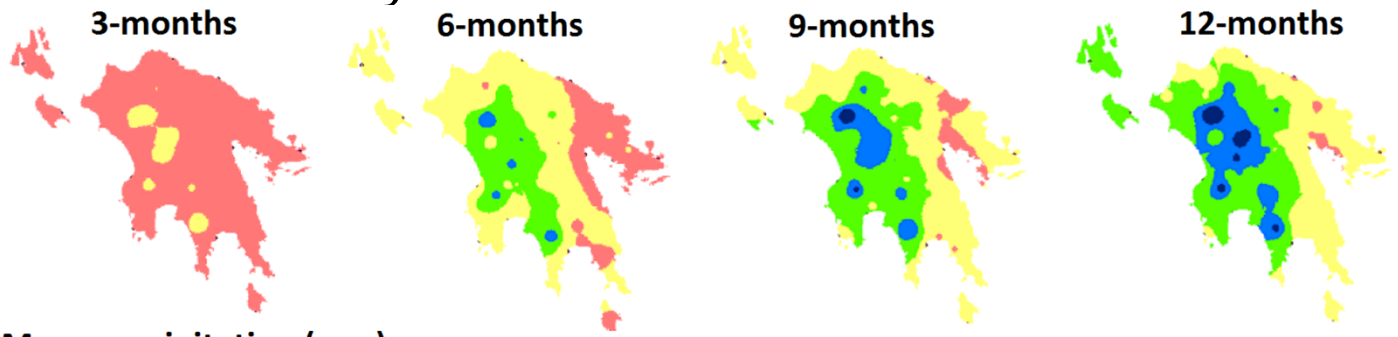
# Drought Risk Management: The policy context

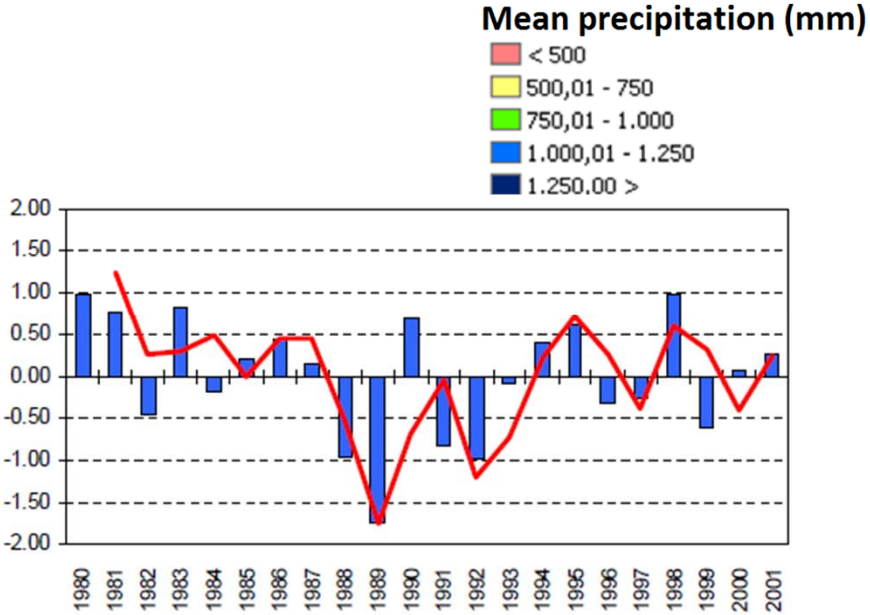
**Goals and Objectives of the GR DWSMPs:**

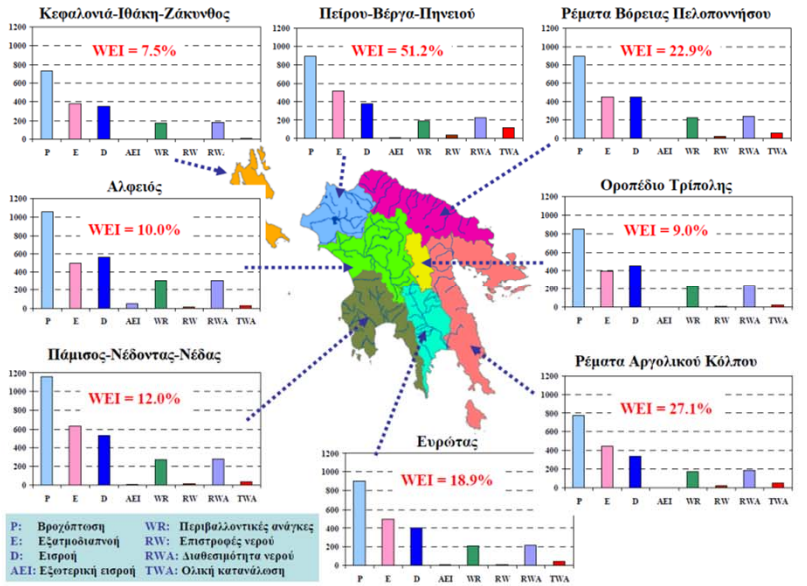
- Identification and analysis of historic D&WS events, and their characteristics (duration, intensity, extent) based on suitable indicators (SPI, SRI, WEI are the most common ones)
- Mapping D&WS in the RBD so that the stakeholders /end-users have a simple and understandable monitoring tool, at the adequate scale, useful for further defining the related risks in the next stages
- Assessment of the impacts (environmental and socio-economic) of past drought events in the RBD, evaluation of their adverse effect in achieving the targets of the WFD Art. 4
- Vulnerability and risk to assessment and definition of relevant vulnerability zones taking into consideration the prevailing physical (climate change, land use, etc.) and socioeconomic conditions
- Analysis for the purpose of early warning, methodology for the early detection of potential upcoming drought events to support operational planning of drought mitigation. Suggestions for an early warning system and alert levels
- Suggestion of measures, linked also to the WFD RBMPs PoMs

# Example 1: Peloponnese (EL01, 02, 03)

- 74 rainfall stations (1980-2001; 1980-2011)
- Analysis from 3-months to 5-yr periods
- Prediction (3-6 month window)



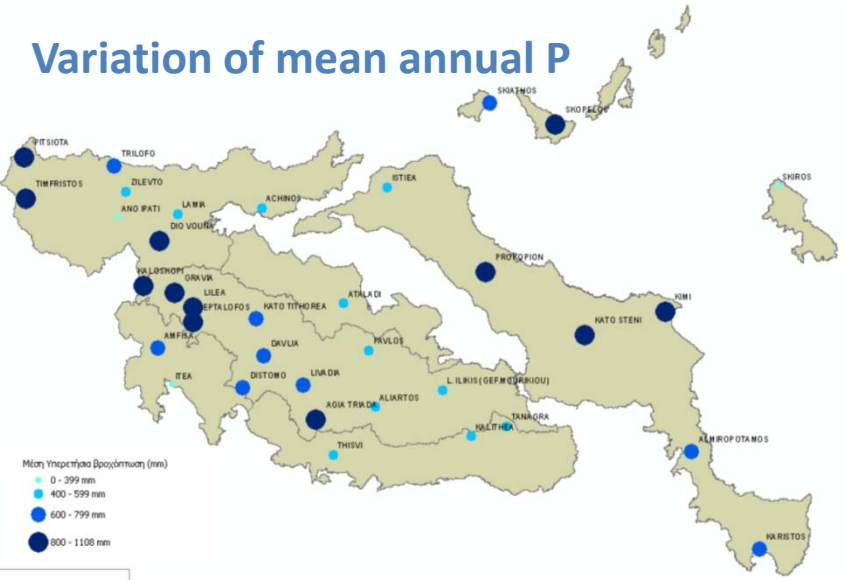



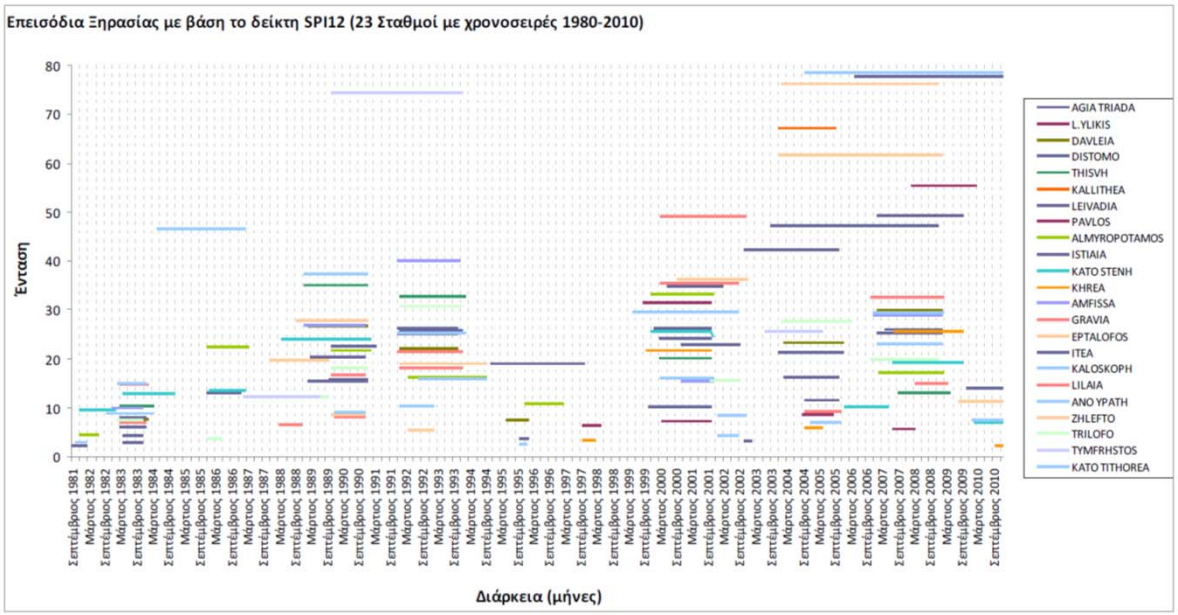
# Example 2: Eastern Sterea Ellada (EL07)

- 80 rainfall stations (1980-2010)
- Analysis from 3-12months periods
- SPI, DHI, WEI
- Prediction for 3-6 months window

## Variation of mean annual P



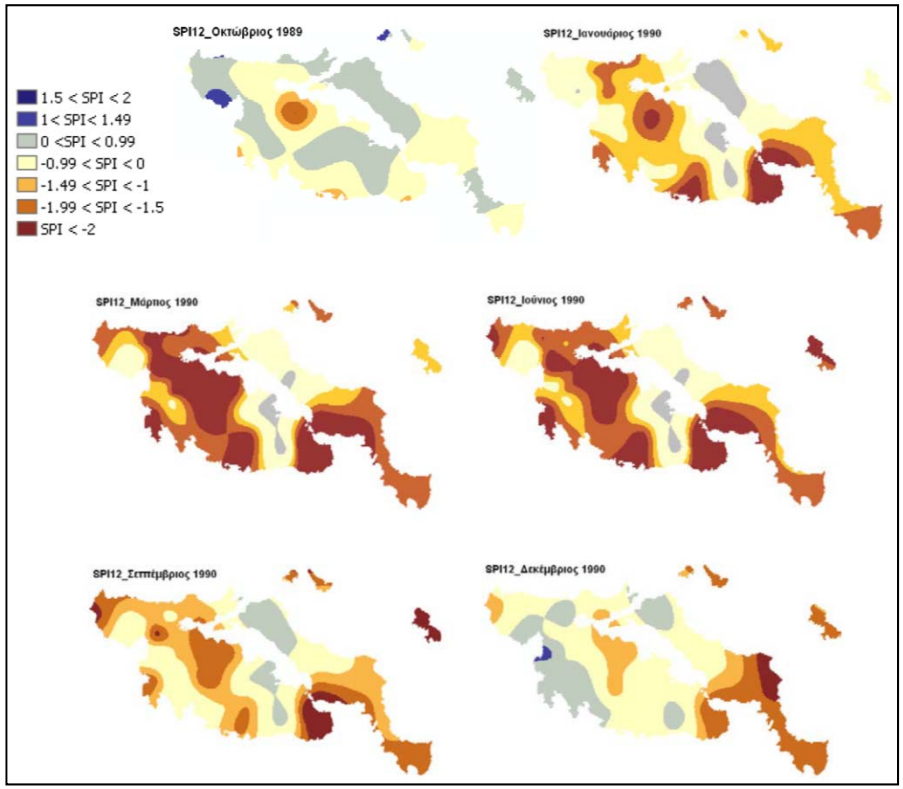

## Drought events (and magnitude) based on the SPI-12



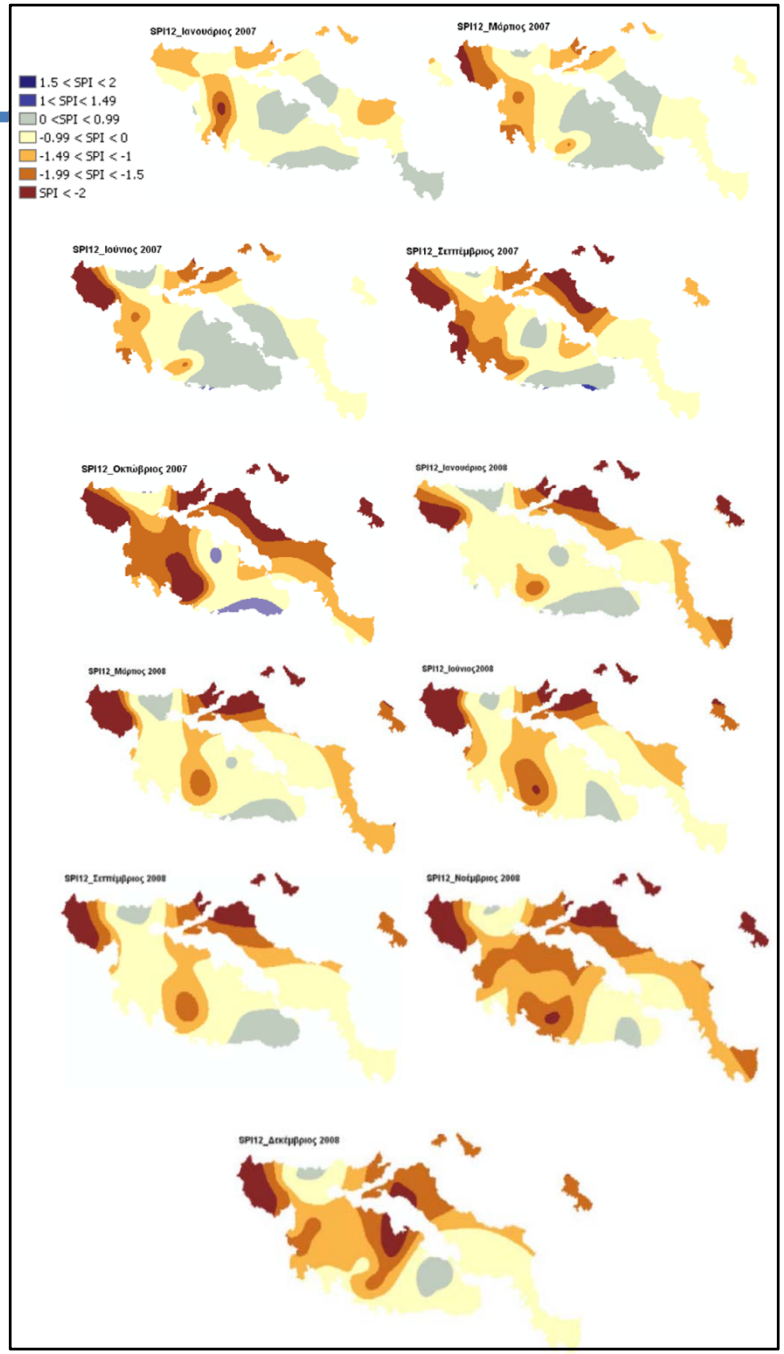
# Example 2:
# Eastern Sterea Ellada (EL07)

**Spatiotemporal evolution of 2 events based on SPI-12**

**October 1989-December 1990**




**January 2007-December 2008**



# Example 2:
# Eastern Sterea Ellada (EL07)

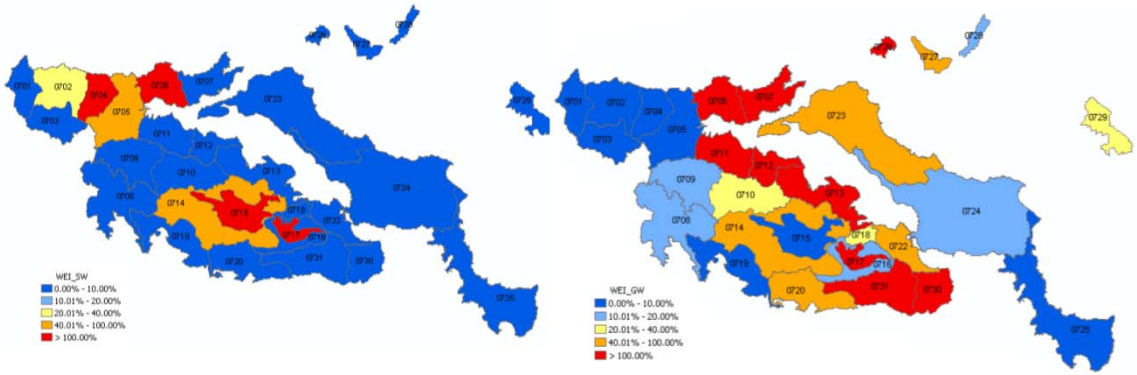
- **Drought Hazard Indicator (DHI)**

No. of drought events
No. of drought events with duration >24 months
Max magnitude within the ref. period
Max duration within the ref. period

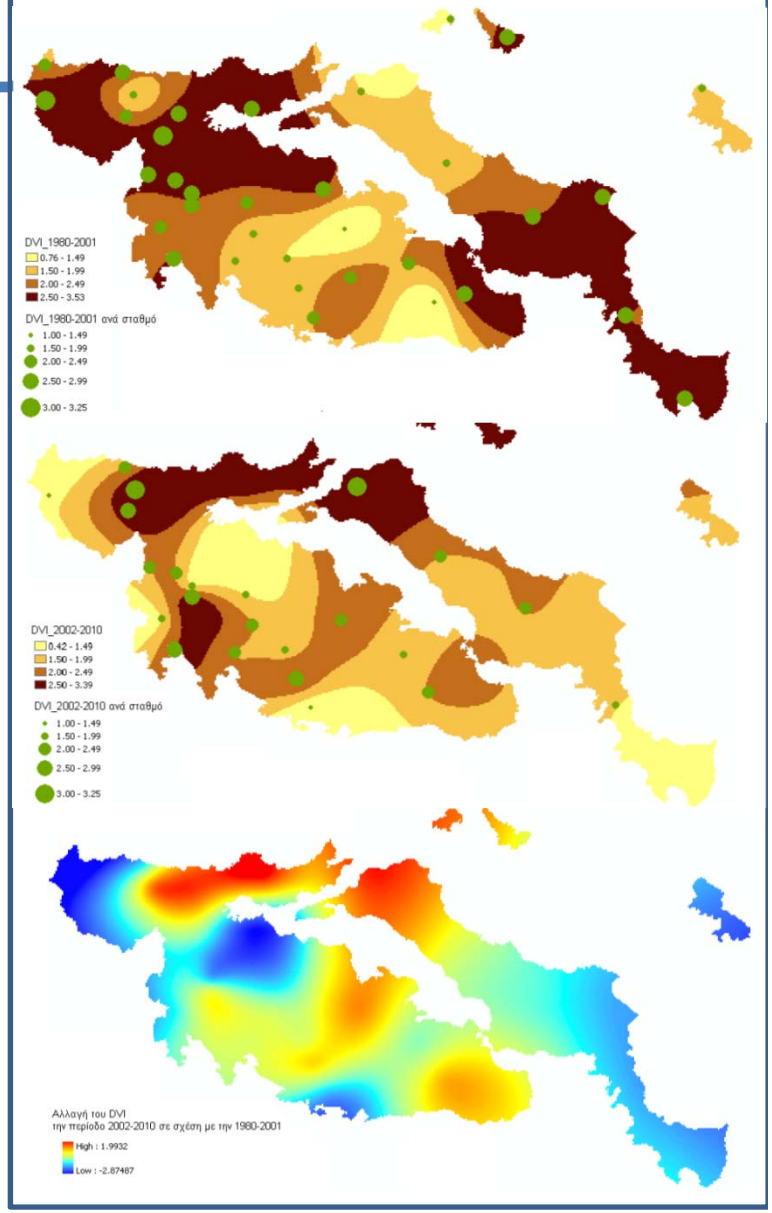
Post-processing of SPI12, scoring, blending
*DHI=0.25 * Score(# drought events) + 0.25 * Score(# drought events with duration > 24months) + 0.25 * Score(DM_max) + 0.25 * Score(Duraion_max)*

- **Water Exploitation Index**

**WEI Surface water, WEI Groundwater**

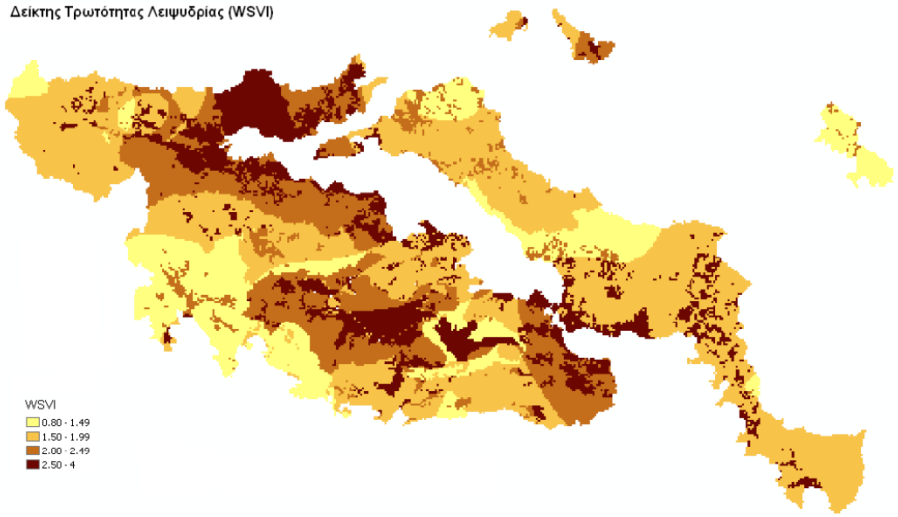



**DHI 1980-2001 ; 2002-2010, change**



# Example 2: Eastern Sterea Ellada (EL07)

- **Vulnerability Zones**: DHI + WEI_SW + WEI_GW + LandUses




- **Prediction - Conservation Target & Measures for each alert level**

| Κλάσεις SPI6_Μαρτίου | Κλάσεις SPI9_Ιουνίου | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| 0 | 78.7% | 13.8% | 0.1% | 0.0% | 0.0% |
| 1 | 0.3% | 3.8% | 1.9% | 0.6% | 0.1% |
| 2 | 0.0% | 0.0% | 0.0% | 0.3% | 0.0% |
| 3 | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| 4 | 0.0% | 0.1% | 0.0% | 0.0% | 0.1% |

| Κλάσεις SPI6_Μαρτίου | Κλάσεις SPI9_Σεπτεμβρίου | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| 0 | 55.4% | 29.2% | 5.4% | 2.1% | 0.2% |
| 1 | 0.7% | 1.2% | 2.1% | 1.6% | 1.3% |
| 2 | 0.0% | 0.0% | 0.0% | 0.0% | 0.4% |
| 3 | 0.0% | 0.1% | 0.1% | 0.0% | 0.0% |
| 4 | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |

| Κατάσταση | Alert Level | 3-month window | 6-month window | Water Reserves |
|---|---|---|---|---|
| Φυσιολογική (normal) | no alert | SPI3 > 0<br>SPI6 > 0 | SPI3 > 0,7<br>SPI6 > 0,7 | sufficient |
| Προειδοποίηση (warning) | Mild alert | - 0,5 < SPI3 < 0<br>- 0,5 < SPI6 < 0 | 0 < SPI3 < 0,7<br>0 < SPI6 < 0,7 | slight deficit |
| | Modelrate alert | SPI3 < - 0,5<br>SPI6 < - 0,5 | SPI3 < 0<br>SPI6 < 0 | moderate deficit |
| Συναγερμού (alert) | High alert | SPI3 < - 1,0<br>SPI6 < - 1,0 | SPI3 < -1,0<br>SPI6 < - 0,5 | significant deficit |
| Έκτακτης ανάγκης (emergency) | Extremely high alert | SPI3 < - 1,5<br>SPI6 < - 1,5 | SPI3 < - 1,5<br>SPI6 < - 1,0 | extreme deficit |

# Case study: Crete island RBD (EL13)

- Variability of precipitation (460-2100 mm/yr)
- Area: 8,240 km2

**Water balance (1980-2009)**

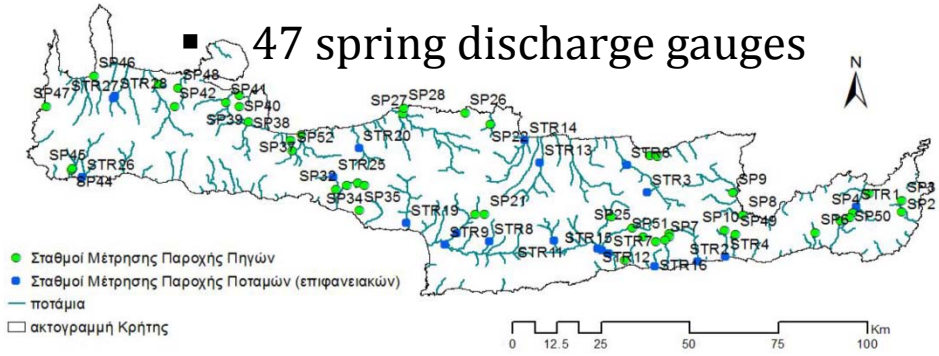
| | Percentage | mm/yr | bill. $m^3$/yr |
|---|---|---|---|
| Precipitation | 100% | 922 | 7.6 |
| ET | 48.7% | 449 | 3.7 |
| Available WR (surface + springs) | 25.4% | | 1.93<br>0.78–3.24 |

**Water Use**

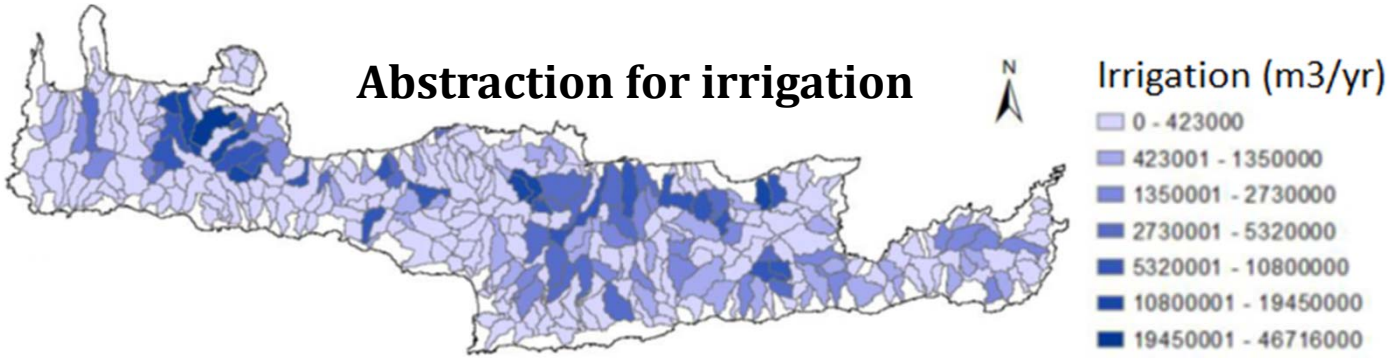
| | Mio m3/yr | Winter | Summer |
|---|---|---|---|
| Total | 485 | 72 | 413 |
| Agriculture/Livestock | 415 | 44 | 371 |
| Domestic/Industry | 70 | 28 | 42 |

- 60 precipitation stations
- 21 temperature stations


- 25 streamflow gauges
- 47 spring discharge gauges

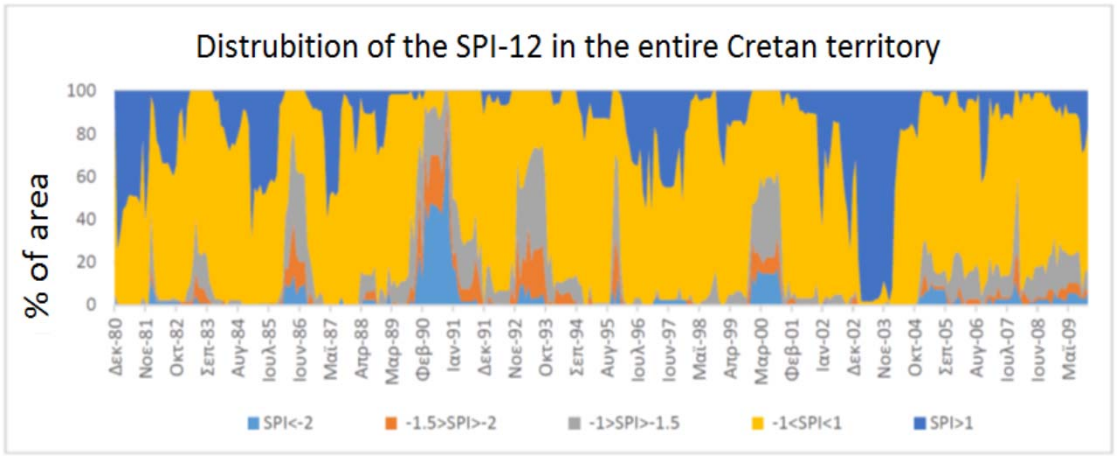



**Abstraction for irrigation**

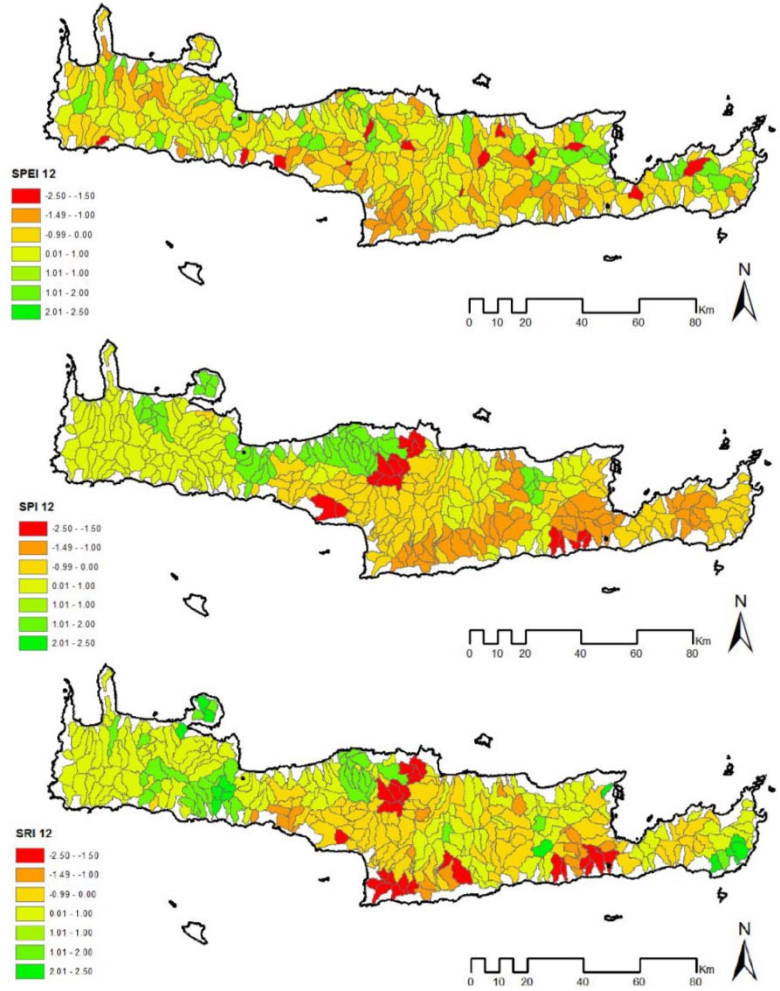


# Case study: Crete island RBD (EL13)

- SPI, SPEI, SRI; WEI
- Analysis from 3-12 months periods
- Analysis of the frequency of Drought
  for T10, 50, 100




**SPI-12, SPEI-12, SRI-12 for September 2007**

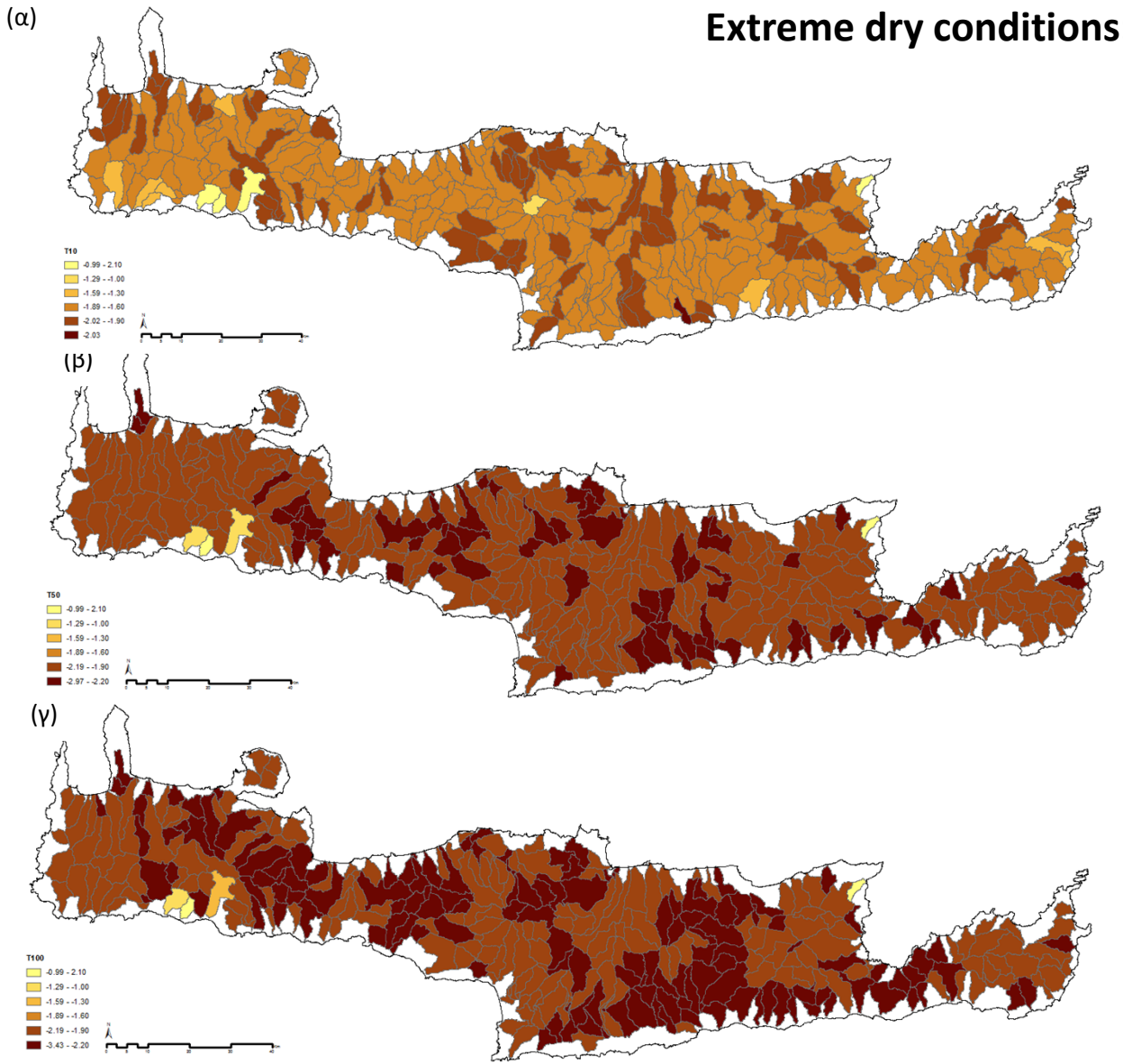


# Case study: Crete island RBD (EL13)

Analysis of the frequency of hydrological drought:
using the annual minimum SRI index
&
GEV distribution

**SRI 3 Index**

**Extreme dry conditions: SRI < -2**



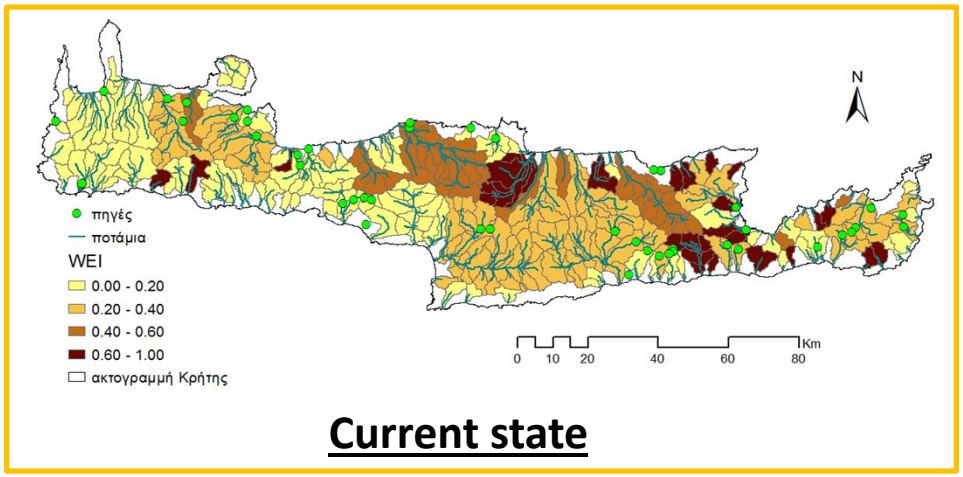

**(α) T=10**

**(β) T=50**

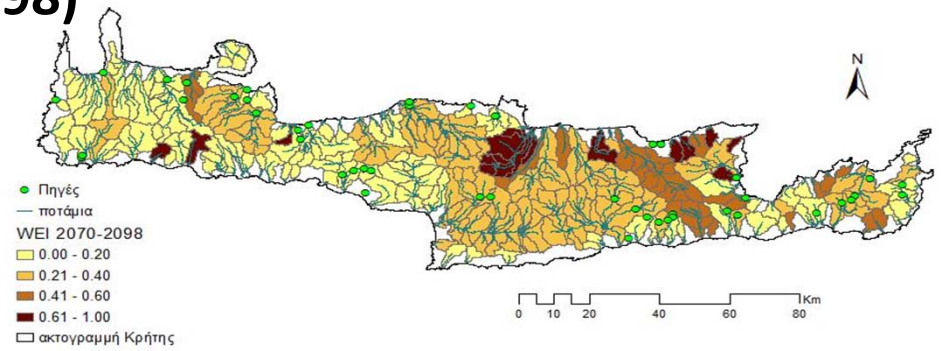
**(γ) T=100**

# Case study: Crete island RBD (EL13)

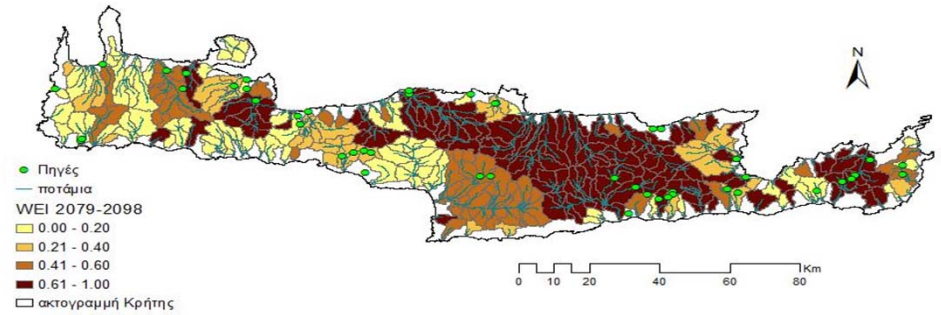
**WEI (current) and WEI future (2079-2098) due to climate change**



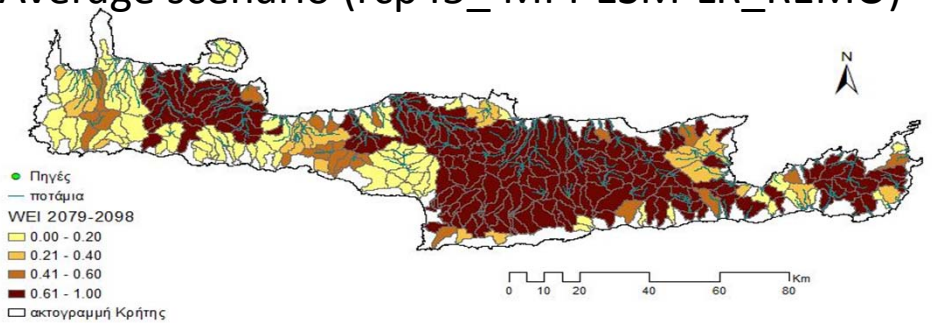

**Current state**




Favorable scenario (rcp26_MPI-ESM-LR_REMO)




Average scenario (rcp45_ MPI-ESM-LR_REMO)




Extreme scenario (rcp85_MPI-ESM-LR_REMO)

EEA – AquaMan Project

# Case study: Crete island RBD (EL13)

**Measures**:

- Harmonized with the WFD RBMP
- Focus: leakage losses reduction in water supply networks, treated wastewater reuse, minimize dams' function failure through inter-basin water transfers, deficit irrigation, demand management and reduction

**Future steps**

- Detail elaboration on response and mitigation measures at the Regional level (in progress)
- Specialization of the measures at the level of municipality, mainstreaming of the measures in the towns' Masterplans
- Development and implementation of a governance model:

- Regional Directorate for Water: operation of the monitoring network, data collection, analysis and calculation of the indicators, issue of drought bulletin and press releases, mobilization of the municipalities.
- Municipalities: implementation of the measures, enforcement/ control

# Gaps, Issues, Future steps

- Harmonization of WSDMPs across the RBDs
- Agreement on and use of common indicators (to the degree this is possible given the local characteristics)
- Impacts, common assessment methods/ standards

- Updating of the DWSMPs
- Move to Operational level (incl. governance) → bring the plan to "life", establish implementation mechanisms (monitor, alert, measures)
- Public participation to ensure effective implementation of the measures
- Transparency in the decision-making process (e.g. clear communication to farmers and other sensitive groups)

# Acknowledgements


ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ & ΕΝΕΡΓΕΙΑΣ

ΕΙΔΙΚΗ ΓΡΑΜΜΑΤΕΙΑ ΥΔΑΤΩΝ

**Directorate for Water of the Region of Crete (Dr. M. Kritsotakis)**