SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Definition of Drought Risk Profile: methods. tools, challenges

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SWIM-Horizon 2020 SM Regional Training on

"Drought Risk Management Mainstreaming (DRMM)"

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Presentation Outline

- Drought Risk Profiling (DRP): problem statement
- How to develop a DRP?
- Drought Hazard assessment & mapping (indicators, case studies)
- Drought Vulnerability assessment (components, approaches)
- Blending to create a DRP

Re-cap from DRMM steps

Drought Risk Management Mainstreaming basic steps:

Step 1– DEVELOP DROUGHT RISK PROFILE

- Drought Hazard Mapping
- Assessment of Water Resources and key components
- Drought & Water Scarcity Vulnerability Assessment
- Synthesize Drought Risk Profile (DRP)

FOCUS

Step 2 – IDENTIFY DRM OPTIONS

- Selection of measures, definition of criteria, screening
- Develop a library of measures (with costs-benefits)
- Develop cost-effective "intervention curves"
- Simulate the measures, assess performance

Step 3 – PRIORITIZE DRM OPTIONS

- Definition of the optimization process (algorithm, objective functions, etc.)
- Development of a Decision Support Platform for the identification of the optimal mix of measures

Step 4 – ITERNALIZE DRM

- Assessment of the measures' robustness under future scenarios
- Define indicative Policy Targets
- Integration, Implementation & Monitoring

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Disaster Risk Profiling: the general context

- **Disaster risk profiles in general,** and thus DRPs in the case of drought, form the **basis of implementation of the proactive risk reduction** approach as recognized by different initiatives
  (Ref.: Hyogo Framework for Action (HFA) (UNISDR, 2012);
  UN Advocacy Policy Framework (APF) on drought (UNCCD, 2013))

- Risk profiling **helps direct the policy and programmatic focus onto the underlying causes of droughts (risks) rather than their effects (impacts)** (UNDP, 2011), since they show the combined physical and socio-economic pressure on a community at a specified scale (e.g. river basin, region, country, etc.) and help to determine who and what is at risk and why.

As such, assessing Drought Risk is a pre-condition to the correct identification of mitigation measures

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Drought Risk Profiling: problem statement

- **No unique definition** of risk. Risks of drought occurrence depend on the **combination** of exposure to natural **Hazard** events and the social, economic and environmental **Vulnerability** (or resilience) to these challenges in the affected communities

- Many indicators to characterize the drought hazard are available, yet the **selection of the most appropriate(s) indicators** under the specific context is still challenging
- Many frameworks to assess vulnerability to drought exist, yet specifying the most relevant **components of vulnerability must be tailored** to the specific context and characteristics of the area under investigation → challenging

- Although disaster risk profiles of different formats (matrix, curves, factsheets, maps, etc.) have been investigated for different hazards, and in some cases (e.g. floods) methodologies for developing them are well elaborated, **in the case of drought risk profiles common and standard methodologies are lacking**

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How to Develop a Drought Risk Profile?

The profiling of drought risk involves:

A. the analysis of the climatic hazard (drought hazard)

B. the subsequent analysis of vulnerability/resilience factors, using various indicators tailored to the context and specificities of the region under investigation

C. the combination/integration of the above two

A. Drought Hazard Assessment & Mapping

- **No unique universal** drought hazard index (due to the subjectivity in the definition of drought and the complexity of drought phenomena)
- **Plethora** of indices of different complexity **per type** (hydrological, meteorological, agricultural, etc.)
- Latest advances: **Combination**, **aggregation** (e.g. US Drought Monitoring, NDMC, 2008)
- **Selection ~ local specificities** & criteria

Common Indicators
Standard Precipitation Index (SPI)
Percent Normal Precipitation and percentiles/ deciles
Reconnaissance Drought Index (RDI)
Palmer Drought Severity Index (PDSI)
Soil Moisture Anomaly
Crop Moisture Index (CMI)
Low Flow Q90
Base Flow Index
Regional Streamflow Deficiency Index (RSDI)
Normalized Difference Vegetation Index (NDVI)
Standardized Vegetation Index (SVI)
Surface Water Supply Index (SWSI)

Related parameters
Precipitation, Evapotranspiration
Soil moisture, Vegetation
Streamflow, Groundwater level

A. Drought Hazard Assessment & Mapping:

Criteria for Indicators

The selection of an appropriate index which minimizes on one side the hydrological information/ data required, while it is robust enough to accurately characterize the drought hazard is challenging

- Suitability for drought types of concern
- Capacity of integration, combination
- Clarity and validity
- Data availability and consistency, reproducibility
- Temporally and spatial sensitivity
- Diagnostic ability
- Statistical consistency
- Linked with water management goals (and available responses: DMPs)
- Transparency
- Quantitative and qualitative assessment potential
- Uncertainty quantification potential
- Forecasting ability

The Drought Hazard Indicator (DHI)

Investigating the **spatial and temporal variability** of drought hazard based on a **new index accounting for the intensity, magnitude, duration and frequency** of drought events, which is based on easily obtained **monthly precipitation** data.

1. **Calculate the SPI-12** (fitting a 2-parameter Gamma distribution to the 12-month cumulative precipitation) for each rain gauge in the area, for a minimum 30-year period

- Identify the drought episodes within the reference period (SPI<0 onset, and reaches a value <-1)
- Calculate drought magnitude (DM) for each event $DM = -(\sum_{j=1}^{x} SPI_{12j})$

2. **Post –process (meta-analysis) the results of SPI-12, and derive 4 new sub-indicators** reflecting: recurrence, severity, magnitude, duration
3. **Classification of the 4 sub-indicators** and assignment of relevant scores
4. **Blending** to produce DHI (weights based on AHP, equal), and classify DHI

$$DHI = (\theta_1 \times score_{FRQ}) + (\theta_2 \times score_{FRQ24}) + (\theta_3 \times score_{DM\max}) + (\theta_4 \times score_{d\max})$$

5. **Interpolation** of the DHIs across the rain gauges to obtain coverage for the entire area and a drought hazard map

Ref.: Kossida and Mimikou, 2015

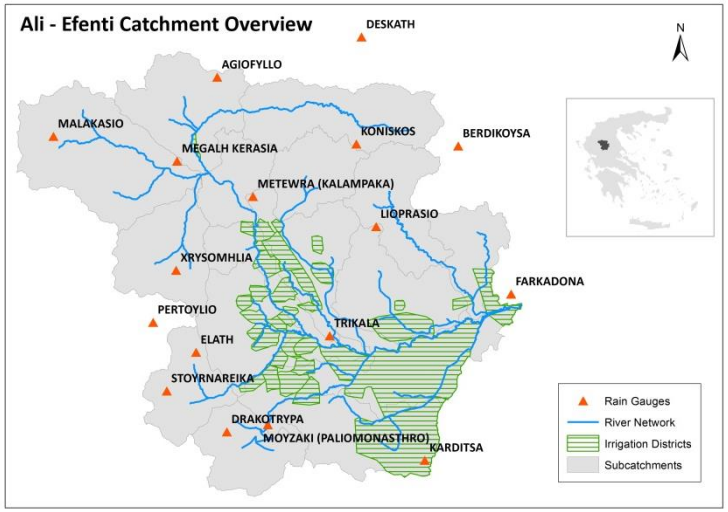
The 4 sub-indicators of DHI

FRQ	number of drought episodes (events) observed within the reference period (expressed as absolute number or as % over the total duration of the period of analysis)	used as metrics of “recurrence”
FRQ24	number of drought episodes with duration > 24 months, within the reference period. This sub-indicator is used as a sensible descriptor of prolonged drought	used as metrics of “severity”
DMmax	maximum drought magnitude observed within the reference period.	used as metrics of “magnitude”
dMAX	maximum duration (in months) among the drought episodes observed within the reference period.	used as metrics of “duration”

Classification thresholds for each sub-indicator				
FRQ *number of episodes (% over years of the period)*	**FRQ24** *number of episodes with d>24 months*	**DMmax** *maximum magnitude*	**dmax** *maximum duration*	**Assigned Score/ Class**
1 – 3 (≤10%)	1	≤ 35.0	24 – 36	1
4 – 6 (10.1% - 20%)	2	35.1 – 50.0	37 – 48	2
7 – 9 (20.1% -30%)	3	50.1 – 70.0	49 – 60	3
≥ 10 (> 30%)	4	≥ 70.1	≥ 61	4

DHI value	Score / Class
1.00 – 1.49	1 – low
1.50 – 1.99	2 – moderate
2.00 – 2.49	3 – severe
≥ 2.50	4 – extreme

Case Study 1: Drought analysis in the Ali-Efenti RB, GR

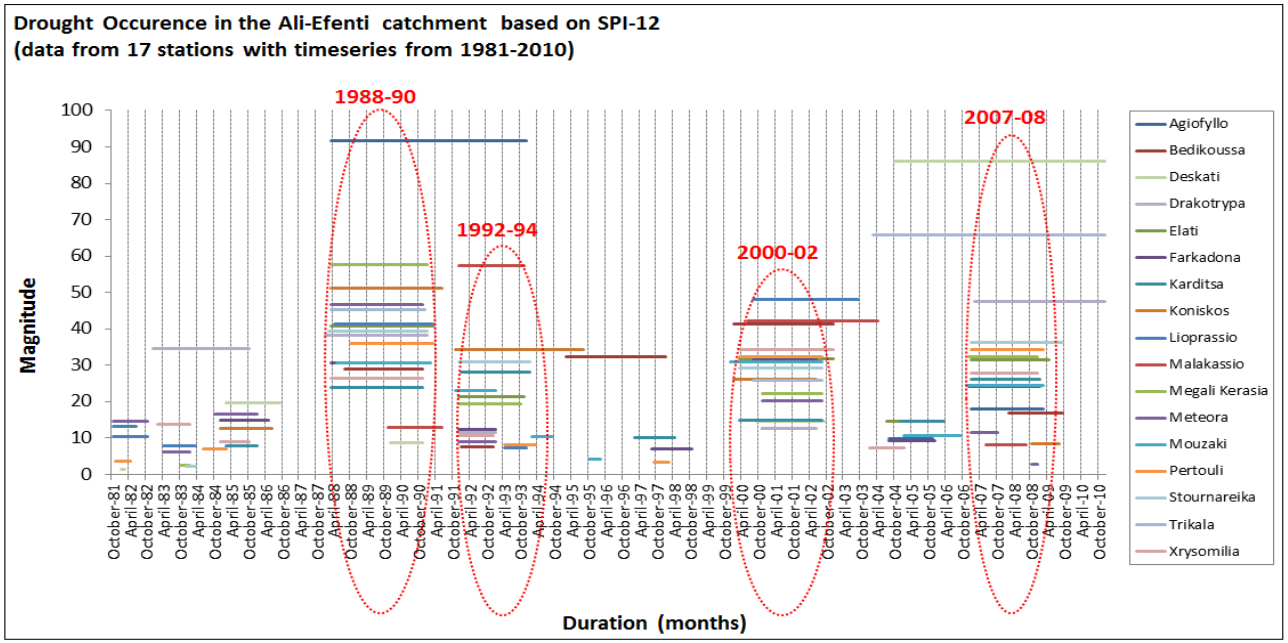


- 17 rain gauges
- 30 years (1981-2010), 2 sub-periods

Characteristics of the main drought events

Statistics	Main Drought Events			
	1988-90	1992-94	2000-02	2007-08
Number (%) of stations where the event was observed	17 (100%)	15 (88%)	17 (100%)	16 (94%)
Average DM*	36.7	20.1	27.7	24.6
Max DM*	57.7	57.5	48.0	47.6
Average duration*	32	19	29	25
Max duration*	40	46	47	47

** The 3 prolonged drought events experienced in the 3 locations mentioned previously are excluded from these statistics.*



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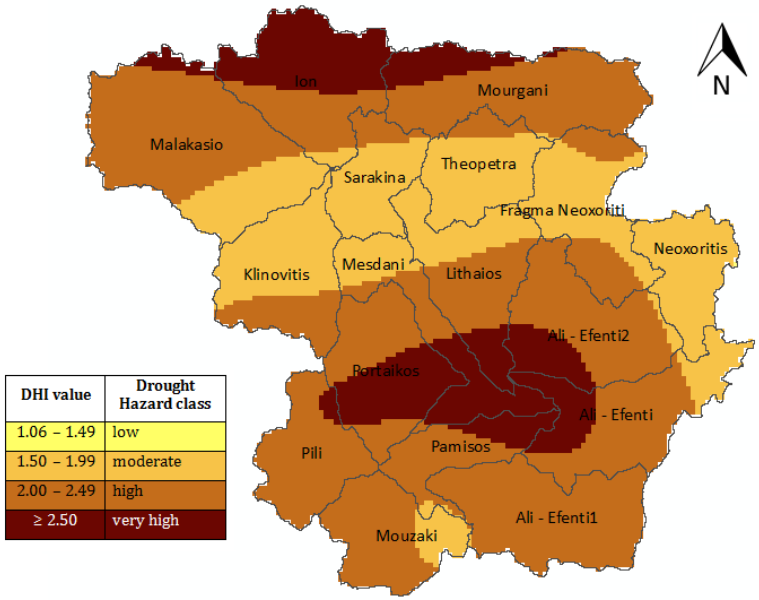
DHI in the Ali-Efenti RB, GR

- DHI across all stations: -6% in 1996-2010
- The max DHI value in 1996-2010 (2.75 in Deskati station) is 10% higher
- Overall, in 60% of the stations the DHI has decreased in 1996-2010; in 24% of the it has increased
- In 1981-1995 the drought hazard was more significant in the Northern part of the catchment (DHI > 2); it has now "migrated" to the southern part.

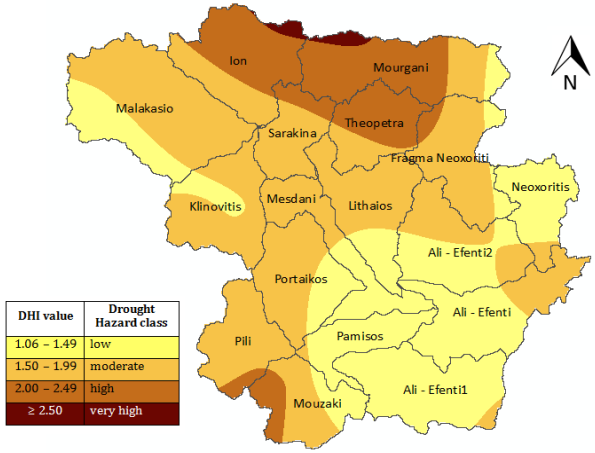
Drought Hazard Index (DHI) 1981 - 2010



DHI value	Drought Hazard class
1.06 – 1.49	low
1.50 – 1.99	moderate
2.00 – 2.49	high
≥ 2.50	very high

Ref.: Kossida, 2015

Drought Hazard Index (DHI) 1981 - 1995



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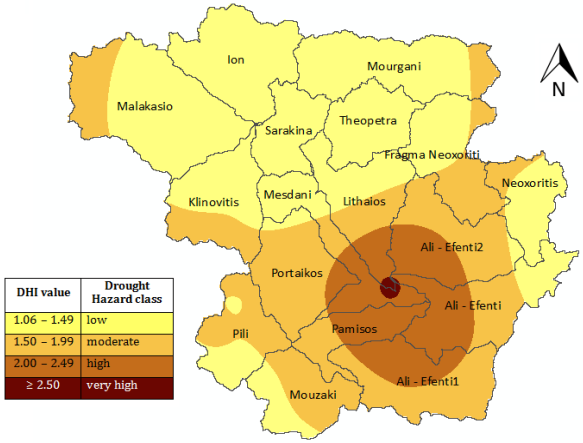
Drought Hazard Index (DHI) 1996 - 2010



DHI value	Drought Hazard class
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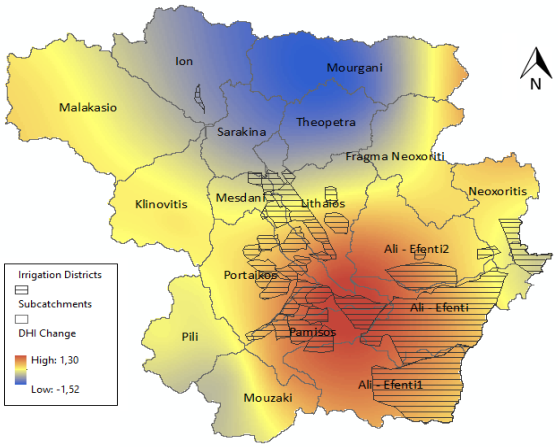
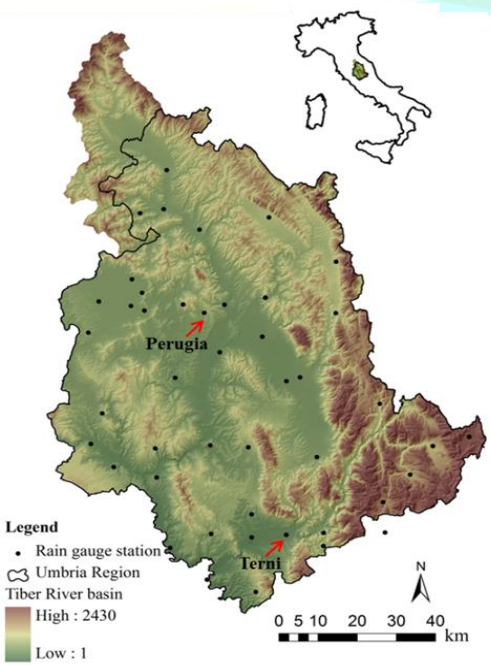
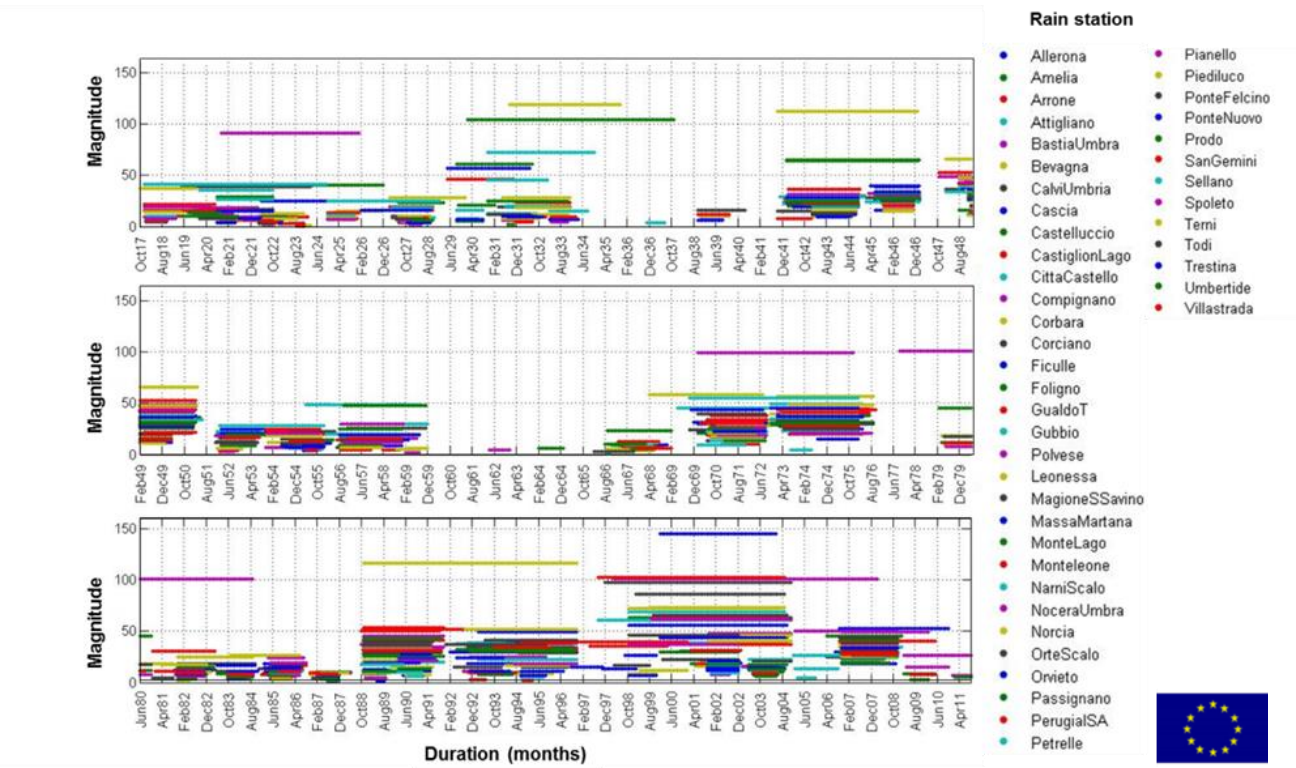
Change in DHI from 1981-1995 to 1996-2010



Case Study 2: Drought analysis in Upper Tiber Basin, IT



- 45 rain gauges
- 94 years (1917-2011), 3 sub-periods



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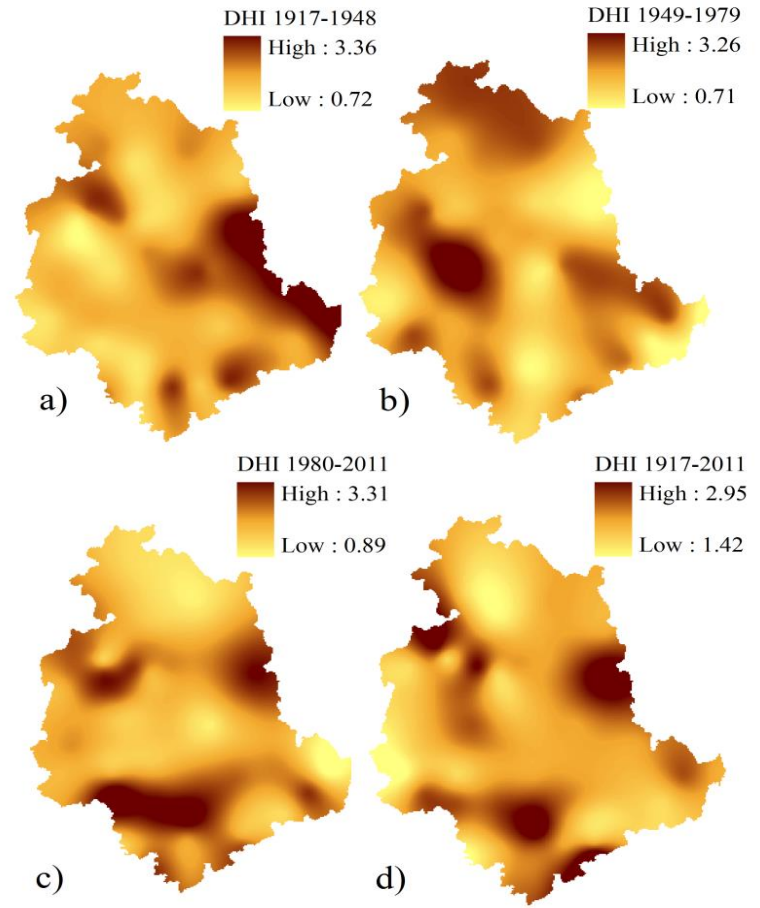
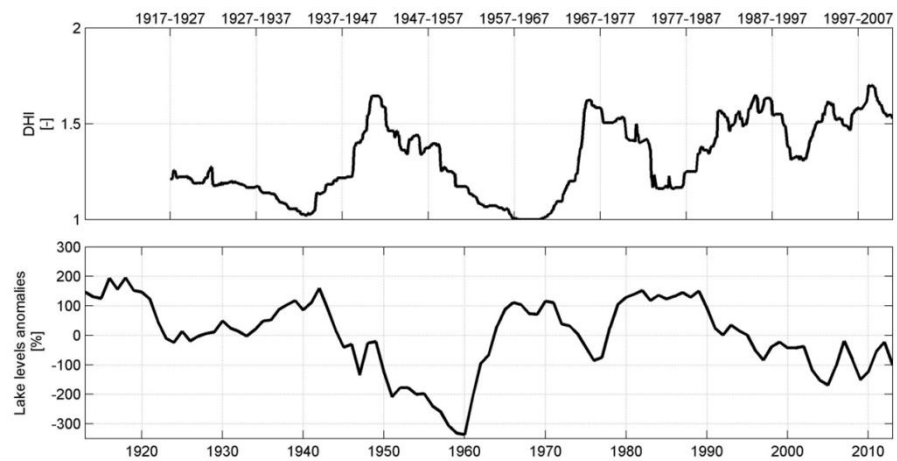
DHI in the Upper Tiber Basin, IT

- **1917-2011**: medium-high vulnerability in the Southern and Eastern parts, the north-central part is much less affected.
- **Evolutionary comparison** across every 30-year sub-period: spatial shift and a temporal trend (increased trends of the drought frequency, duration and intensity, are clearly observed from 1980 onwards)
- The **validity** of DHI as an indicator suitable to represent the drought hazard severity has been **tested against observed impacts on the water levels of lake Trasimeno**. Low levels in the lake are observed during periods with high DHI values, and vice-versa. The temporal behaviour of DHI reflects very well the variations of the water levels, clearly identifying the periods affected by droughts.





Ref.: Maccioni et al., 2015

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B. Assessment of D&WS Vulnerability

Background

A vulnerability assessment is **the process of identifying, quantifying, and scoring the vulnerabilities in a system,** with an ultimate target to identify risk, define priorities, select alternative response strategies or formulate new

- **Many concepts and definitions** of vulnerability, analyzed by many authors
- The **most common concept:** it describes the **degree to which a socio-economic system or physical assets are either susceptible or resilient** to the impact of natural hazards
- It is determined by **a combination of several factors** (physical, social, economic, environmental) **which are interacting in space and time** (e.g. conditions of human settlements, infrastructure, public policy and administration, organizational abilities, social inequalities, economic patterns, etc.)
- It is **inversely related to the capacity to cope and recover or adapt**
- Multiple **methods** have been proposed **to systematize vulnerability**. They can be generally grouped under two perspectives:

  (a) the technical or engineering sciences perspective → focus on the physical aspects of the system and on the assessment of hazards and their impacts

  (b) the social sciences perspective → the role of human systems in mediating the impacts is acknowledged
- Various conceptual **models and frameworks** have been proposed **to quantify & measure** vulnerability, with their own advantages and drawbacks

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B. Assessment of D&WS Vulnerability

Methods & Approaches

- **Quantitative** drought vulnerability **assessments are difficult**, defining quantification criteria and methods is still a challenge
- The most **common assessment methods**: vulnerability curves (intensity-damage functions), fragility curves, damage matrices, vulnerability profiles, vulnerability indicators/ indices
- **Indicator-based assessments** are the most common and widely used, expressing drought vulnerability through a number of proxy indicators or through composite indices
- The use of a **composite index** to assess the vulnerability could result into **loss of information or over-simplification**, as compared to the use of numerous indicators which allow for a more comprehensive analysis
- **On the other hand, the condensed information** provided by composite indices allows for a broad variety of issues to be addressed through a single value, **an easy communication to stakeholders and to decision makers**, and they have thus been adopted in a number of water-related studies

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B. Assessment of D&WS Vulnerability

Factors adding complexity, Challenges

The assessment complexity is attributed to the fact that drought vulnerability is:

a) **multi-dimensional and differential:** it varies from a physical context to another, with a wide variety of impacts strongly correlated to regional characteristics
b) **scale dependent:** with regard to the unit of analysis e.g. individual, local, regional, national etc.
c) **Dynamic:** the characteristics that influence vulnerability are continuously changing in time and space)

This complexity is also further exacerbated by:

- the existing **conflicting views on the concept** of vulnerability and its constitutive **elements and key drivers**
- the lack of universal frameworks, and **lack of consensus around the criteria**, **parameters and thresholds** used

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B. Assessment of DV

Some parameters

- Population density and Growth rate
- Rural population density
- Literacy rate
- Poverty rate
- Total water use per sector, Susceptibility of a water user
- Population without access to improved water (% of total)
- Income per capita
- % of workforce that works within community
- GDP form agriculture, Farm income
- Agricultural employment (% of total)
- % of Irrigated area over agricultural areas
- Area without any irrigation potential (%)
- Crop yield sensitivity
- Number of different crop categories, Crop diversification index
- Presence of government irrigation scheme
- Irrigation water use efficiency
- Losses in the water supply network
- Number of animal units/number of holdings
- Number of different livestock categories
- Insurance (€/agricultural holdings) , Subsidies (€/agric. holdings)
- Access to credit
- Governance (Share of tax revenue)
- Coping options (labor in HH industries)
- Legal & institutional frameworks

Vulnerability to Drought & Water Scarcity

Exposure, Sensitivity
(relates to DPSIR -pressures and state)

Water Resources availability/ exploitation
Water Demand/ needs
Population
Land Use
Economy & Living conditions
Infrastructure
Practices & Awareness
Ecosystem Goods & Services

Potential Impacts
(relates to DPSIR -impacts)

Environmental/ Ecological
Economic
Social

Adaptive capacity
(relates to DPSIR -responses)

Ability, Resources and Willingness to mitigate, respond, recover
Institutions
Legislative framework
Economy
Technical capacity
Education
Social perception

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B. Assessment of D&WS Vulnerability

Suggestions, Remedies?

State-of-the-Art
- Multiple schools, and vulnerability frameworks/ models
- Combination, aggregation
- Selection ~ specificities & criteria

Question	Suggestion
How to define the main objectives of the DV assessment?	The most important goal of the DV assessment and quantification is its use in supporting risk reduction strategies, and its operational application in the decision-making processes
DV cuts across different temporal and spatial scales, and sectors: agriculture, livestock, domestic, tourism, etc. Should we address everything? Where to start from?	Link the selection of DV components to the local study context DV definition inevitably requires the prioritization of the most important components and pressing factors which shape a region's potential risk
What s important in the context of water stressed areas?	The pressing (or limiting) factor is usually the balance between water availability and demand, for the various economic sectors (incl. the environment) Unmet demand, which is associated with different drivers , and water supply reliability, are commonly the limiting factors and main pressures leading to increased vulnerability

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The Drought Vulnerability Index (DVI)

data on unmet demand/ water supply reliability unavailable → estimates, proxies modeling

- Estimate **unmet demand** at sub-catchment
- Calculate 3 sub-indicators, which reflect metrics of: reliability, distance to target (to meet demand) and resilience to extreme conditions
- Classify and assign scores to the sub-indicators
- Blend the sub-indicators to a DVI

$$DVI = \frac{score_{REL} + score_{DIS} + score_{EXT}}{3}$$

Why unmet demand? Captures drivers, pressures; is multi-dimensional, multi-scale, dynamic; directly feeds risk reduction strategies

How to estimate it? WRMM / WBM (e.g. WEAP21)

Vulnerability components as captured by the "unmet demand"

Drivers	Pressure	State
▪ Population ▪ Daily water use per capita ▪ Rate of losses	▪ Domestic Water Demand ▪ Water supply delivered (as a function of availability and priority)	**Unmet demand in the Urban sector**
▪ Number of nights spent in touristic lodges (hotel, motel, etc.) ▪ Daily water use rate per lodge type (hotel, motel, etc.) ▪ Rate of losses	▪ Touristic Water Demand ▪ Water supply delivered (as a function of availability and priority)	
▪ Animals' population (per type) ▪ Typical daily water use rates (per animal type) ▪ Rate of losses	▪ Livestock Water Demand ▪ Water supply delivered (as a function of availability and priority)	**Unmet demand in the Agricultural sector**
▪ Crop types ▪ Irrigated area (per crop type) ▪ Irrigation needs (per crops type) ▪ Combined irrigation efficiency (conveyance, application)	▪ Irrigation Water Demand ▪ Water supply delivered (as a function of availability and priority)	
▪ Number of industrial units/facilities (per type) ▪ Daily water use rate per unit (per industry type) ▪ Return water from industry (inflow minus consumption)	▪ Industrial Water Demand ▪ Water supply delivered (as a function of availability and priority)	**Unmet demand in the Industrial sector**

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The 3 sub-indicators of DVI

REL	percent (%) of years with unmet demand within the period of analysis	used as metrics of "water supply reliability"
DIS	Average unmet demand within the period of analysis as percentage (%) of the respective total demand	used as metrics of "distance to target"
EXT	Maximum annual unmet demand within the period of analysis as percentage (%) of the respective total demand of that same year	metrics of "resilience to extreme conditions"

Classification of the REL sub-indicator

% of years with unmet demand	Score / Class
0-9%	1 - low
10-19%	2 – moderate
20-29%	3 – high
>30%	4 – very high

Classification of the DIS sub-indicator

Average Unmet demand as % of Total demand	Score / Class
0-9%	1 – low
10-19%	2 - moderate
20-29%	3 - high
>30%	4 - very high

Classification of the EXT sub-indicator

Max annual unmet demand as % the total demand of that year	Score / Class
0-9%	1 – low
10-19%	2 – moderate
20-29%	3 – high
>30%	4 – very high

Classification of the DVI

DVI value	Vulnerability class
1.00 – 1.49	1 – low
1.50 – 2.49	2 – moderate
2.50– 3.49	3 – high
3.49 – 4.00	4 – very high

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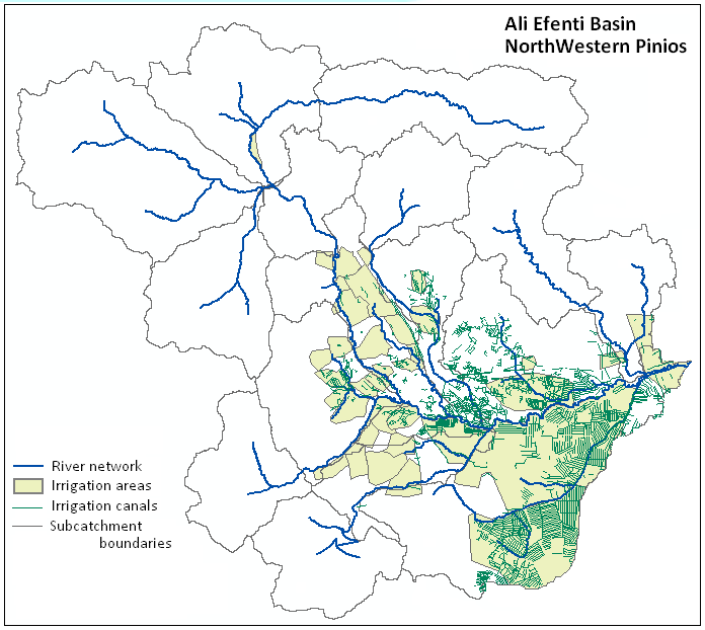
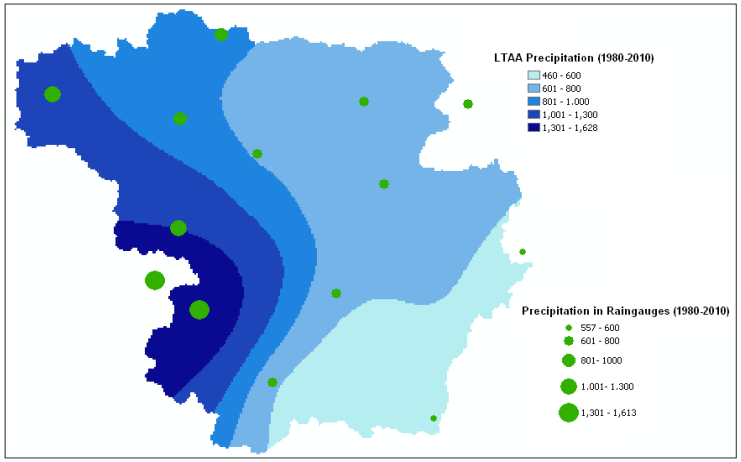
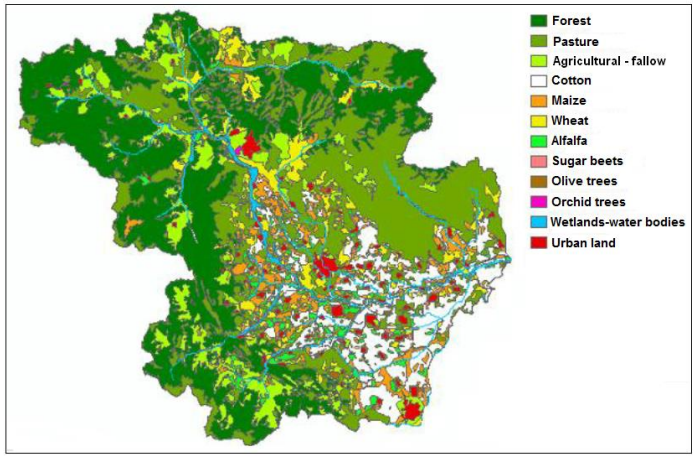
Case Study: Vulnerability analysis in Ali-Efenti RB, GR



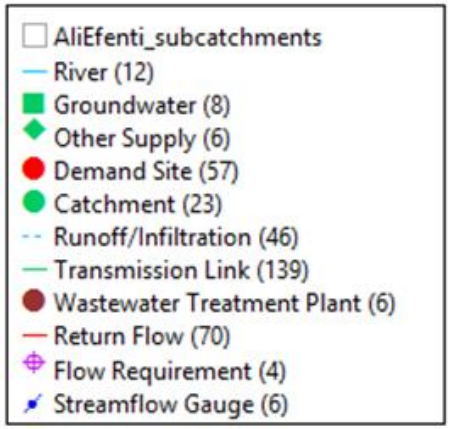
- Drainage area: 2,920 km2 (1/3 of Pinios)
- Population: 190,276 inhabitants
- Mean Annual Precipitation: 460-1,630 mm
- Land Use: 33% Forest, 33% Agriculture, 31% Pasture, 2% Urban
- Main crops: cotton, maize, alfalafa, sugarbeet, (wheat)
- Extensive irrigation, low efficiency
- Water stress, unmet demand is highly pronounced during the summer
- Over-abstraction → degradation of groundwater resources, declining groundwater levels
- Week institutional and policy setting

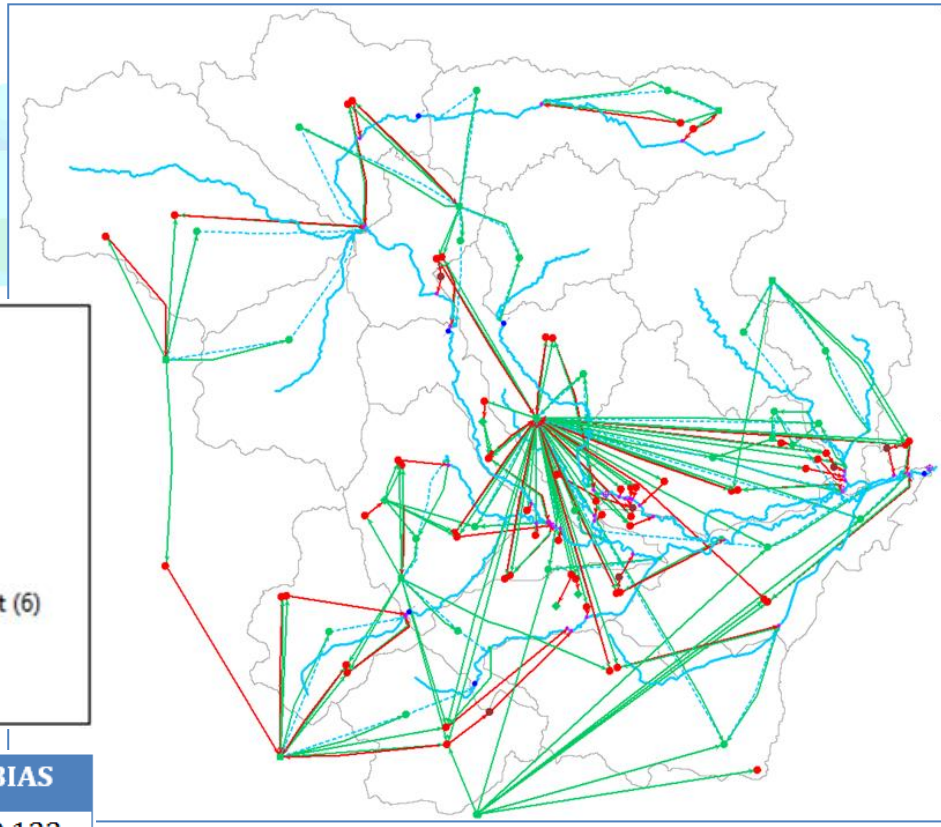




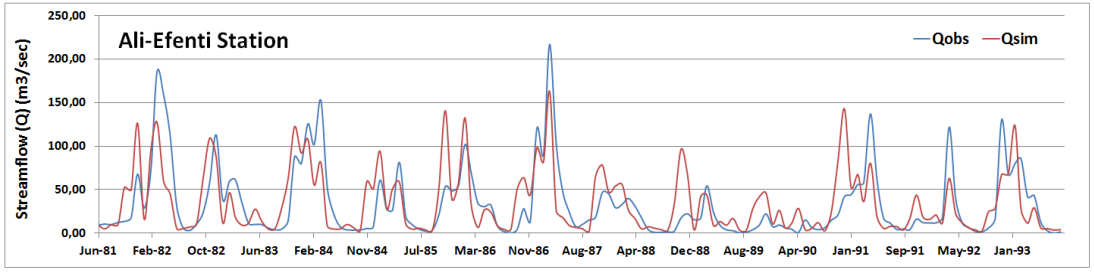
WRMM set-up

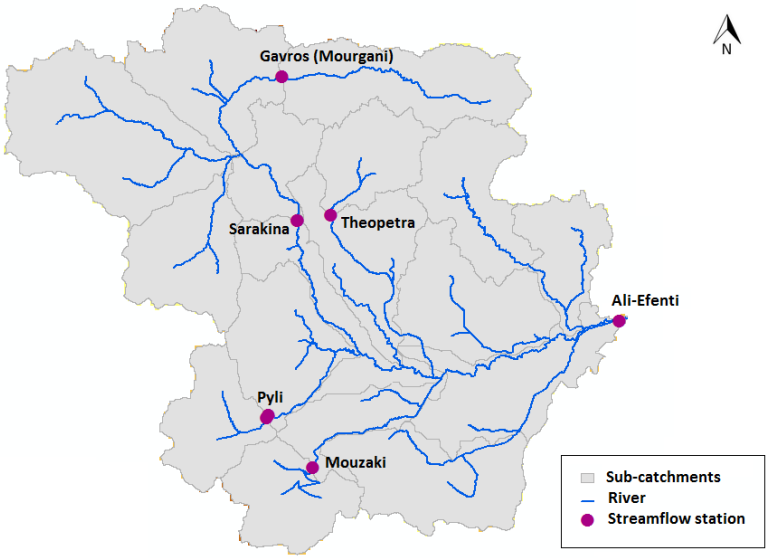
- WEAP21
- node-based
- monthly resolution
- Calibrated and validated for 1980-1994
- Baseline (reference) period 1995-2010



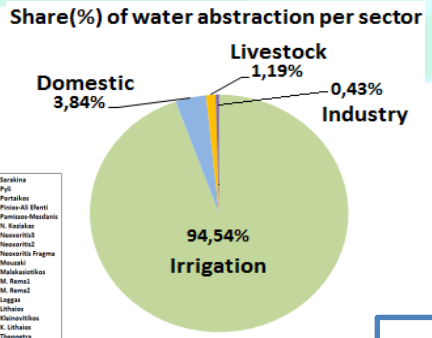


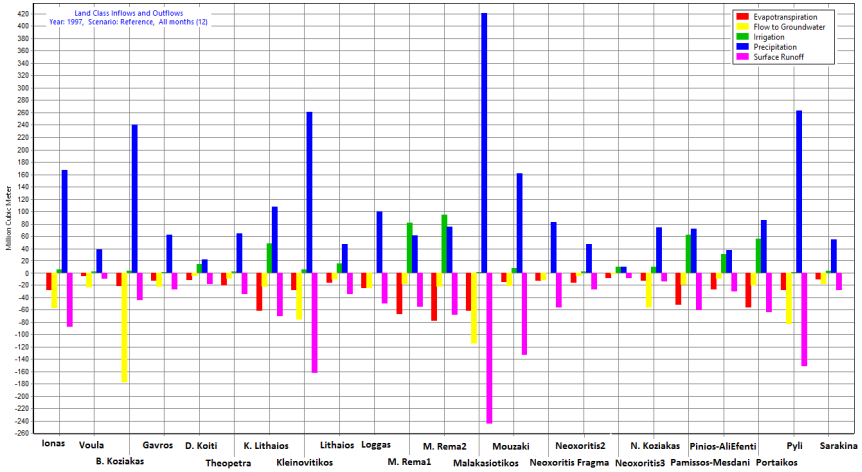
Gauge station	Validation period	E	r	BIAS
Pyli	10/1990 - 9/1993	0.639	0.811	-0.133
Mouzaki	10/1992 - 9/1994	0.565	0.802	-0.309
Gavros (Mourgani)	10/1988 - 9/1993	0.650	0.820	0.197
Sarakina	10/1988 - 9/1993	0.680	0.875	-0.201
Theopetra	10/1988-9/1993	-0.088	0.161	-0.683
Ali Efenti	10/1984 - 9/1993	0.595	0.790	0.078

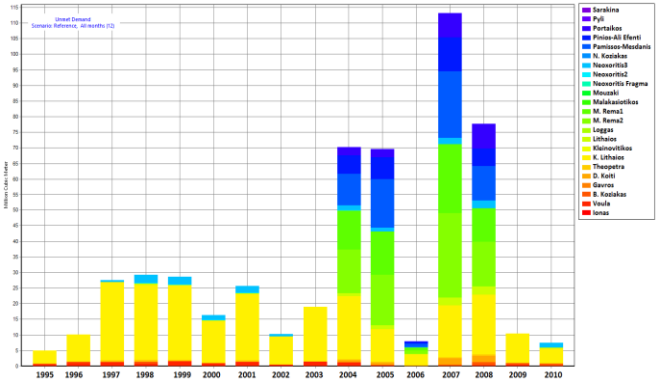




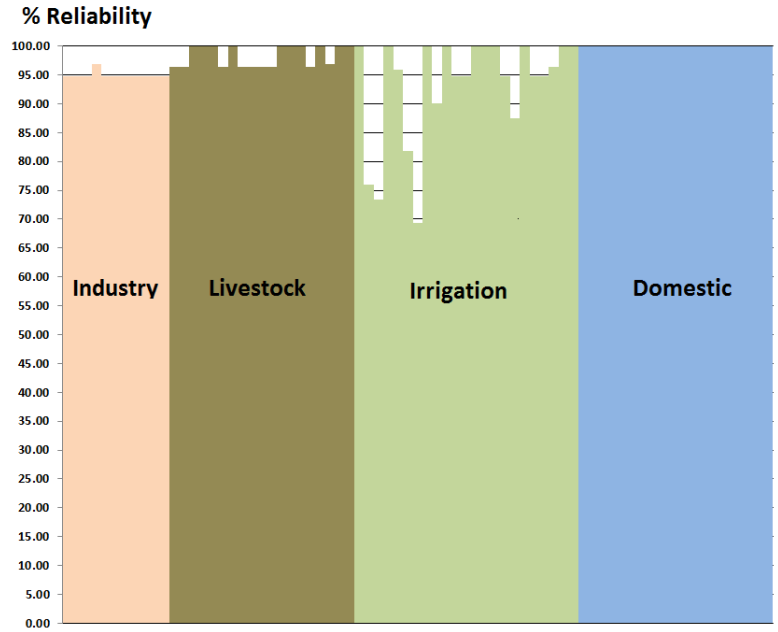
WRMM results: unmet demar







Year	Total Supply Delivered (mio m³)	Total Demand (mio m³)	Total Unmet Demand (mio m³)	Unmet Demand as % of Total demand
1995	476.65	481.57	4.92	1,02%
1996	489.16	499.33	10.18	2,04%
1997	483.39	510.87	27.47	5,38%
1998	494.44	523,.72	29.30	5,59%
1999	490.44	518.97	28.52	5,50%
2000	519.46	535.78	16.31	3,04%
2001	508.02	533.63	25.62	4,80%
2002	483.82	494.07	10.25	2,07%
2003	479.53	498.49	18.97	3,81%
2004	446.36	517.16	70.79	13,69%
2005	442.35	512.34	70.02	13,67%
2006	500.47	508.65	8.21	1,61%
2007	402.39	516.27	113.96	**22,07%**
2008	436.75	515.06	78.34	15,21%
2009	504.13	514.60	10.47	2,03%
2010	495.64	503.03	7.38	1,47%
SUM	**7,653.00**	**8,183.54**	**530.71**	**6,49%**
Average	**478.30**	**511.50**	**33.17**	**6,49%**

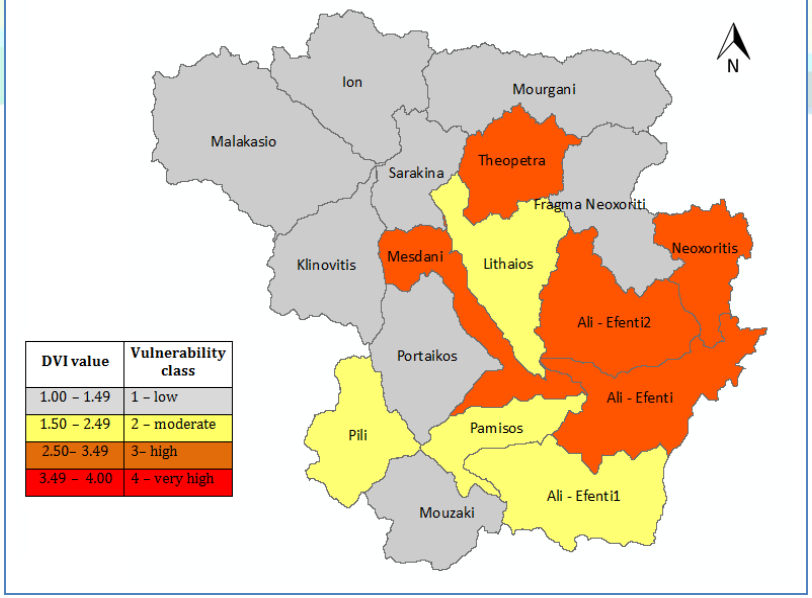


Reliability	Domestic users	Livestock users	Industrial users	Irrigation users
Very High (>97%)	100%	53%		43.5%
High (90-97%)		47%	100%	34.8%
Medium (75-90%)				13.0%
Low (<75%)				8.7%

DVI in Ali-Efenti RB

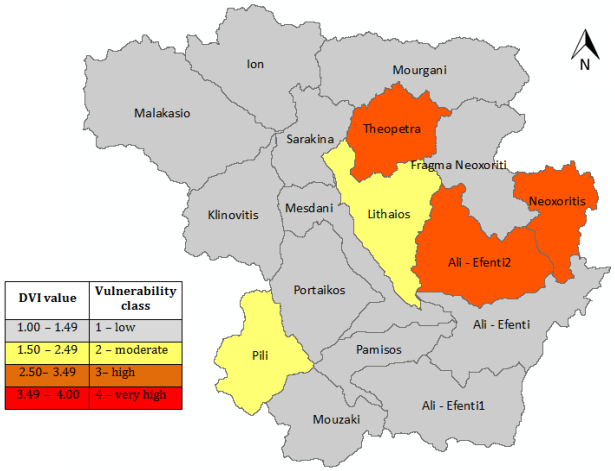
- 1981-2010: 29% of sub-catchments class 3; 24% in class 2; 47% in class 1
- 1981-1995 to 1996-2010: overall increase in vulnerability ~ 0.37, which represents 37% of a class span (1/3rd of a class)
- The South-eastern part is most vulnerable (medium to high degree of vulnerability) in 1981-2010 (spatial expansion)
- Vulnerability increases in: Mesdani, Ali-Efenti, Ali-Efenti1, Pamissos

DVI (1981-2010)



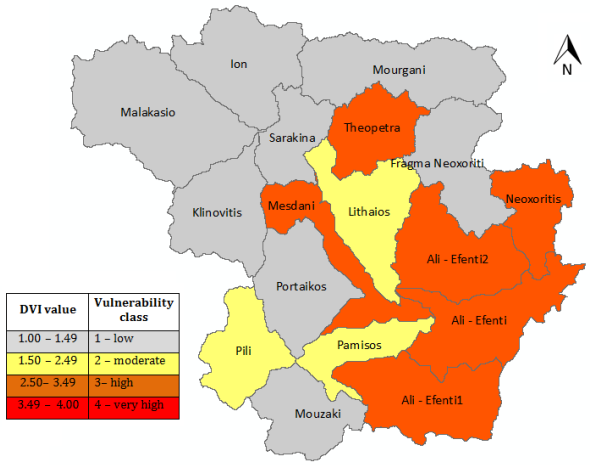
DVI value	Vulnerability class
1.00 – 1.49	1 – low
1.50 – 2.49	2 – moderate
2.50– 3.49	3– high
3.49 – 4.00	4 – very high

DVI (1981-1995)



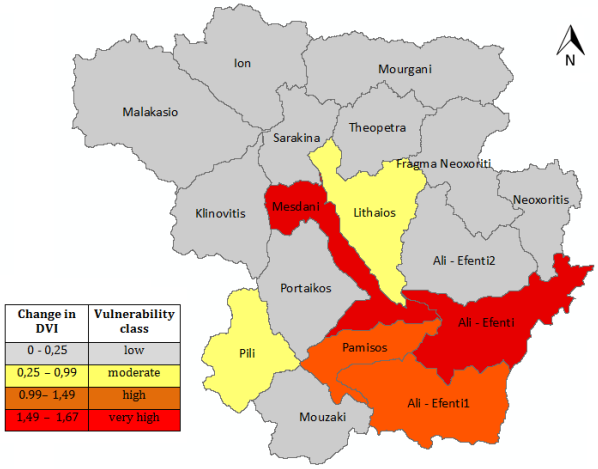
DVI value	Vulnerability class
1.00 – 1.49	1 – low
1.50 – 2.49	2 – moderate
2.50– 3.49	3– high
3.49 – 4.00	4 – very high

DVI (1996-2010)



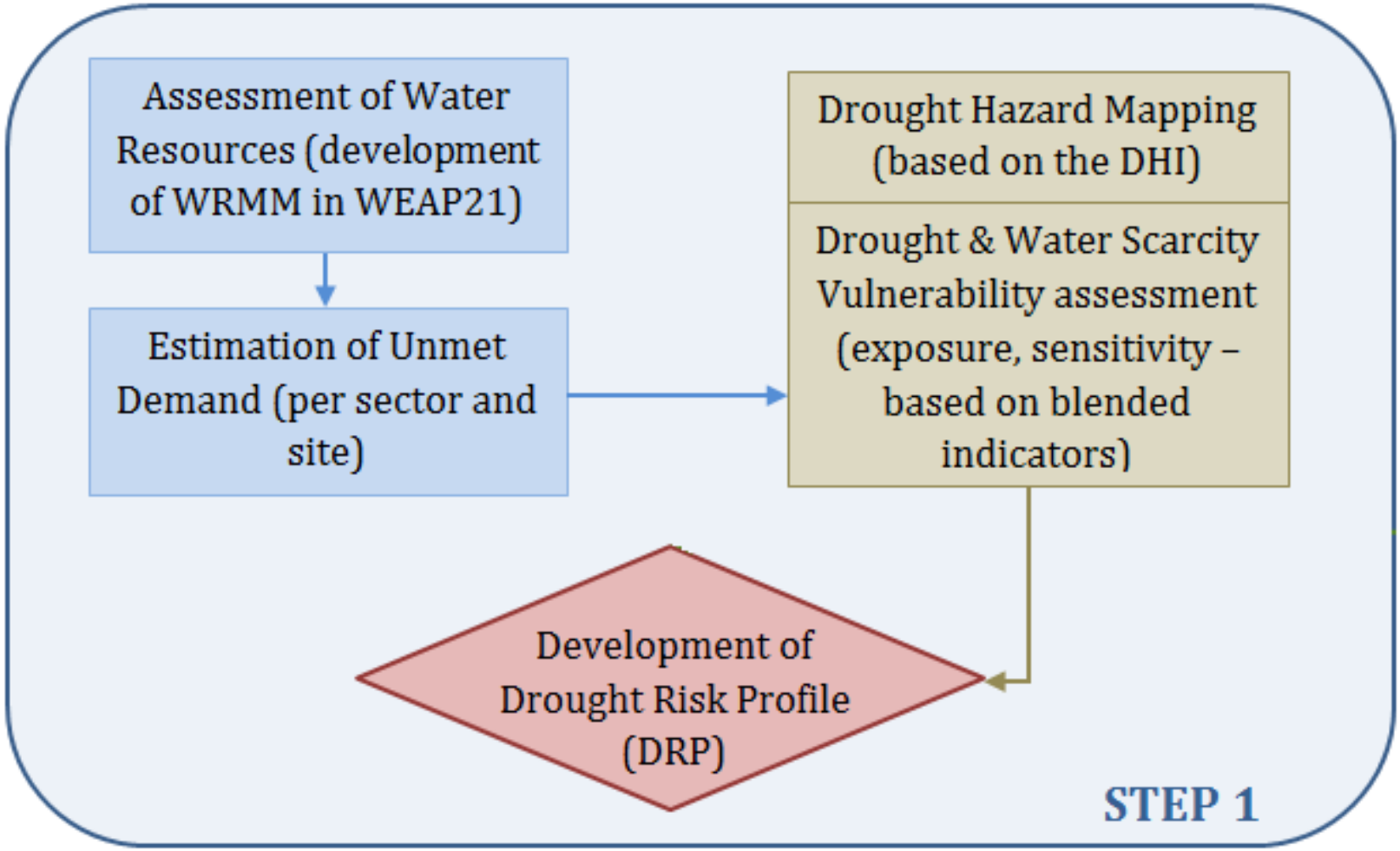
DVI value	Vulnerability class
1.00 – 1.49	1 – low
1.50 – 2.49	2 – moderate
2.50– 3.49	3– high
3.49 – 4.00	4 – very high

Change in DVI from 1981-1995 to 1996-2010



Change in DVI	Vulnerability class
0 - 0,25	low
0,25 – 0,99	moderate
0.99– 1,49	high
1,49 – 1,67	very high

Schema: Integrating DRP and DV to obtain Risk



Drought Risk Index (DRI)

- Estimate the Drought Risk Index (DRI)

Risk = Hazard x Vulnerability ➔ **DRI = DHI x DVI**

- GIS processing for matching of spatial resolutions required

Classification of the Drought Risk Index (DRI)

DRI value	Drought Risk class
1.00 – 2.00	1 – low
2.10 – 5.00	2 – moderate
5.10 – 8.00	3 – high
≥ 8.10	4 – very high

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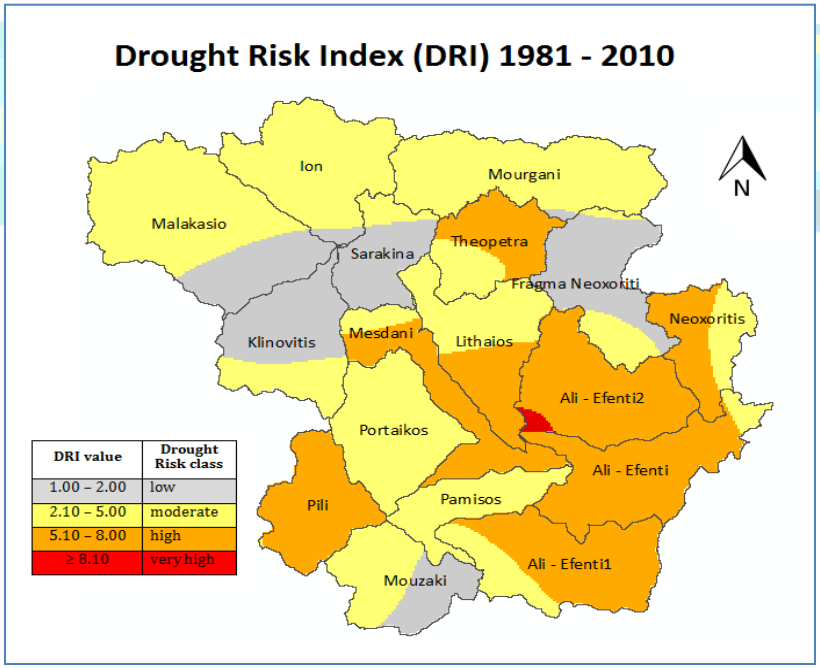
Case Study: Drought Risk Profile In Ali-Efent RB, GR

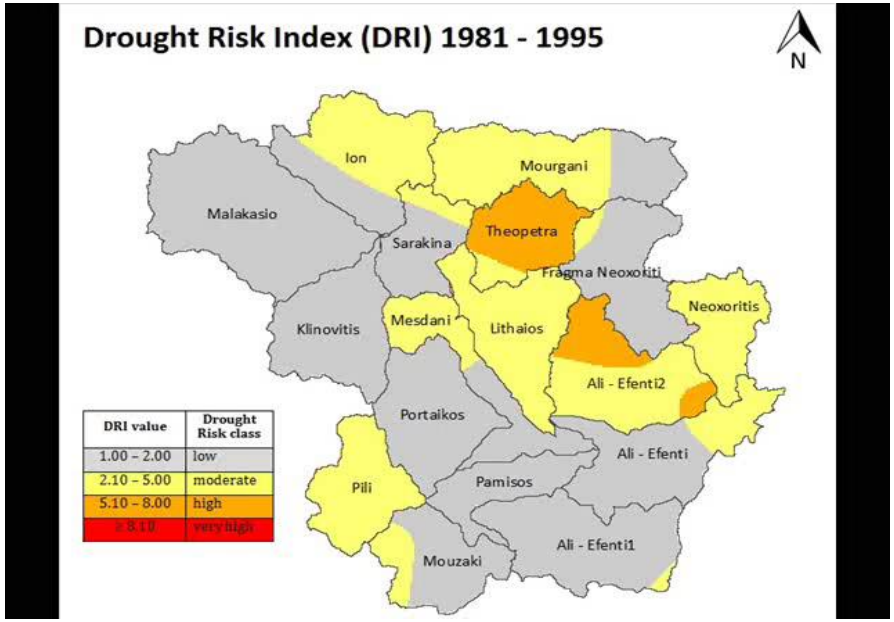


- **1981-2010:**

Moderate risk in the Northern part and some areas in the Center
High risk in the South-eastern part
Very high risk in an small area in the Center

- **Evolution of risk:**

Shift of the risk areas towards the Southern part of the basin:
→ the northern part of the is becoming less prone (risk classes decline), while the south-eastern part becomes more prone (risk classes increase from low to high).
The highest increases in the DRI: Mesdani, Ali-Efenti where the main irrigated areas are



Title

Sustainable Water Integrated Management and Horizon 2020 Support Mechanism

SWIM-H2020 SM

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Working for a Sustainable Mediterranean, Caring for our Future.

This project is funded by the European Union

The SWIM-H2020 SM Project in a Snapshot

Working for a Sustainable Mediterranean, Caring for our Future.

Mediterranean Issues and Challenges

The environmental problems of the Mediterranean are many, complex and interlinked. Uncontrolled coastal development, population growth, increasing tourism, loss of biodiversity and environmental pollution stemming from the above and from poor management of municipal waste, urban wastewater and industrial emissions, including their respective pressures to the quantitative and qualitative characteristics of surface and groundwater resources ending up in the Mediterranean, constitute major pressures on its marine and coastal environment. Their impact is particularly reflected in the land-sea interface, the coastal zone. In addition, economic and social crises, high refugee flows, in combination with climate variability and change have made it more difficult to deal with the accumulated problems. Renewed efforts to address the challenges are made within **the SWIM-H2020 SM Project** (Sustainable Water Integrated Management and Horizon 2020 Support Mechanism 2016-2019) jointly by the Mediterranean countries and the European Union.

The SWIM-H2020 SM Project

The SWIM-H2020 SM Project, funded by the European Union, aims to contribute to reduced marine pollution and a sustainable use of scarce water resources in the Mediterranean Region with emphasis on the countries of North Africa and the Middle East (Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, [Syria] and Tunisia). The Project is the continuation and merging of two successful previous EU-funded service contracts, Horizon 2020 Capacity Building/Mediterranean Environment Programme (H2020 CB/MEP) (2009-2014) and the Sustainable Water Integrated Management Support Mechanism (SWIM SM) (2010-2015).

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SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Thank you for your attention.

This Project is funded by the European Union