SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

SWIM-H2020 SM EFS-JO-1 "Mainstreaming Drought Risk Management, with a focus on proactive measures"

Drought Vulnerability in the Amman-Zarqa catchment in Jordan

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Consultation Workshop "Roadmap for developing a Drought Risk Management Plan in the Amman-Zarqa catchment"

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Presentation Outline

- Scope of the vulnerability analysis
- Methodological approach
- Land uses contributing to drought vulnerability in AZ
- Results
- Limitations, recommendations

Scope of the Drought Vulnerability analysis

- Identify Drought Vulnerability (DV) in relation to the key economic sectors in the Amman-Zarqa (AZ) catchment, i.e. domestic, agricultural, industrial

- Quantify DV on the basis of suitable indicators (clear, reproducible, transparent...)

- Map the Drought Vulnerability Profile of the AZ

- Capability of integration to obtain Drought Risk Profile of AZ

- Link science to the decision and policy-making process

- Promote proactive risk management

Disaster Risk Profiling: the general context

- **Disaster risk profiles in general,** and thus Drought Risk Profiles 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 = Hazard x Vulnerability**

- Vulnerability profiling **helps direct the policy towards a programmatic focus** showing the 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 Vulnerability (as part of the Risk) is a pre-condition to the correct identification of mitigation measures

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

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

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

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

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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
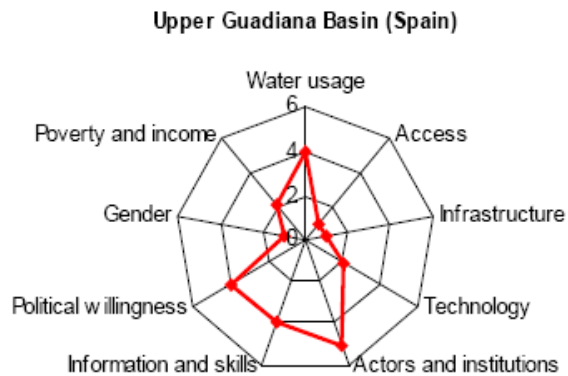*Education*
Social perception

Assessment of DV - Some examples
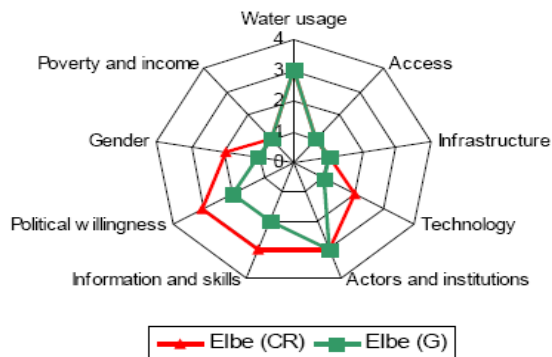
Vulnerability profile
Upper Guadiana Basin, Spain (top)
Elbe RB, Czech Republic-Germany(bottom)
(Source: Downing & Bharwani, 2006)

Upper Guadiana Basin (Spain)

Comparison of common attributes of vulnerability
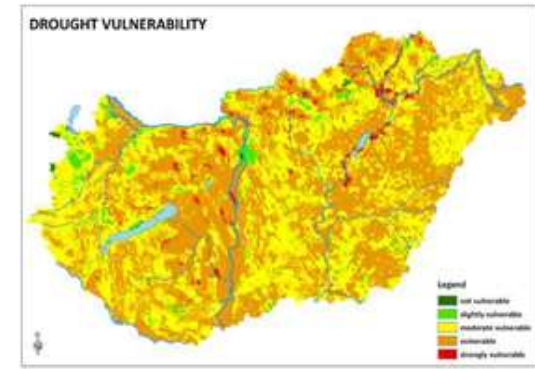
Elbe (CR)   Elbe (G)

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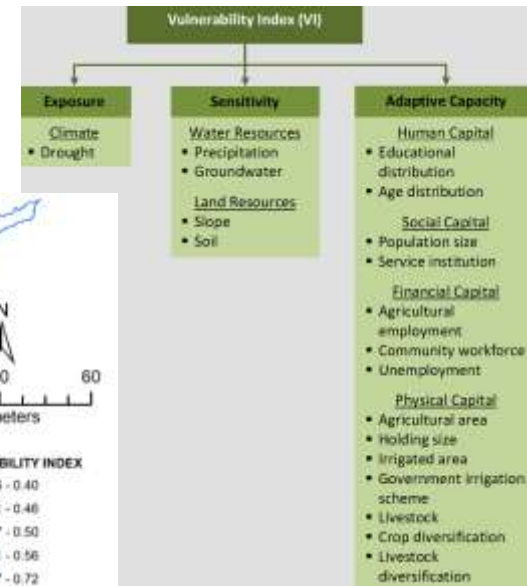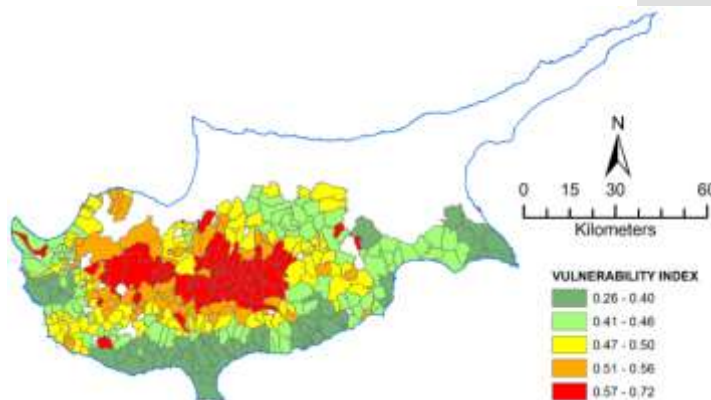## Multi-criteria simulations: Drought vulnerability map of agriculture in Hungary
(Source: DMCSEE, Source: Gregorič, 2012)

Physical factors
(precipitation, solar radiation, soil water-holding capacity, slope)
Socio-economic factors
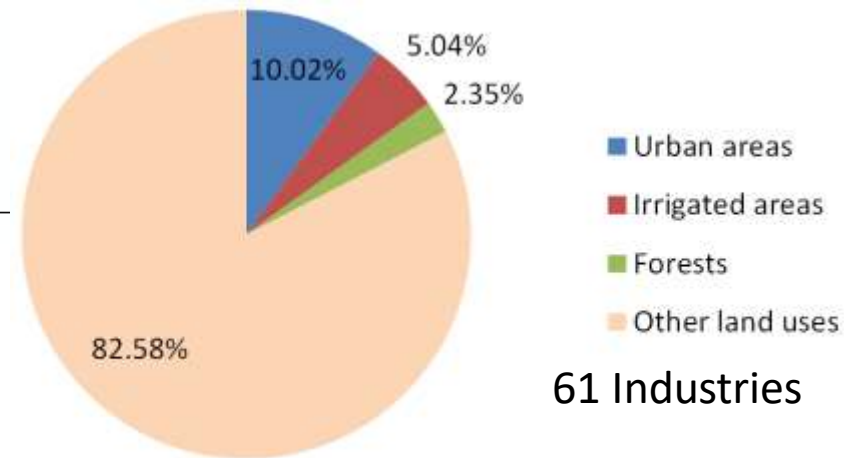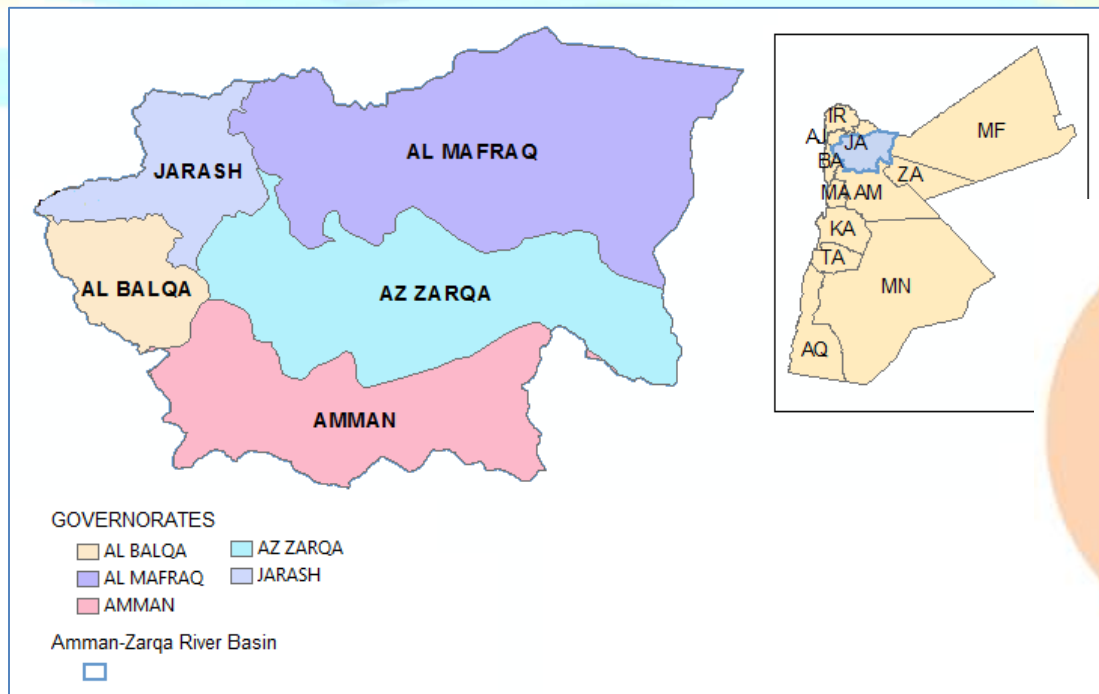(land use, irrigation)

DROUGHT VULNERABILITY

## Using a Blend of Indicators to derive Vulnerability Index
(Source: Deems, 2010)

Land Uses contributing to Drought Vulnerability in the AZ basin

GOVERNORATES
- AL BALQA
- AL MAFRAQ
- AMMAN
- AZ ZARQA
- JARASH

Amman-Zarqa River Basin

Pie chart:
- 10.02% Urban areas
- 5.04% Irrigated areas
- 2.35% Forests
- 82.58% Other land uses

61 Industries

Land use per Governorate within the Amman-Zarqa basin

Land Uses per Governorate within the AZ Basin	Amman	Zarqa	Mafraq	Jarash	Balqa
Urban areas (km²)	190.59	82.26	51.16	16.67	16.09
Irrigated areas (km²)	0.95	43.77	124.59	4.88	6.76
Forests (km²)	4.03	4.61	4.53	45.48	25.94
Industrial units (number of)	6	38	10	1	5
Total area (km²) of the Governorate within the AZ basin	735.29	947.79	1327.49	320.14	254.71

Land Uses contributing to Drought Vulnerability in the AZ basin
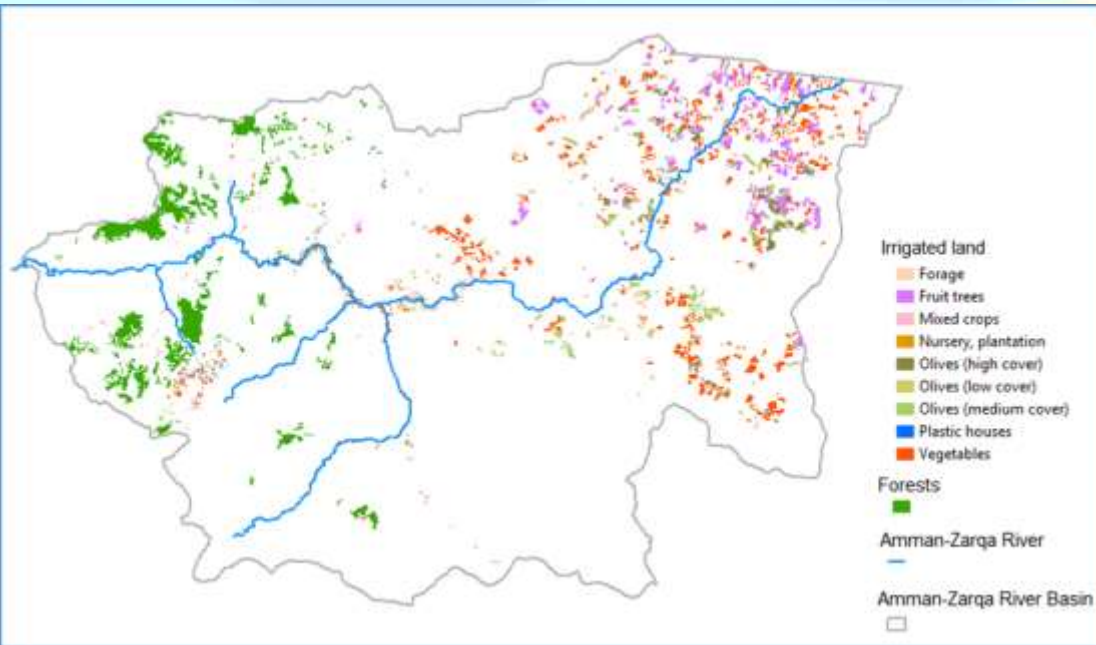
Land use_Irrigated areas and Forests
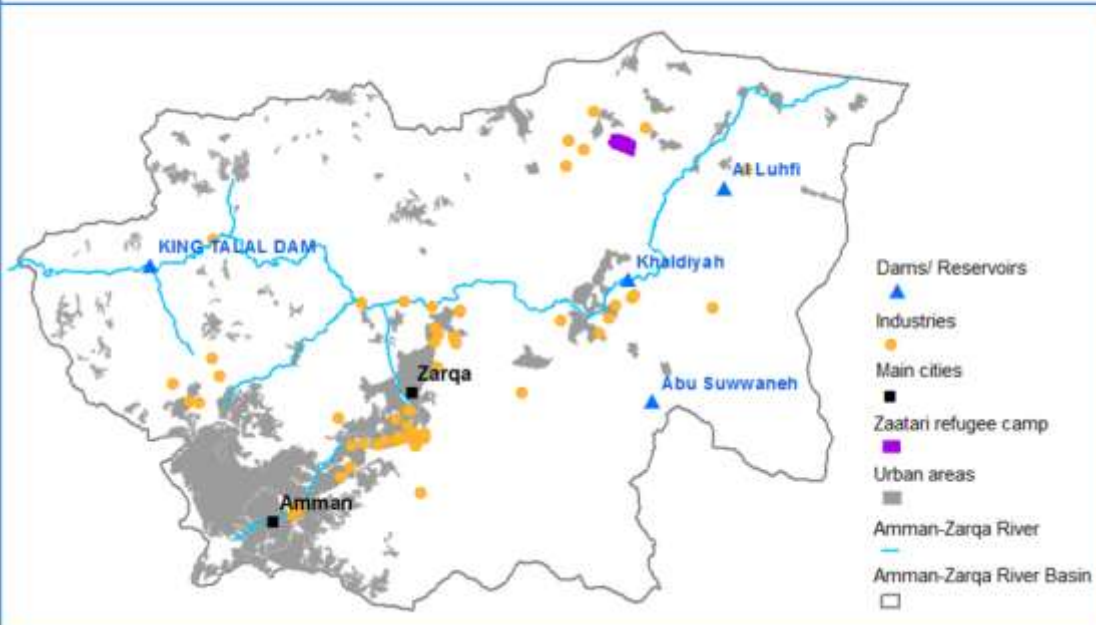
Land use_Urban areas and Industries

Groundwater Abstraction in the AZ basin

Monthly average groundwater abstraction/ supply (all sites, m3)

Monthly average groundwater supply per Sector (m3)

Monthly average groundwater supply per Governorate (m3)

Groundwater Abstraction in the AZ basin

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Monthly average groundwater supply per Sector (m3)

Monthly average groundwater supply per Governorate (m3)
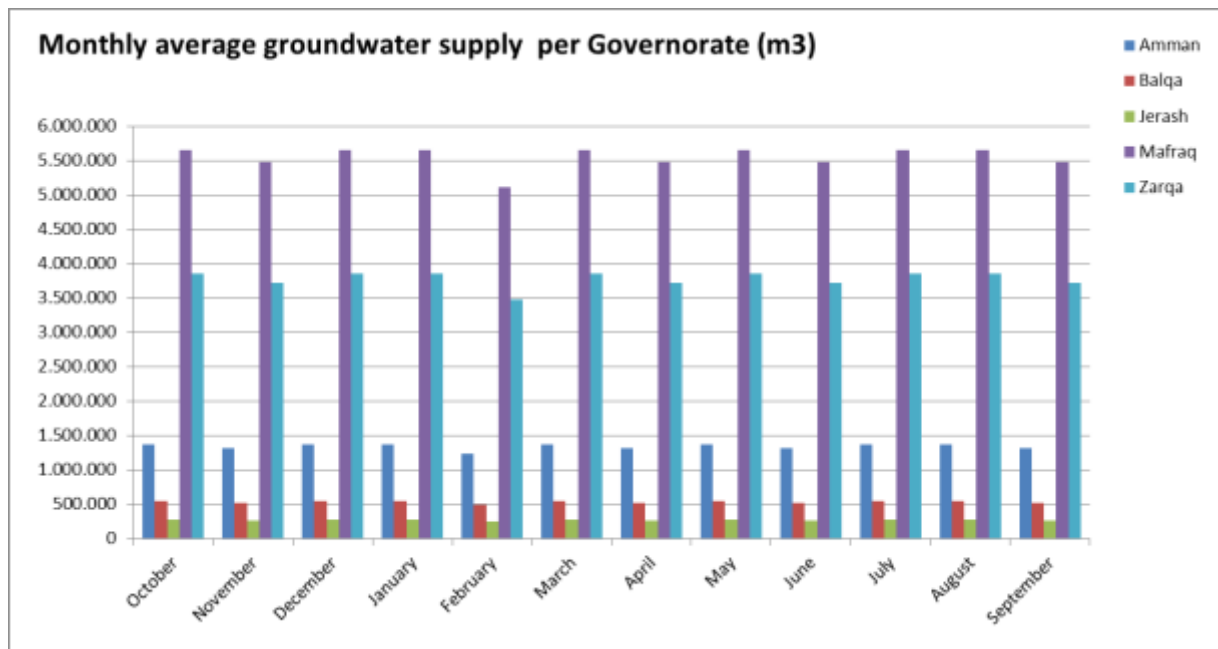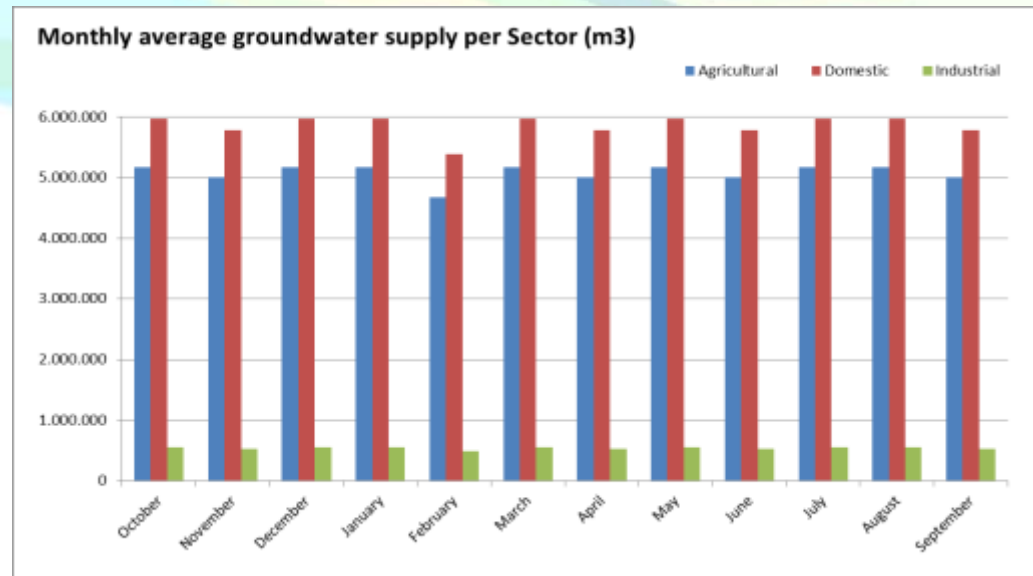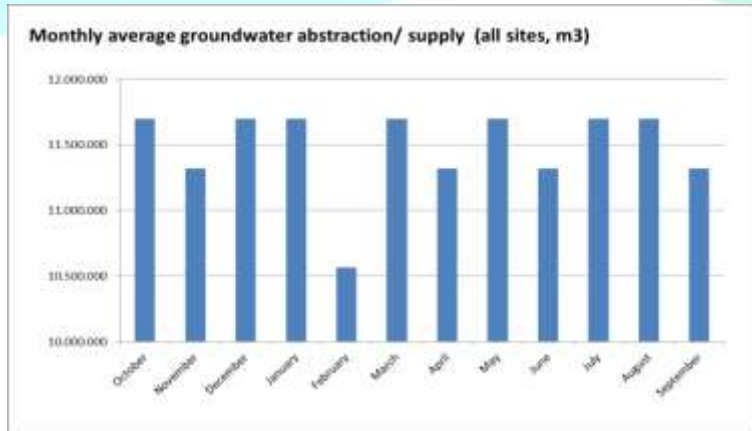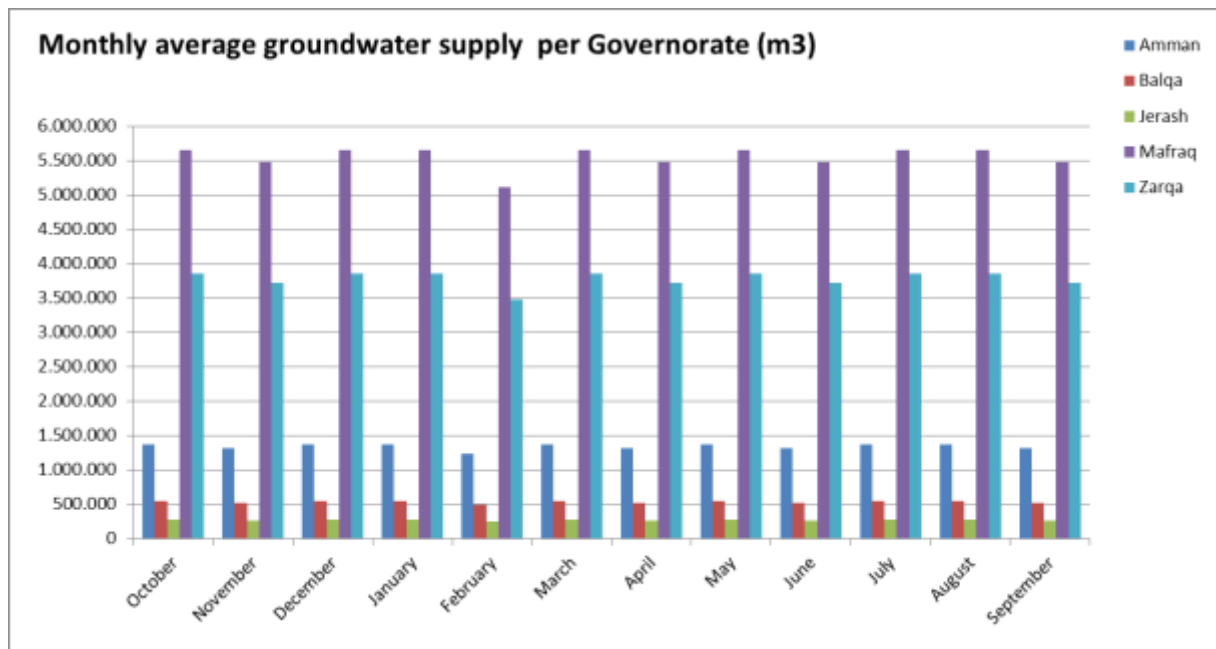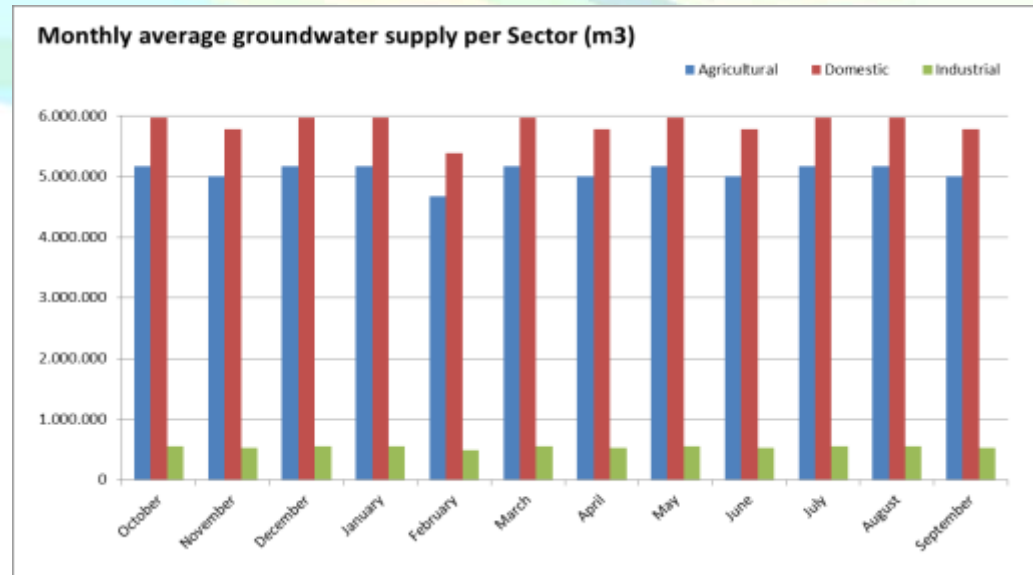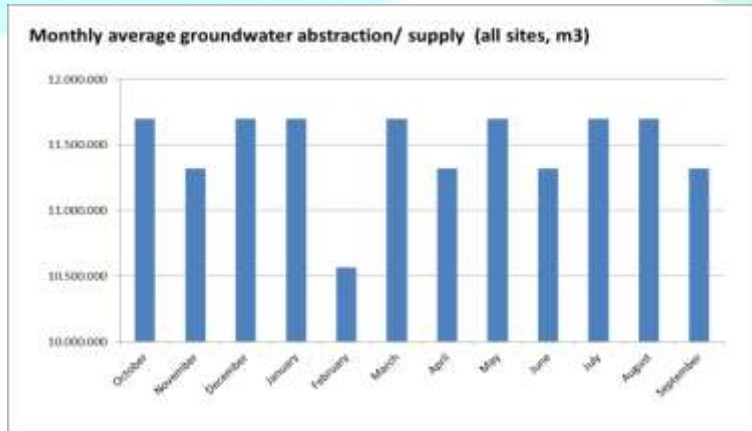
Groundwater Over-abstraction in the AZ basin

Summary statistics of over-abstraction ("unmet demand") for the period 2001-2015

Annual over-abstraction	MCM / year
Mean	49.57
Median	49.29
Standard error	1.69
Maximum	59.99 (year 2010)
Minimum	38.32 (year 2005)
Range	21.67
Standard deviation	6.54
Variance	42.71
Sum of the period 2001-2015 (15 years)	743.60 MCM

Annual over-abstraction per sector

Monthly average over-abstraction (unmet demand) (all sites, m3)

Total over-abstraction (unmet demand) per Governorate (m3)
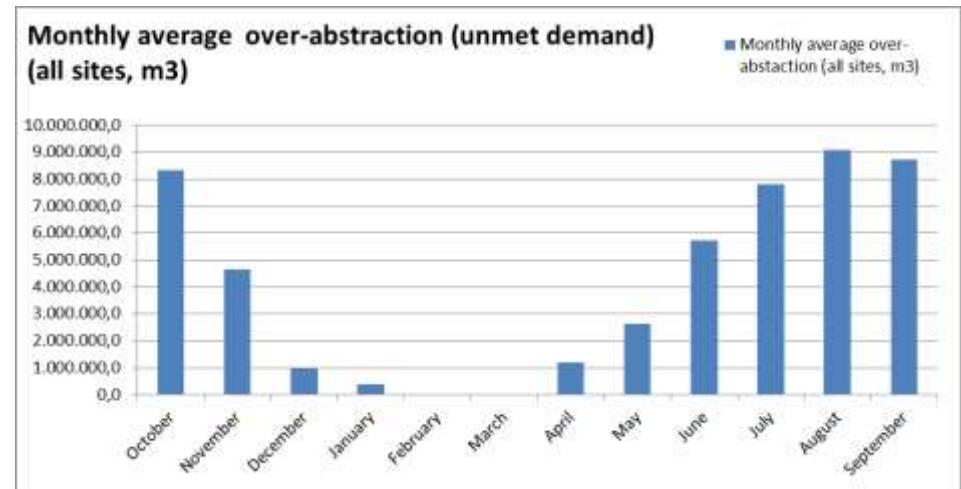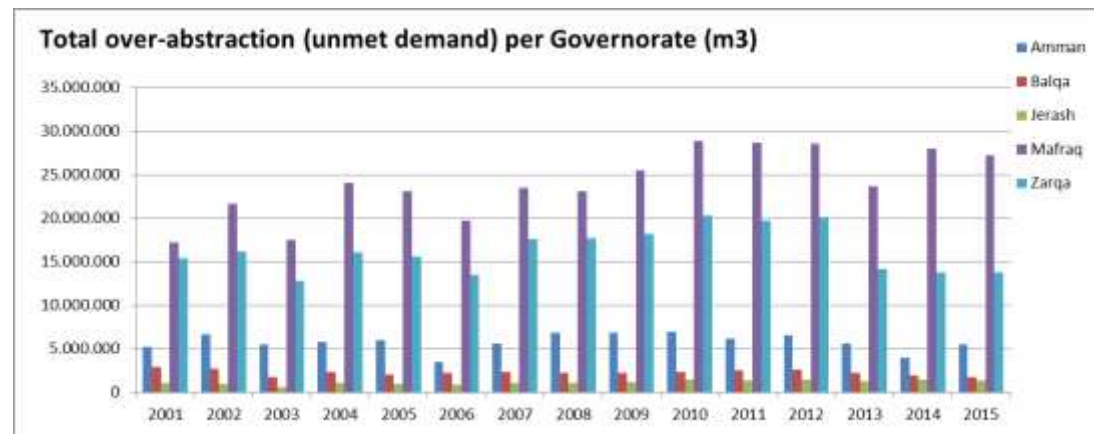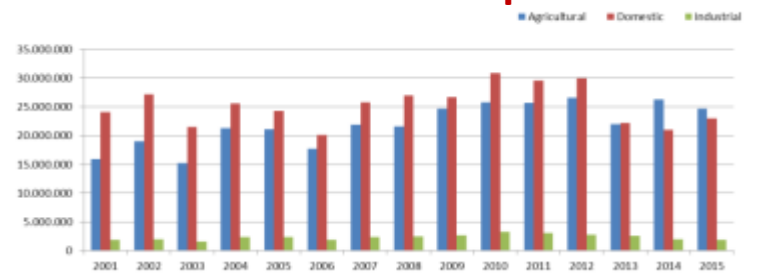
Groundwater supply reliability in the AZ basin

Reliabity of the system (% of requirements met without over-abstraction) per site and month

Legend: Amman Agricultural, Amman Domestic, Amman Industrial, Balqa Agricultural, Balqa Domestic, Balqa industrial, Jerash Agricultural, Jerash Domestic, Jerash Industrial, Mafraq Agricultural, Mafraq Domestic, Mafraq Industrial, Zarqa Agricultural, Zarqa Domestic, Zarqa Industrial

Percent (%) of months that fall under the 4 reliability classes (very low, low, medium, high, very high) for the 15-year period 1995-2010

Reliability class	% of Months	Respective months
Very High (>95%)	25.0% (3 months)	January, February, March
High (85-95%)	16.7% (2 months)	April, December
Medium (70-85%)	8.3% (1 month)	May
Low (50-70%)	8.3% (1 month)	November
Very Low (<50%)	33.3% (4 months)	July, August, September, October

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**

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
0-19%	1 - low
20-39%	2 – moderate
40-59%	3 – high
>60%	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

Maximum annual unmet demand as % the total demand of the corresponding year	Score / Class
0-19%	1 – low
20-39%	2 - moderate
40-59%	3 – high
>60%	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

The 3 sub-indicators of DVI for the AZ catchement

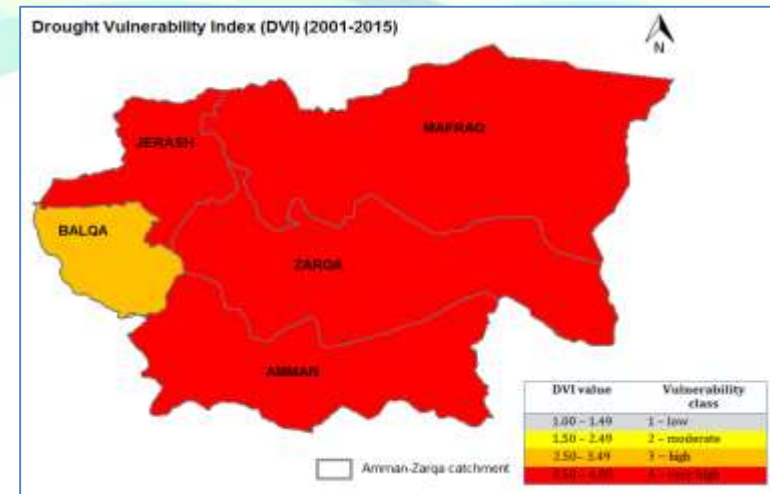Results and classes for the REL, DIS and EXT sub-indicator for each demand site

DVI in AZ catchment
26.7% nodes VHV
73.3% nodes HV

Demand sites (nodes)	REL sub-indicator			DIS sub-indicator		EXT sub-indicator				Drought Vulnerability Index (DVI) value	Vulnerability Class
	Number of years with over-abstraction	% of years with over-abstraction	REL sub-indicator Class	Annual average over-abstraction as % of the Total Abstraction	DIS sub-indicator Class	Maximum over-abstraction (m³)	Year of maximum over-abstraction	Max over-abstraction as % of the Total Abstraction of that year	EXT sub-indicator Class		
Amman Agricultural	15	100%	4	36.4%	3	542,223	2015	36.1%	3	3.33	3
Amman Domestic	15	100%	4	35.9%	3	6,402,272	2002	35.5%	3	3.33	3
Amman Industrial	15	100%	4	36.7%	3	133,398	2012	40.3%	4	3.67	4
Balqa Agricultural	15	100%	4	35.6%	3	1,060,904	2002	35.4%	3	3.33	3
Balqa Domestic	15	100%	4	35.6%	3	1,776,013	2001	32.3%	3	3.33	3
Balqa Industrial	15	100%	4	36.3%	3	166,412	2011	39.8%	3	3.33	3
Jerash Agricultural	15	100%	4	35.9%	3	935,683	2014	36.0%	3	3.33	3
Jerash Domestic	15	100%	4	36.2%	3	843,085	2010	40.6%	4	3.33	4
Jerash Industrial	10	67%	4	35.2%	3	6,940	2014	35.8%	3	3.67	3
Mafraq Agricultural	15	100%	4	36.3%	3	19,220,202	2014	36.0%	3	3.33	3
Mafraq Domestic	15	100%	4	35.7%	3	11,245,921	2002	35.5%	3	3.33	3
Mafraq Industrial	15	100%	4	36.7%	3	667,647	2013	34.8%	3	3.67	3
Zarqa Agricultural	15	100%	4	35.6%	3	6,847,283	2001	33.6%	3	3.33	3
Zarqa Domestic	15	100%	4	36.2%	3	12,209,471	2011	40.0%	4	3.33	4
Zarqa Industrial	15	100%	4	35.9%	3	2,594,289	2010	40.6%	4	3.33	4

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The DVI per Governorate in the AZ catchment

Variability (in terms of drought vulnerability classes) within each Governorate and across its different water users does exist.

- **DATA ON UNMET DEMAND**
- **THRESHOLDS**
- **IMPACTS**

Drought Vulnerability Index (DVI) (2001-2015)

DVI value	Vulnerability class
1.00 – 1.49	1 – low
1.50 – 2.49	2 – moderate
2.50 – 3.49	3 – high
3.50 – 4.00	4 – very high

Amman-Zarqa catchment

Governorates	REL sub-indicator			DIS sub-indicator		EXT sub-indicator				Drought Vulnerability Index (DVI) value	Vulnerability Class
	Number of years with over-abstraction	% of years with over-abstraction	REL sub-indicator Class	Annual average over-abstraction as % of the Total Abstraction	DIS sub-indicator Class	Maximum over-abstraction (m³)	Year of maximum over-abstraction	Max over-abstraction as % of the Total Abstraction of that year	EXT sub-indicator Class		
Amman	15	100%	4	35.9%	3	6,988,564	2010	40.7%	4	3.67	4
Balqa	15	100%	4	35.6%	3	2,928,855	2001	32.3%	3	3.33	3
Jerash	15	100%	4	36.1%	3	1,514,341	2012	40.4%	4	3.67	4
Mafraq	15	100%	4	36.0%	3	28,820,192	2010	43.2%	4	3.67	4
Zarqa	15	100%	4	36.0%	3	20,322,037	2010	40.7%	4	3.67	4

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Thank you for your attention.