Case study 4.4a: Water quantity in the Pinios River basin in Greece

Macroeconomic perspective on water quantity issues of relevance of to the SEEAW

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Evaluating Economic Policy Instruments for Sustainable Water Management in Europe

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Presentation Outline

- **Scope and objectives of the Task 4.4.a**
- **Activities breakdown and description**
- **Key issues, challenges and constraints**

1. Scope & Objectives

Scope

- For the purpose of **water quantity** aspects as related to the economy, task 4.4.a will focus on capturing the fragile balance between water availability and use and modeling it in terms of an accounting system
- Evaluate the **impacts of EPI (water markets) on hydrology**
- Relate the contribution of water to the economy and the impact of the economy on water resources

Specific Objectives

- Develop a **generic hydro-economic model** to assess the performance and impacts of EPIs on the hydrological system (EPIs will be simulated and evaluated on a physically based catchment model) under current & future scenarios
- Provide a **DSS tool** for the optimal use of EPIs
- **Link** the hydro-economic model to the **SEEAW**
- Facilitate the **communication of EPI's performance** to the policy-makers through the use of a quantifiable set of indicators built on the SEEAW parameters.

2. Added Value

- Generic integrated (hydrologically distributed) hydro-economic model and optimization module, transferable to other river basins

→ **Linking** the "**paper trades**" (estimated by economic model) **to physical water transfers** (estimated by hydrological model)

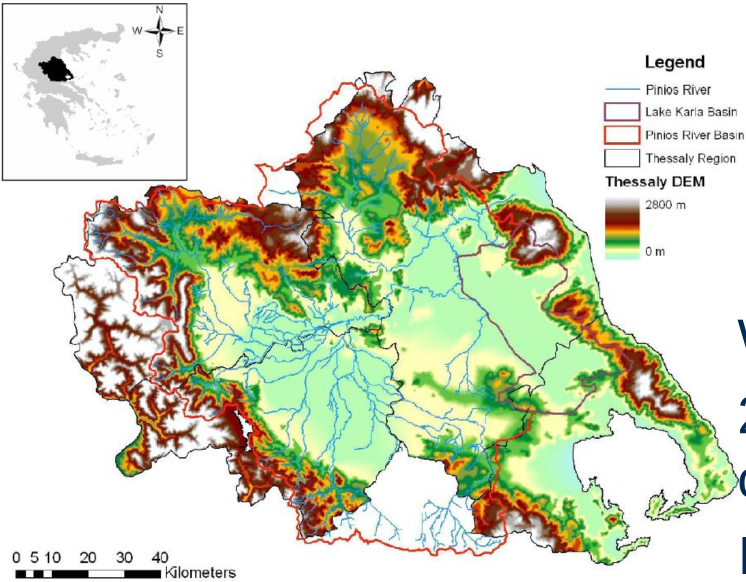
- Capability for evaluation of EPIs' impacts on the case's specific hydrology, thus assessing the (environmental) attractiveness (and feasibility) of the proposed solution

→ **Identification of physical bottlenecks** in the system (i.e. operational and infrastructure constraints … irrigation canals, storage, env.flows, etc.)

- Before implementing the proposed EPI as a mechanism for better water allocation, alternative measures on the demand reduction will be assessed (benchmarking the effect on an "alternative policy" focused on demand reduction across all economic sectors

3. The Study Area: Pinios River Basin, GR

Selected due to: increased risk of water scarcity, competence of major water uses, inadequacy of the existing WR management schemes



Area = 9.500 km2

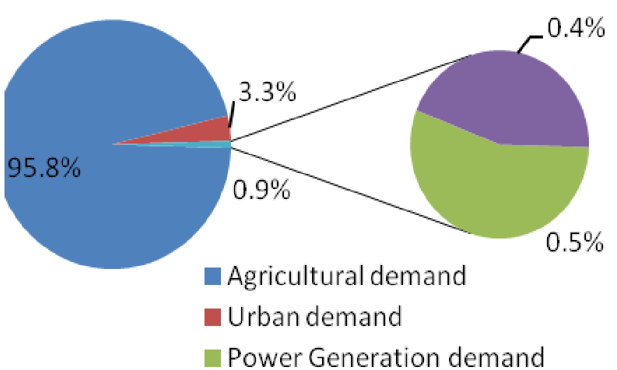
Mean annual P=700mm (400-1850, variability)

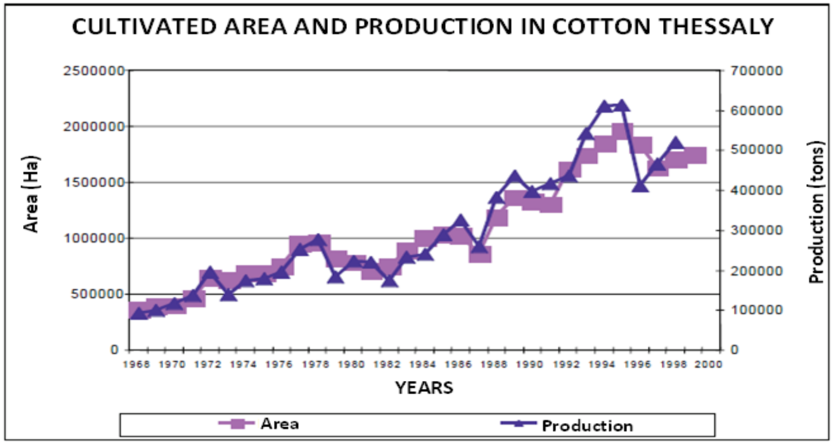
Rain is rare June-August, many drought episodes

Water availability=3.209 mio m3 (80% SW, 20% GW)

252.500 ha irrigated (of which 210.000 from GW) : cotton (63%), maize, sugar beets, vegetables

Irrigation water use = 750 mio m3 (30% SW, 70% GW)





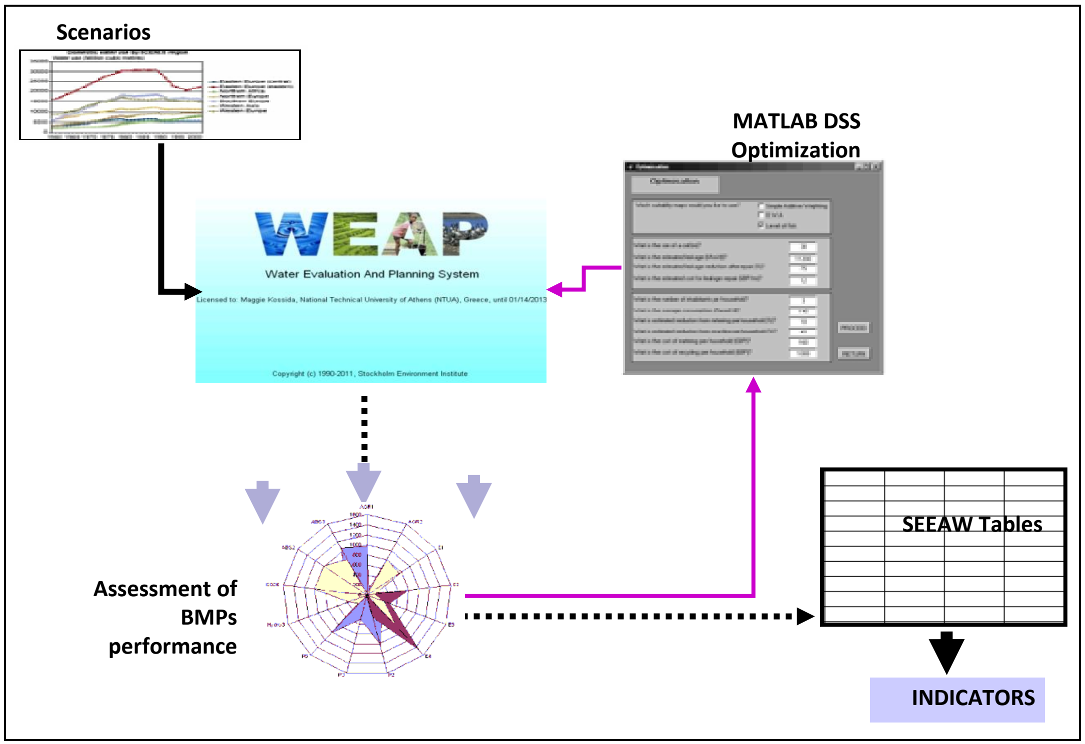
4. Policy and Institutional background

- **Fragmented policy measures**, including a number of projects on utilization of WR (such as dam construction, water reserves, artificial lakes etc.), and at research activities on water management/ irrigation practices.
- The allocated **subsidies to farmers** to replace traditional non-irrigated crops like wheat with irrigated crops like sugar beet, cotton, tomatoes, etc., and to acquire individual irrigation equipment systems (such as high pressurized mobile rain gun systems and center pivot sprinkler systems) **led to the increase of irrigation needs and to over-abstraction**
- In the last decade a copiousness of Regulations, Decisions, Laws etc. have been edited concerning the CAP, WFD and National Agricultural Policy. Yet, **this legislative framework was not satisfactory implemented**
- An example is illustrated by the **pricing of irrigation water**: the quantity of consumed water is not measured. The charge is based on the irrigated area regardless of the type of crop, season, and method of irrigation (137-289 €/ha)
- **Loose institutional setting** and the **weak cooperation** among the responsible authorities has contributed to **the inability of enforcement and control** (e.g. numerous illegal abstractions are present) and the building up of **water conflicts among the users**

5. Phase A

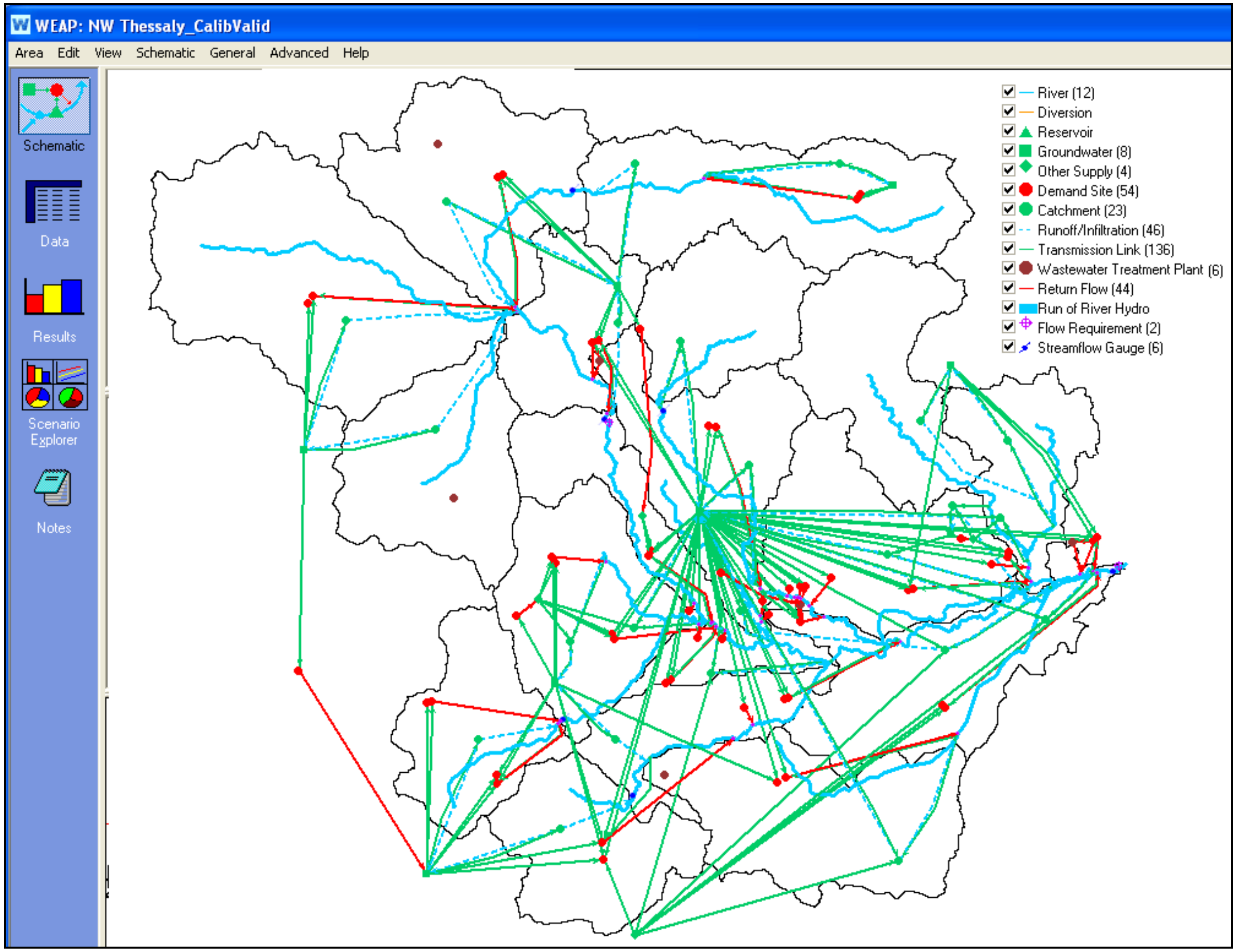
- **Development of a user-friendly WR Management Model in WEAP21**
- **Identifying BMPs and technological measures to increase water use efficiency/reduce demand, coding and simulation**

  Link WRM model to Economic Model and Matlab GAs
- **Run baseline and future climate and socio-economic scenarios**



- The BMPs focus on demand reduction measures and technologies, as prioritized by WFD and EU WSD Communication

6. Water Resources Management (WRM) Model development



<u>Pinios WR Management Model</u>

(using WEAP21 software)

Calibration & Validation:

1980 – 1994

Baseline Scenario:

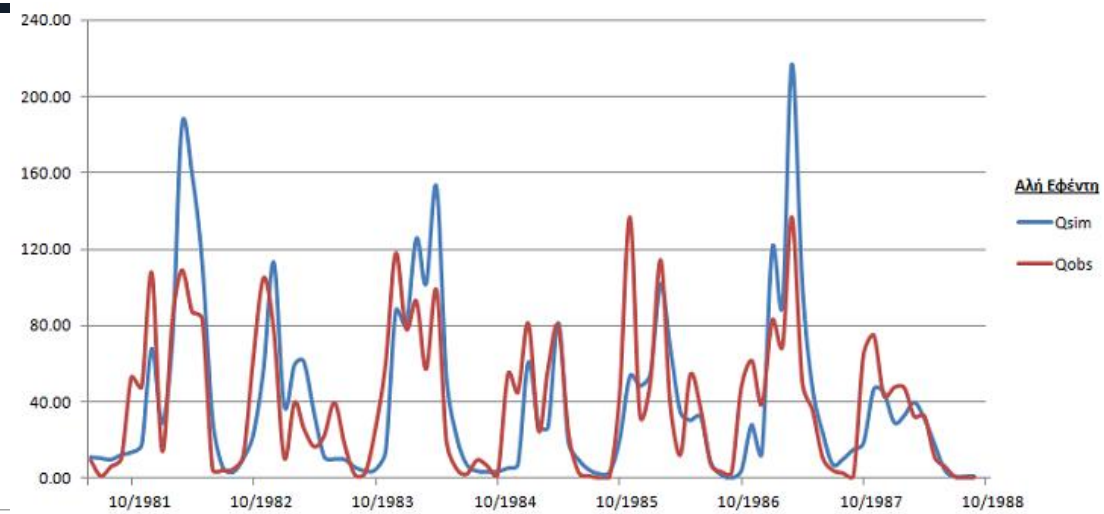
2000 – 2010

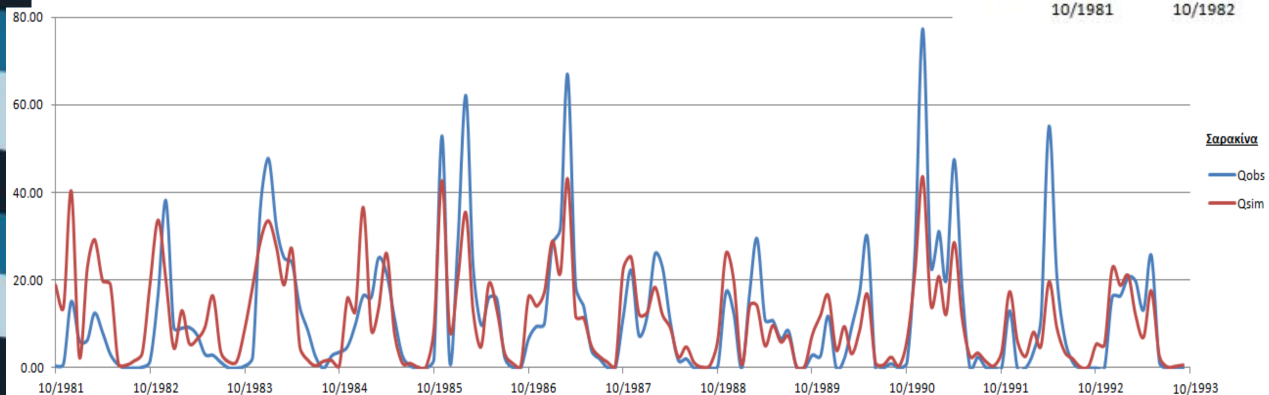
Future Scenarios:

Up to 2030

7. Pinios WRM model calibration

Observed vs. Simulated streamflow





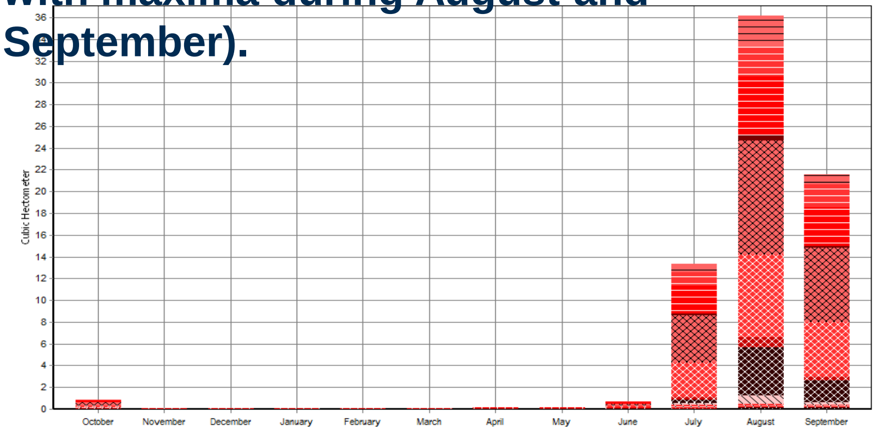
Performance Indicator	Streamflow Station					
	Pyli	Mouzaki	Gavros	Sarakina	Theopetra	Ali Efenti
EFF	0,619	0,565	0,622	0,650	-0,074	0,614
R	0,789	0,802	0,806	0,860	0,177	0,7590
BIAS	-0,095	-0,028	0,001	0,061	-0,473	0,096

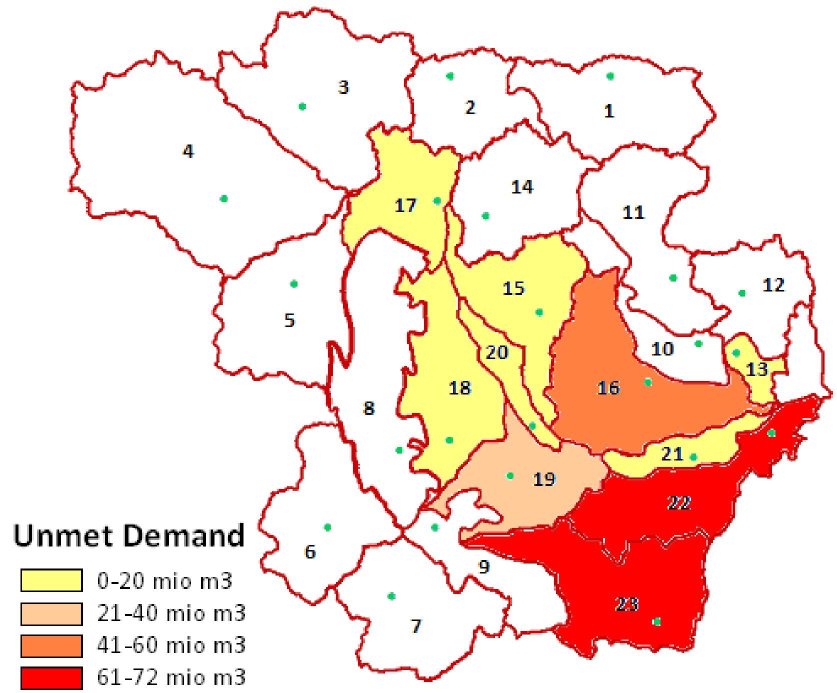
8. WRM model results (baseline)

Results of the baseline scenario for the NW part

Water Demand (hm^3)		Water Supply (hm^3)	
Domestic	19.63	Domestic	19.57
Irrigation	481.20	Irrigation	409.54
Livestock	6.38	Livestock	6.15
Industry	1.17	Industry	0.99
Total	508.39	Total	436.25
Unmet Demand (hm^3)		**Demand Coverage (%)**	
Domestic	0.06	Domestic	99.68
Irrigation	71.66	Irrigation	85.11
Livestock	0.23	Livestock	96.43
Industry	0.19	Industry	84.07
Total	73.49	Total	85.81

Temporal variability of the unmet demand (the dry season June-October is depicted, with maxima during August and September).





Spatial variability of the unmet irrigation demand (the deficit is mostly pronounced in the lowland region of the central plain of Pinios)

9. Future scenarios

- Dynamically **downscaled climatic timeseries**, based on the **A1B** emission scenario (extracted from RCM run results during the EU project ENSEMBLES)
- Comparison with observed timeseries 1980-2010 and correction
- 2015-2030: 0.5 ° C temperature increase, average rainfall may increase slightly by 0.8% (reduction in winter & summer, increase in autumn & spring). During the typical irrigation season (April to September), the reduction of rainfall equal to 8,5% → increase of crop irrigation needs by 2,7-3,9%
- On top of the A1B climate scenario, the **Markets First socio-economic scenario** (as "translated" for Greece and quantified through the IFs indicators) has been simulated. G1 pointed an increase in water demand for the domestic, livestock and industry sector.
- **A1B + G1 in WEAP for 2010-2030 → additional deficit** 3,8 hm3 in the NW
- **Meeting environmental requirements** was imposed in the model as an additional (target: maintain 50% of the naturalized streamflow). The results showed that **the unmet demand is significantly higher (more than double**), reaching 166.53 hm3 in the NW, **while only 68% of the demand can be covered**.

10a. Reference Policy Instrument – BMPs & Optimisation (1)

Before implementing the proposed EPI as a mechanism for better water allocation, alternative measures on the demand reduction will be assessed.

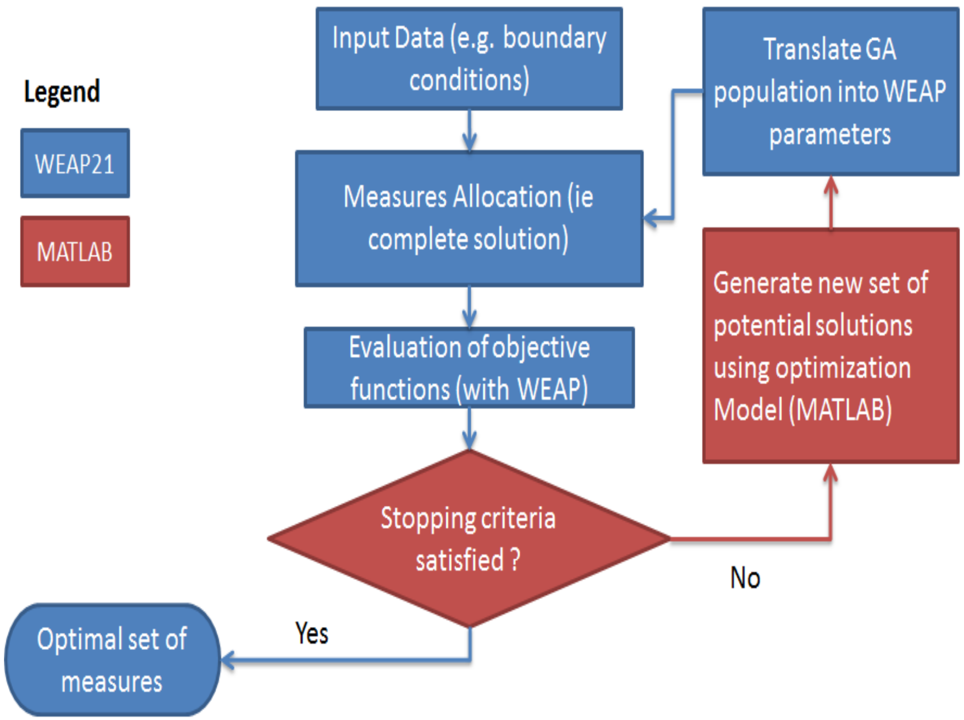
The bundle of measures to be investigated could benchmark the effect on an **"alternative policy" focused on demand reduction** across all economic sectors.

- List of BMPs and technological measures to increase water use efficiency / reduce demand
- Coding of BMPs in WEAP and scripting
- Coupling WEAP21 with UVEG Economic Model and Matlab GA

(**Hydro-economic model development**)

- The algorithm will allocate BMPs and technological interventions throughout the catchment, maximizing the cost-benefit function

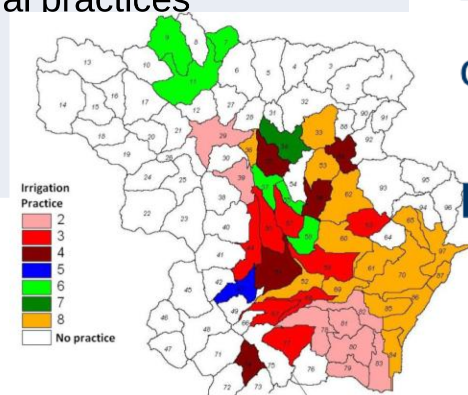
Optimisation Conceptual Schema



10b. BMPs, Economic Model & Optimisation (2)

Measures for Leakage reduction		
Sectors	Measures for L reduction	
Urban	1. Monitoring & leakage repairs 2. Replacement of old pipes 3. Real-time control pressure managmnt.	
Agriculture	1. Monitoring & leakage repairs 2. Replacement of old pressurized pipes 3. Cleaning and lining of open canals 4. Replacement of open canals w/closed pipes	
Industry	1. Monitoring & leakage repairs 2. Replacement of old pipes 3. Real-time control pressure managmnt.	

Measures for Water Saving	
Sectors	Measures for Water Saving
Urban	1. Introducing water metering 2. Low water using appliances 3. Greywater Reuse
Agriculture	1. Improvement of water metering 2. Change of agricultural practices - Switch to drip irrigation - Deficit Irrigation - Precision agriculture 1. Change of crops



optimum measures allocation

OBJECTIVE FUNCTION

$$Max\ Ben = Total\ Income - Total\ cost$$

$$Total\ Income = \sum_k R_k\,(Dem_k - Def_k)$$

$$Total\ costs = \sum_j \sum_k C_{jk}\,X_{jk} + \sum_k P_k\,Def_k$$

CONSTRAINS

Water availability: Sum Deliveries < Resource Availability

$$\textstyle\sum_k X_{jk}\,MC_{jk} \leq AVAI_j \qquad \forall j$$

$$\textstyle\sum_j X_{jk} MC_{jk}\,E_{jk} = Dem_k - Def_k \qquad \forall k$$

Technical constrain: connections min/max capacities

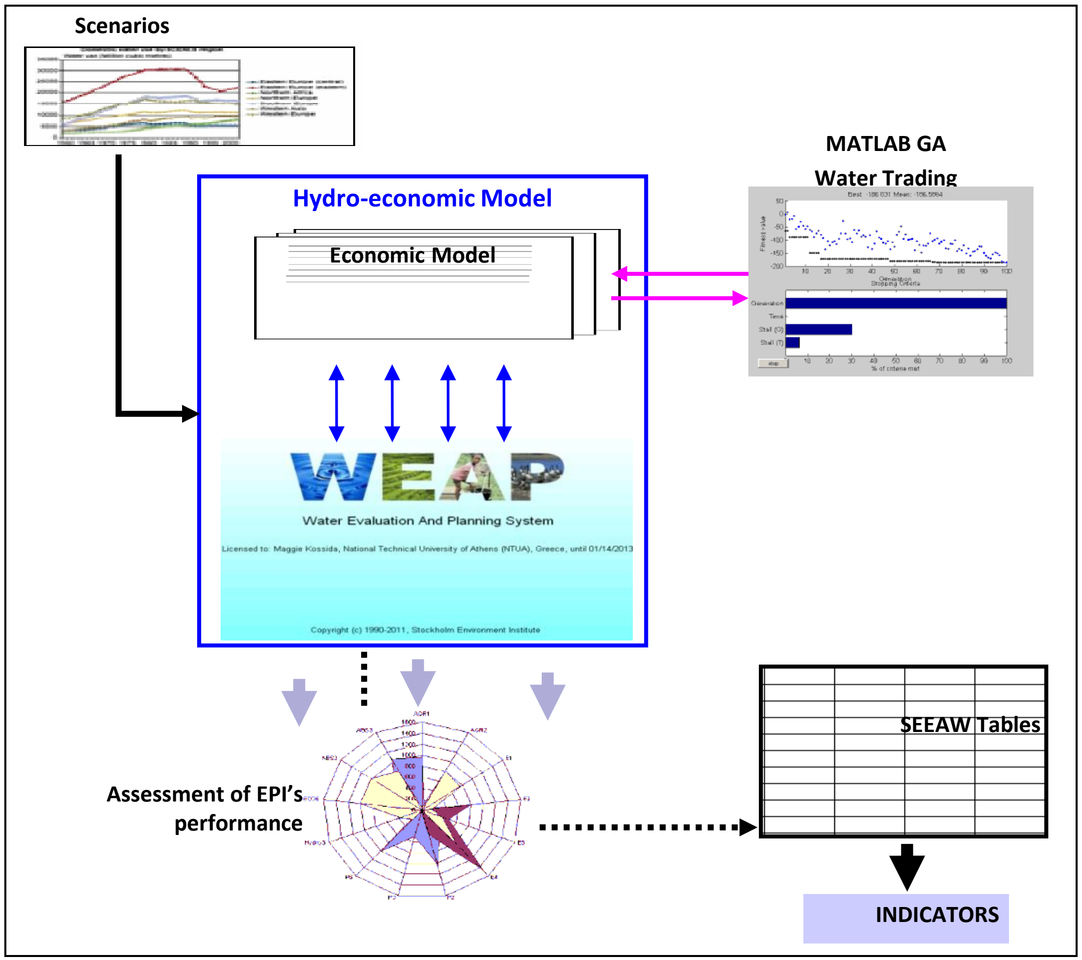
$$Min_{jk} Z_{jk} \leq X_{jk} MC_{jk} \leq Max_{jk} Z_{jk}$$

Legal constrain: min water for urban use

$$Def_u \leq Dem_u - Dmin_u$$

11. Phase B

Investigate the setup of an EPI that could supply additional water to the system (after BMPs have been implemented), efficiently allocating water



- Proposed EPI:

Water Use Right Market

collaboration with IMDEA

12. Water Markets - HydroEconomic Model development

- **Customization of the selected EPI** (Water Markets) for Pinios and coding (scripting in WEAP if necessary to simulate the EPI and translate it into specific impacts on the catchment's hydrology)
- Development of **optimization algorithms** (GA or multi-objective evolutionary). The optimization (which will be part of the economic model) will allocate the additional water, **simulating the results of the biding/trading process**.
- As inputs to this phase, WEAP will provide expected deficits, driving demands.
- **Development of hydro-economic model**. **Test/simulate the impact and effectiveness of the EPI against specific criteria** (e.g. water use reduction per economic activity, cost, environmental and socio-economic benefits) **through a combination of WEAP simulating the hydrologic side of the problem and the Economic Model simulating the water markets** (loop → once the allocation (bidding) is completed through the Economic Model, WEAP will run again with the new water quantities for the different users)

Linking to the SEEAW

Scripting within WEAP21 to generate standard SEEAW export tables (before and after the EPI implementation)

- Asset accounts
- Physical supply and demand accounts

(additional parameters i.e. economic may be needed to complete the tables)

Asset accounts

Physical units

	EA.131 Surface water						
	EA.1311 Artificial Reservoirs	EA.1312 Lakes	EA.1313 Rivers	EA.1314 Snow, Ice and Glaciers	EA.132 Groundwater	EA.133 Soil water	Total
1. Opening Stocks							
Increases in stocks							
2. Returns							
Precipitation							
Inflows							
4.a. From upstream territories							
4.b. From other resources in the territory							
Decreases in stocks							
5. Abstraction							
6. Evaporation/Actual evapotranspiration							
7. Outflows							
7.a To downstream territories							
7.b To the sea							
7.c To other resources in the territory							
8. Other changes in volume							

Physical use table

Physical units

		Industries (by ISIC categories)							Households	Rest of the world	Total
		1-3	5-33, 41-43	35	36	37	38,39, 45-99	Total			
From the environment	**1. Total abstraction** (=1.a+1.b=1.i+1.ii)										
	1.a. Abstraction for own use										
	1.b. Abstraction for distribution										
	1.i. From water resources:										
	1.i.1 Surface water										
	1.i.2 Groundwater										
	1.i.3 Soil water										
	1.ii. From other sources										
	1.ii.1 Collection of precipitation										
	1.ii.2 Abstraction from the sea										
Within the economy	**2. Use of water received from other economic units**										
3. Total use of water (=1 + 2)											

Indicators compilation

- Based on the parameters of the SEEAW (hydro-economic model output)
- Combined indices, relevant and useful for the policy makers

14. Considerations

- **Original allocation of entitlements/rights** in the water markets model: **simple rule** (e.g. based on land property) **vs. set of criteria** (e.g. users with already implemented water efficiency measures receive some additional score, farmers who cultivate economically sustainable and high marketable products receive some additional score, etc.) and current degree of exploitation within the catchment
- **Seasonal allocation of the rights** (% of entitlement available at each time step): flexible and **"updatable" vs. predefined** for the whole irrigation season
- **Objective function** (utility maximization) of the economic model
- How **distributed** would **the solution** have to be?
- **How expensive is the evaluation of the objective function** (ie the model). It is expected that objective functions that require multiple runs of WEAP will be expensive. The economic model should be relatively computationally light.
- **Comment on** the status of water quantity related tables in **the SEEAW** (asset accounts, physical supply and use, hybrid accounts), and its **potential benefit for both ex-post assessments** as well as a **planning ahead tool** for water managers and policy makers (more suitable for coherently organizing the info, rather than a tool useful for assessing EPIs and/or **linking to macro-economy**?)

Thanks!

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