Rareté de l'eau et relations interbassins en Méditerranée sous changements globaux

Développement d'un modèle hydroéconomique à large échelle

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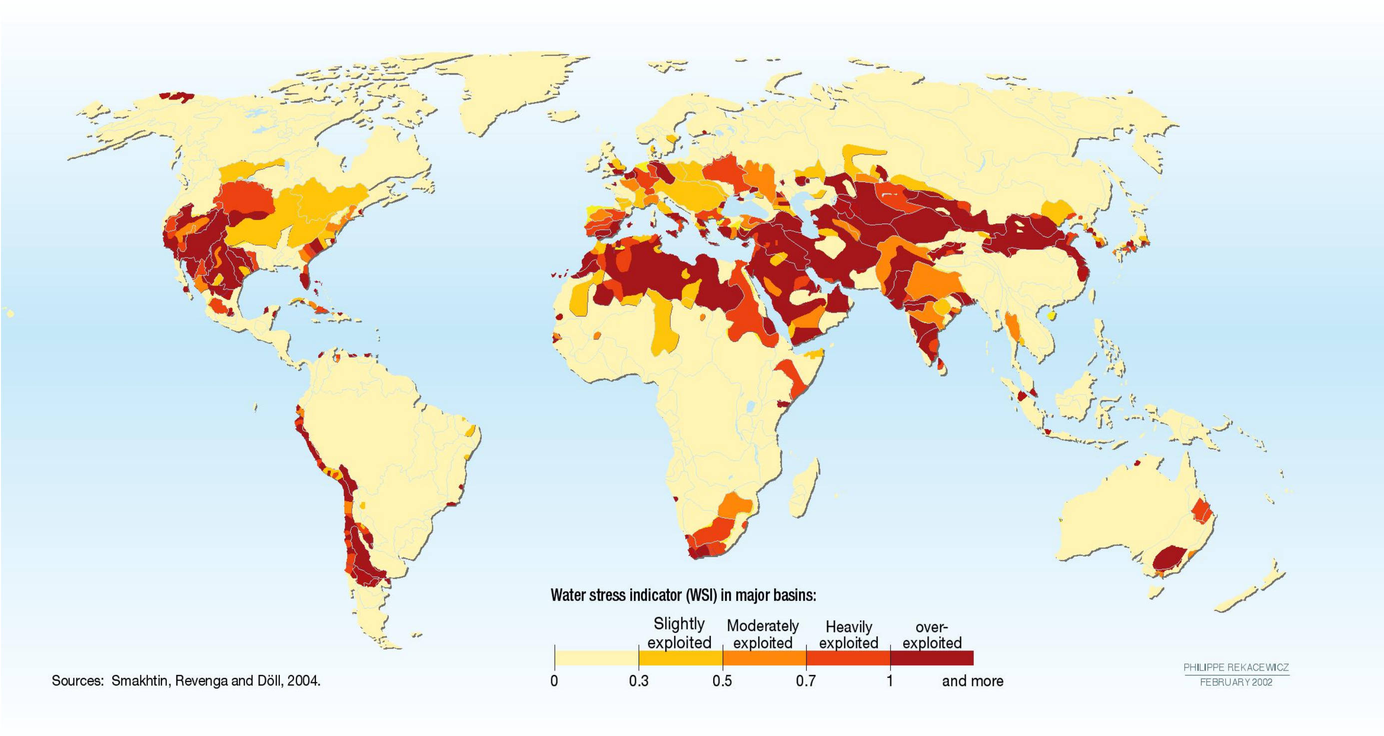
Context: tension on water resources in the Mediterranean

- Water scarcity expected to increase with global changes
  - Projection of reduced freshwater availability and longer and more frequent droughts [Cisneros et al., 2014]
  - Demand increase with population and economic growth



Objectives

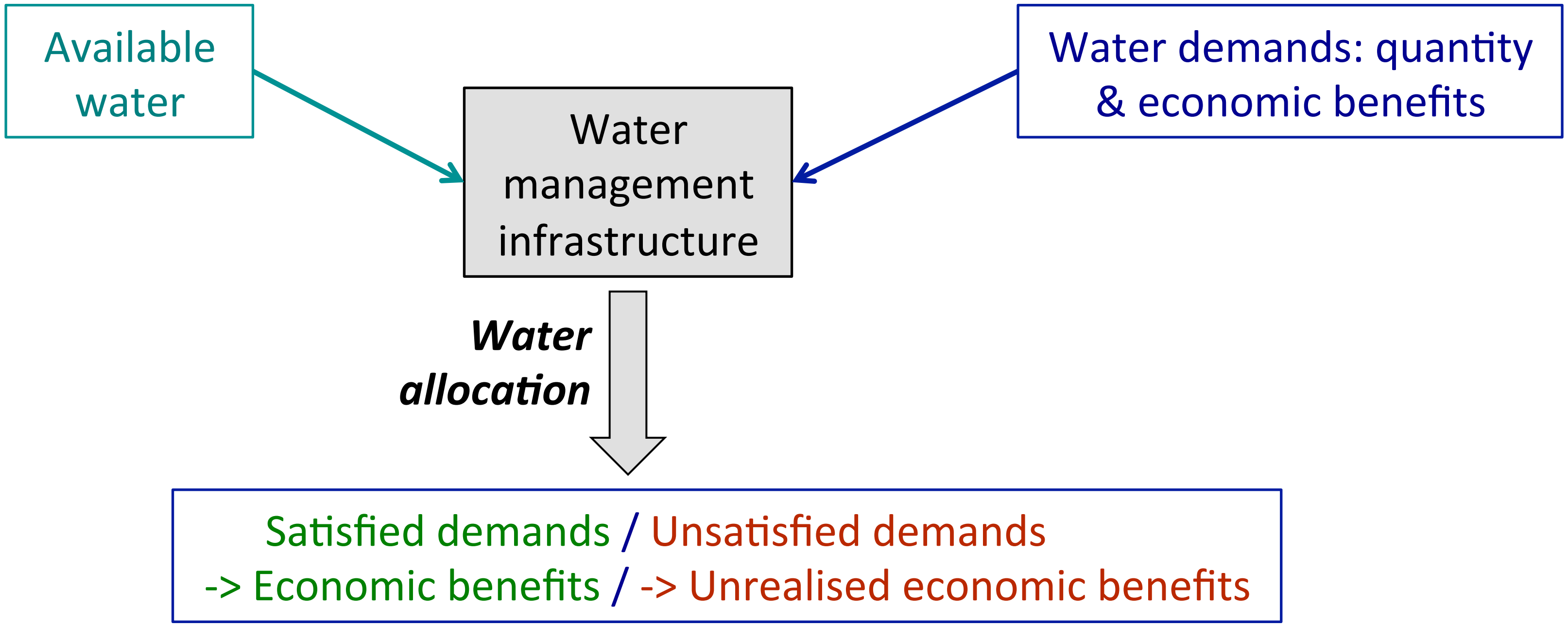
- Constraint for economic activities and populations
  => Anticipate future water scarcity issues (quantities and losses)

- Water scarcity mostly contemplated from the basin scale
- Consider the issue at the multi-basin scale
  - Mobility of demand (population, water-using activities) and supply (transfers, virtual water) – Interactions between basins (electricity networks)

- Hydroeconomic models mainly developed at the river basin scale
- Economic dimension generally absent from large-scale assessments

- **Approach:**
  ⇒ Large-scale hydroeconomic modelling
  ODDYCCEIA framework

Hydroeconomic modelling



- The use of economic criteria for allocation choices:
  - Simple ranking: not enough for intertemporal prioritization

=> Valued uses: a proxy (not a description nor a prescription)

Outline

I. Project demands and their associated economic values

Domestic and irrigation sectors

II. Compare to available water

Manage dams, allocate water to minimize the cost of water scarcity

III. Application to Algeria

I. PROJECTING DEMANDS AND THEIR ECONOMIC VALUES

Domestic and irrigation sectors

Demand side

Introduction

- Usual valuation methods:
  - Irrigation: residual method
  - Domestic: econometric estimation of demand functions

=> Here: simple methodologies suitable for large-scale

1. DOMESTIC WATER DEMANDS

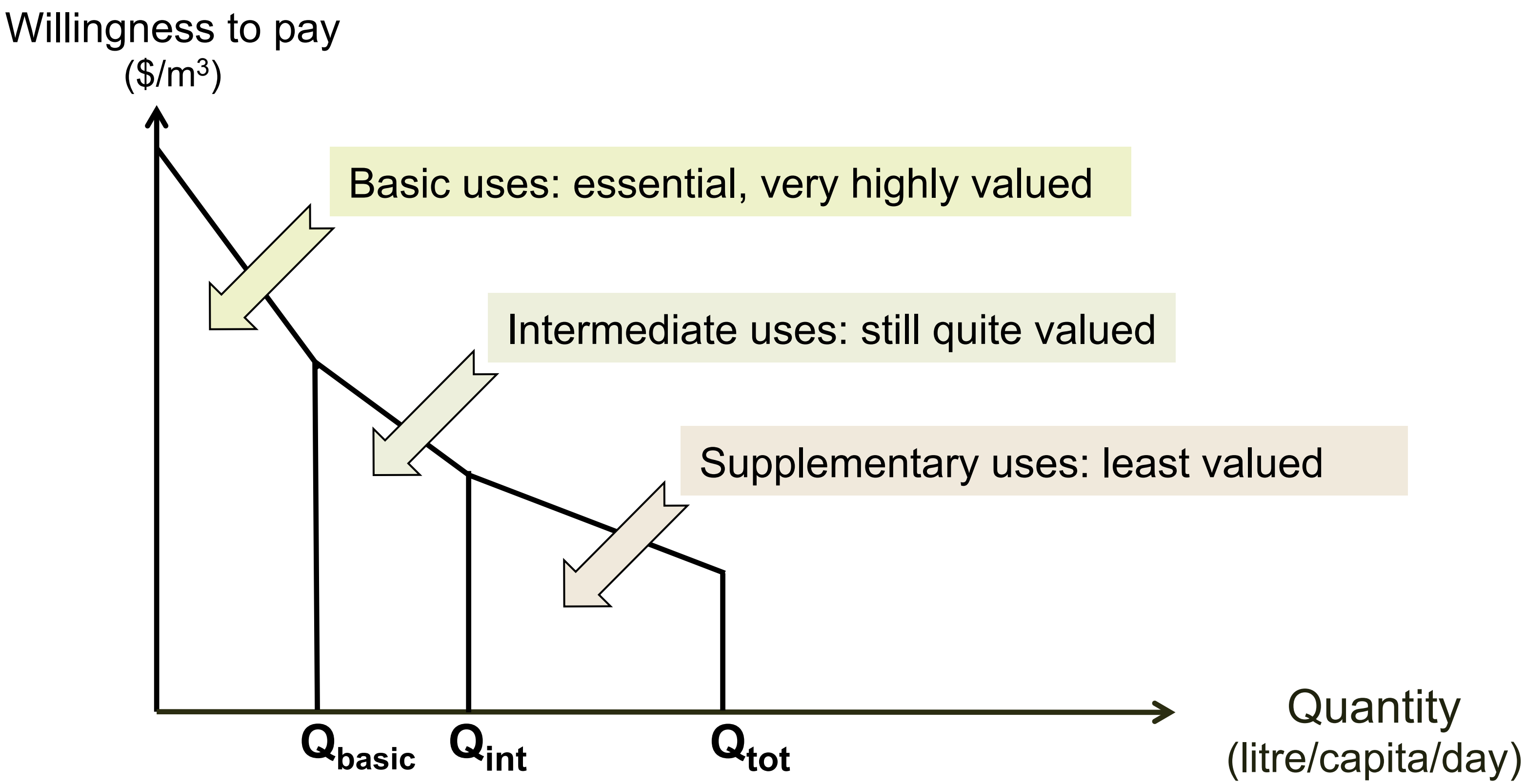
- Project the combined effects of:
  - demographic growth
  - economic development
  - Evolution of water cost (and price)

- Method: build demand functions, at country scale
  - average demand per capita (GDP_t, $price_t$)
  - multiplied by $population_{t,city}$

- Spatial distribution: population homogeneously distributed among existing locations

Building a simple demand function

- 3-part inverse demand function (average demand per capita)



- 4 points of reference, linear interpolation

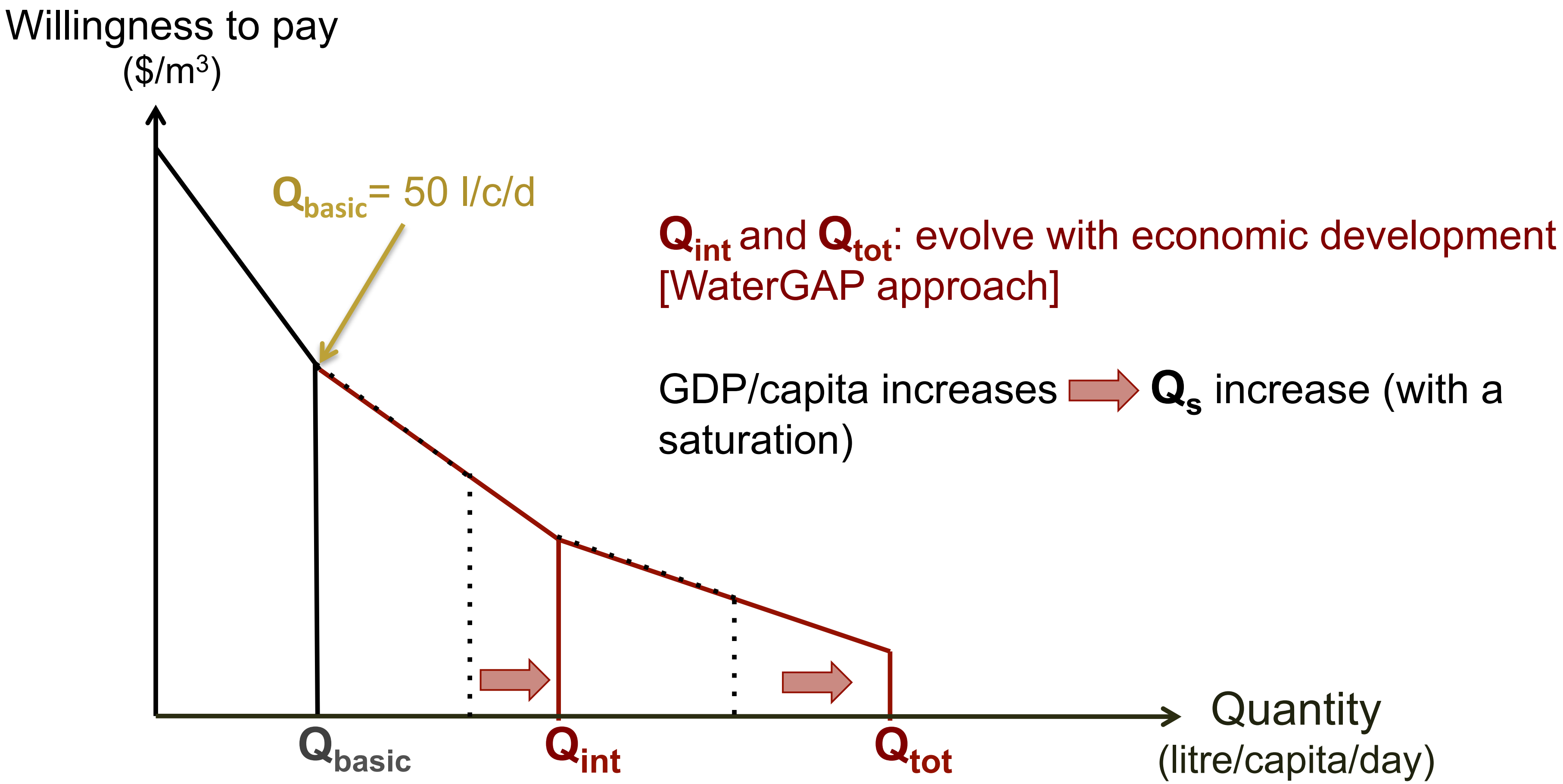
Building a simple demand function: Values

- Willingness to pay based on:

l/cap/day	$\$_{2005}/m^3$	Justification
1^{st}	300	Price of bottled water
50^{th}	50	Out of literature data range => assumption
100^{th}	15	Average value for the 100^{th} l/cap/day, calculated based on price elasticities from econometric studies
Maximum potential $demand_{country}$	P_{2000}	Observed water price

Building a simple demand function: Quantities

- Incorporate structural change



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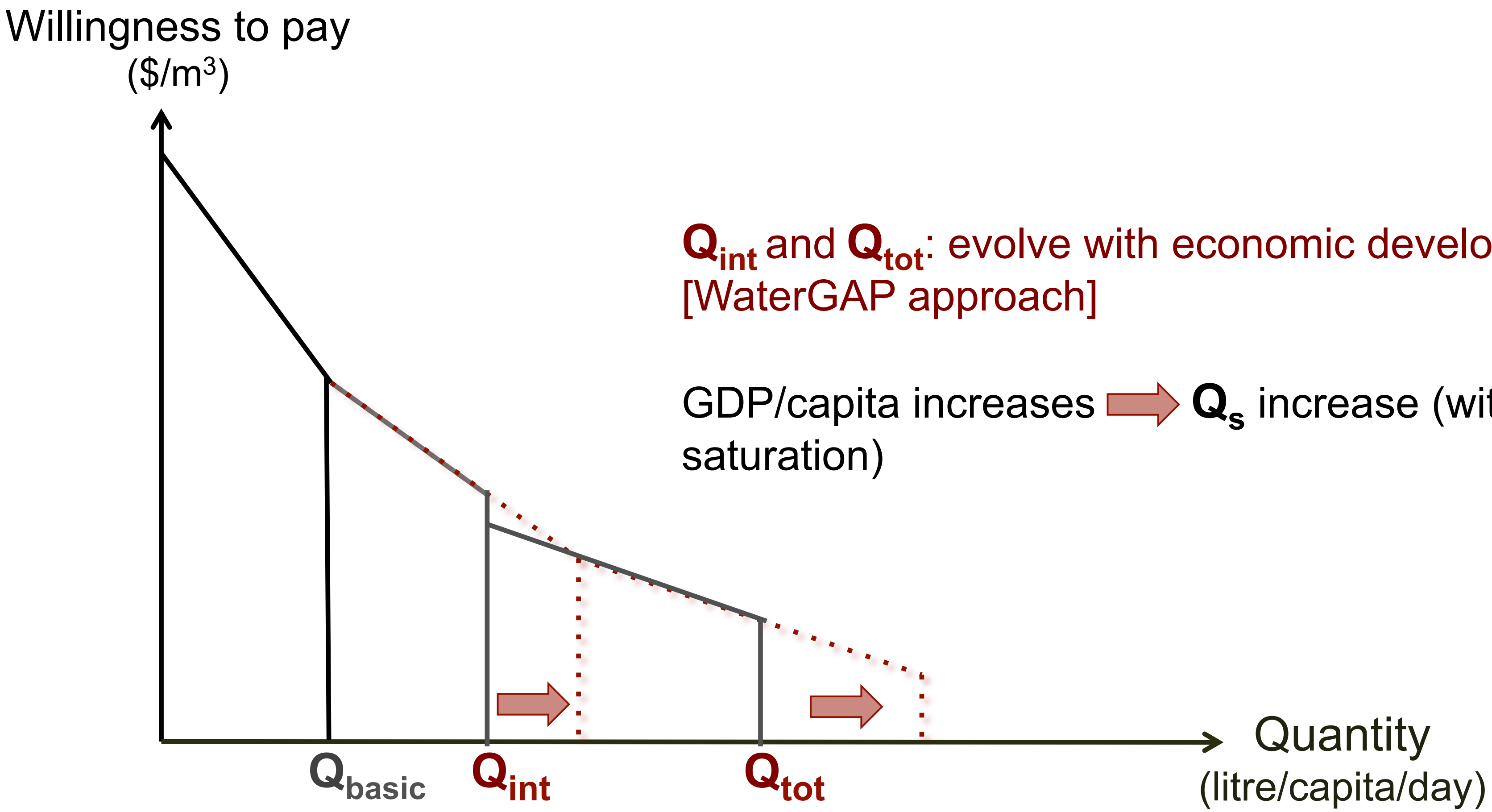

Q_{int} and Q_{tot}: evolve with economic development [WaterGAP approach]

GDP/capita increases ➡ Q_s increase (with a saturation)

Building a simple demand function: Quantities

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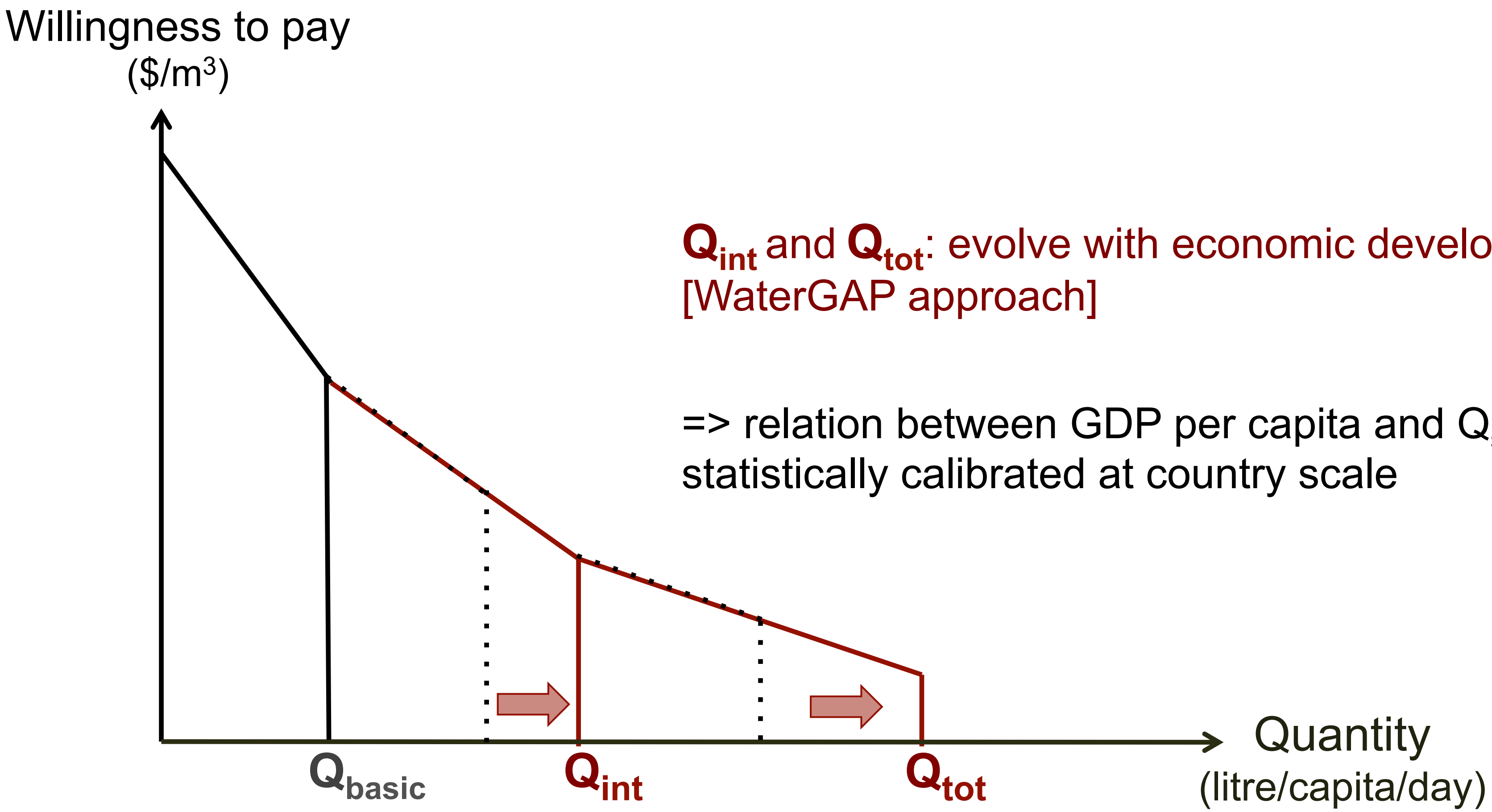
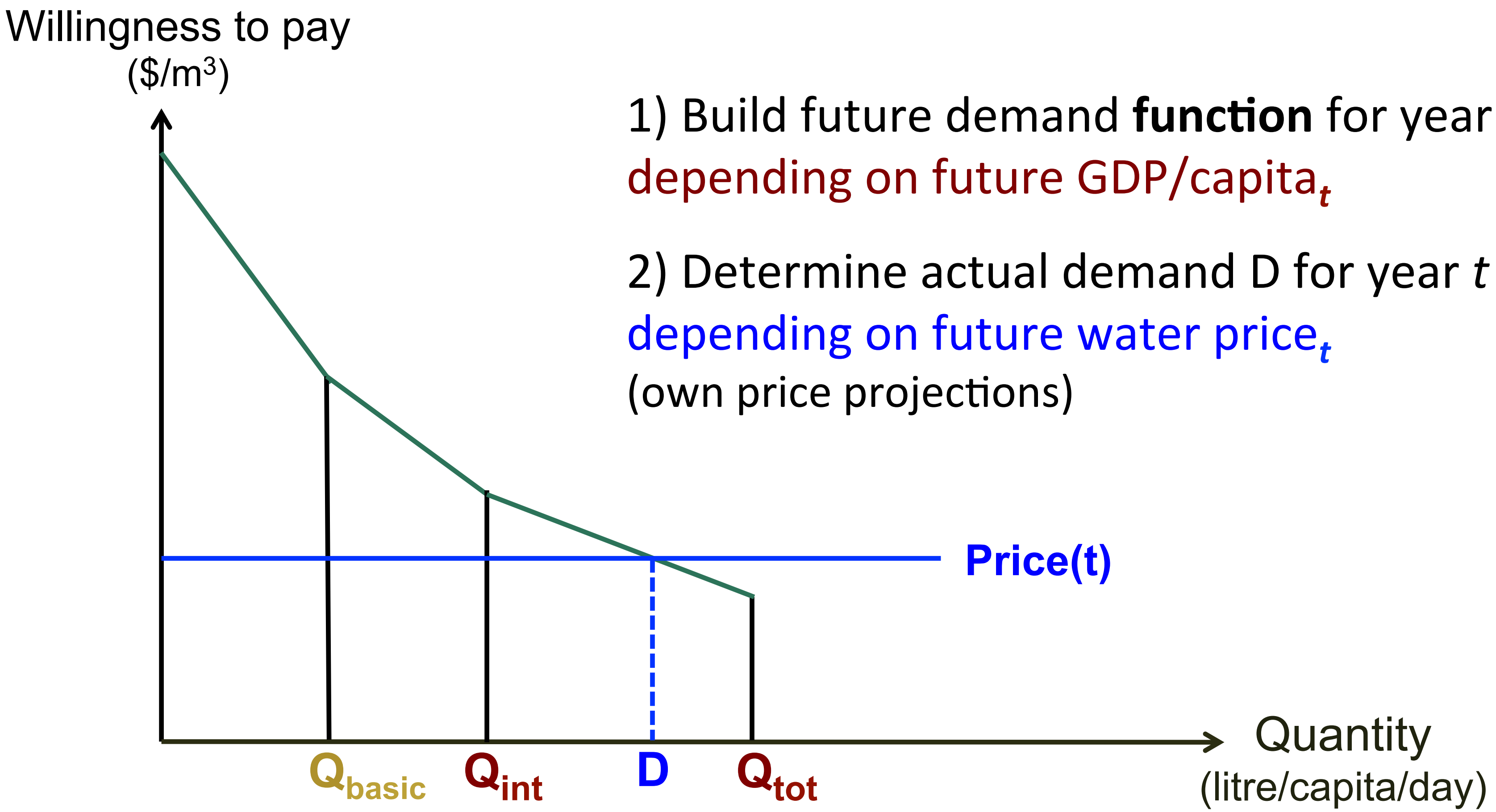


Q_{int} and Q_{tot}: evolve with economic development [WaterGAP approach]

=> relation between GDP per capita and Q_s statistically calibrated at country scale

Projecting demands

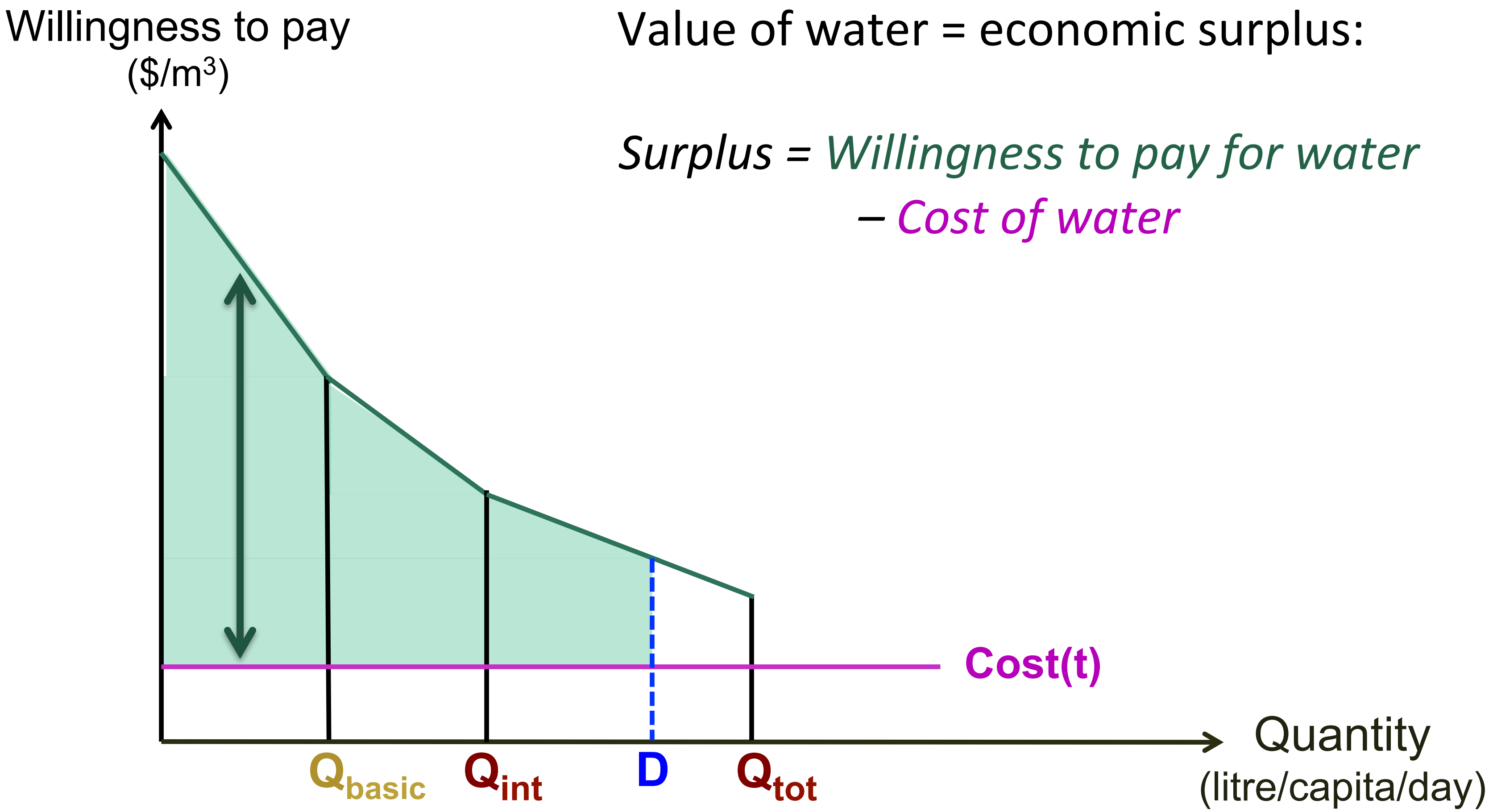
- 2 steps



1) Build future demand **function** for year *t* depending on future GDP/capita$_t$

2) Determine actual demand D for year *t* depending on future water price$_t$ (own price projections)

Projecting demands and values

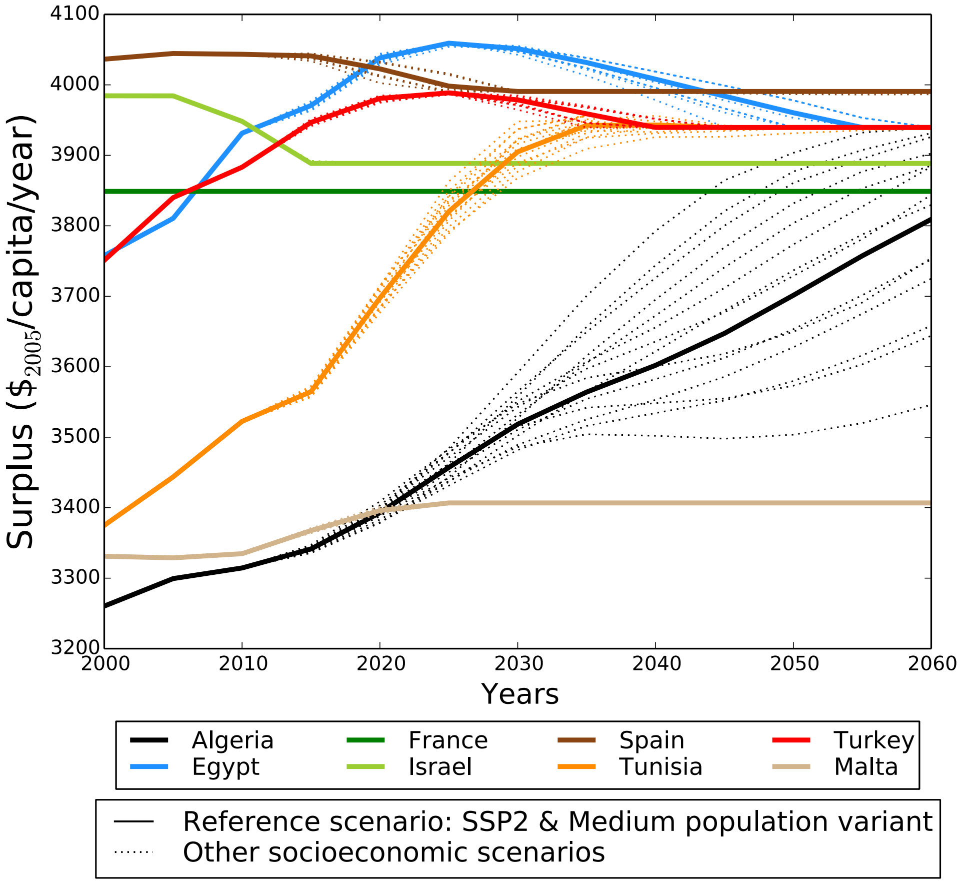


Value of water = economic surplus:

Surplus = *Willingness to pay for water*
– *Cost of water*

Application to Mediterranean countries

- Robust to most uncertainties except level of demand saturation and quantity of basic water needs
- Evolution of surplus per capita in different countries



2. IRRIGATION WATER DEMANDS

- Irrigation water needs [Nassopoulos, 2012]
  - 12 crop types, located in irrigation perimeters
  - Irrigation requirements computed for the different stages of the growing season [Allen, 1998]
  - Water requirements: deficit between *ETc* and *usable precipitation*
  - Future irrigation water demand projected under climate change (CNRM model [Dubois et al., 2012] outputs, A1B scenario)

- Irrigation water value
  - Yield comparison approach

Yield comparison approach

- Yield comparison between rainfed and irrigated crops
  => additional net benefit associated with the use of water

Volumetric value

Net benefit if crop is irrigated

Net benefit if crop is rainfed

$$V = \frac{[Y_{ir} \times Price_{crop} - Cost_{ir}] - [Y_{rf} \times Price_{crop} - Cost_{rf}]}{W}$$

Quantity of irrigation water

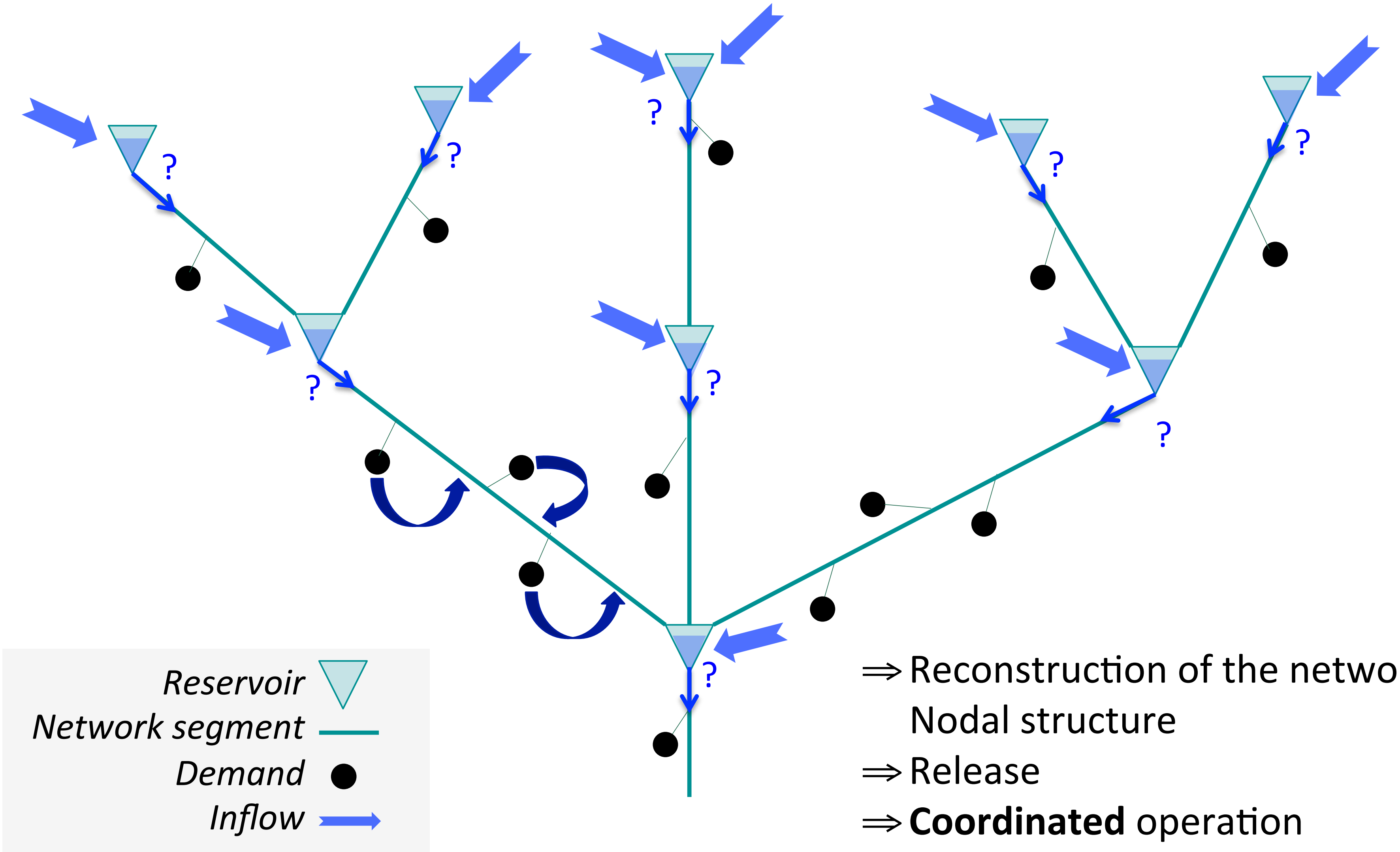
- Model yield as a simple function of available water and crops water needs
  - Calibrated using LPJmL model outputs [Bondeau et al., 2007]
  - $Y_{rf}(precip, ETc)$ $Y_{ir}(precip, W, ETc)$

- Average value

II. ALLOCATING WATER

Supply side

Overview



⇒ Reconstruction of the network
Nodal structure

⇒ Release

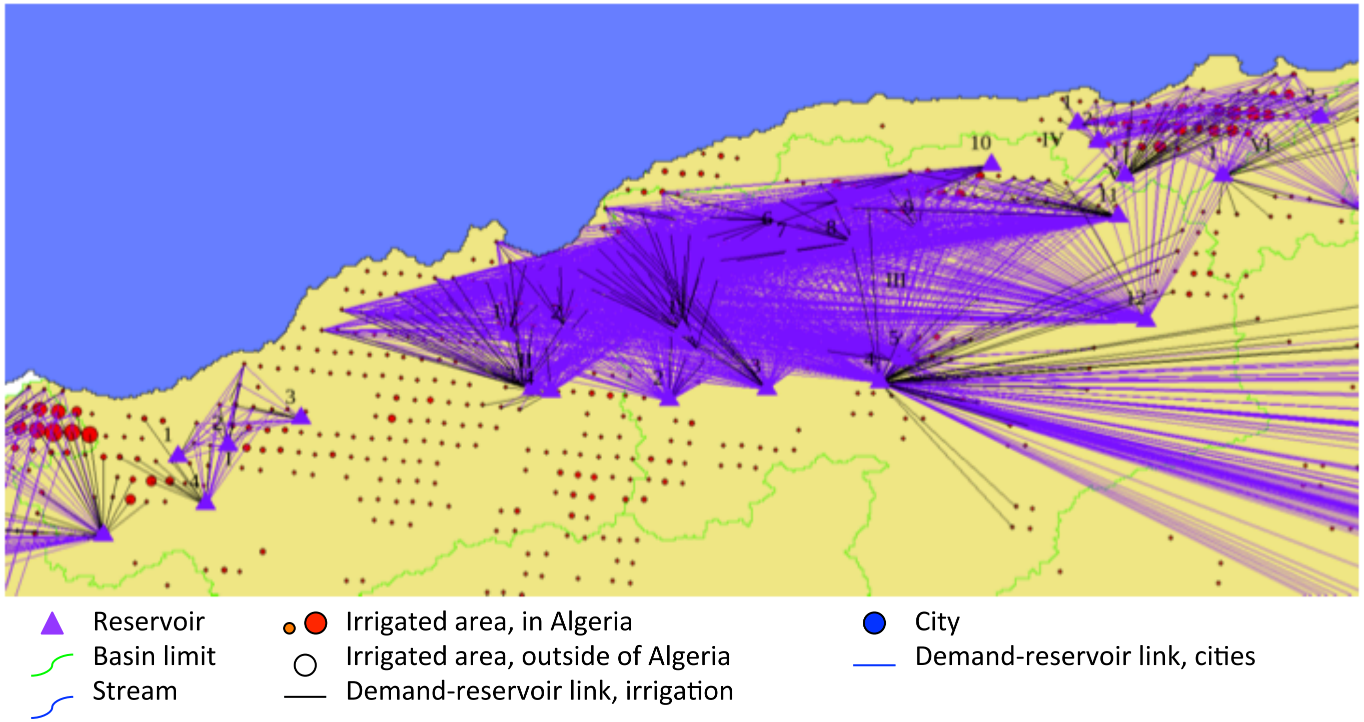
⇒ **Coordinated** operation

⇒ Return flows

1. RECONSTRUCTING THE WATER NETWORK

- Reservoir-reservoir links (upstream-downstream)
- Reservoir-demand links

Association paths based on topography. Cost function: penalisation of distance covered and ascending moves. [Nassopoulos, 2012]



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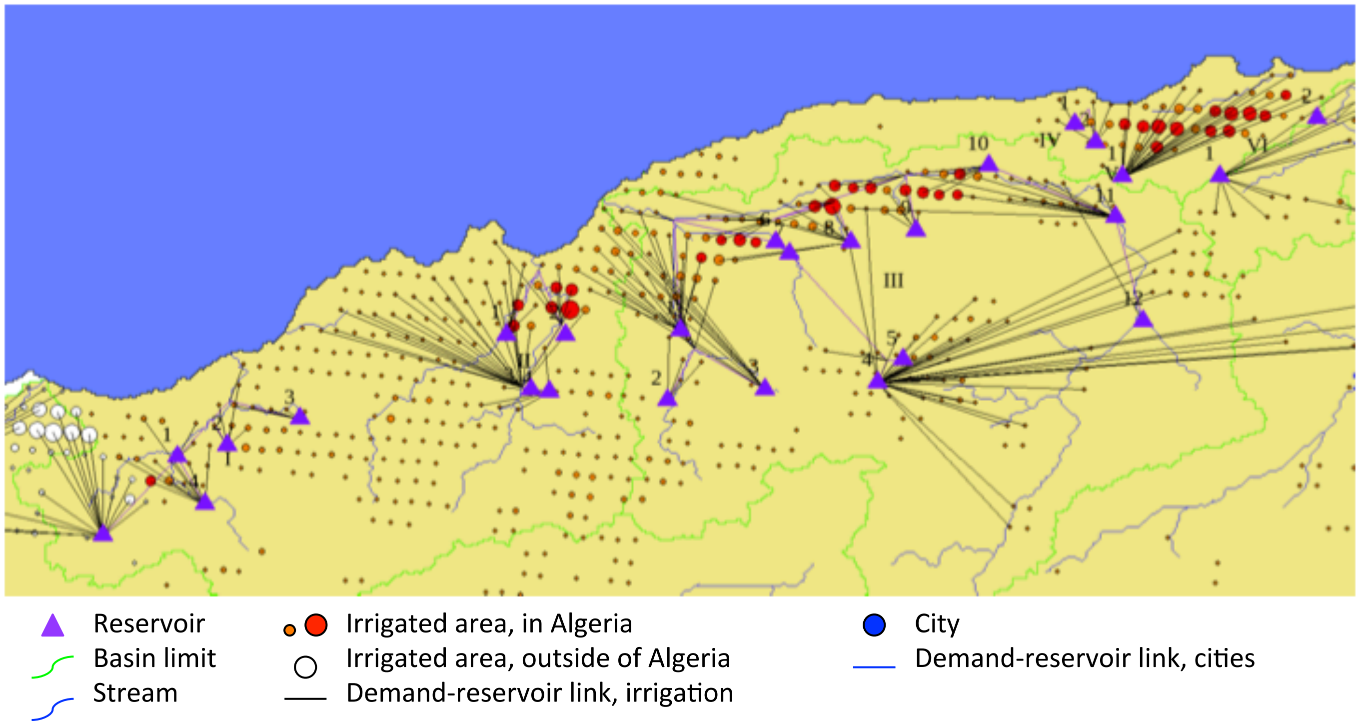


1. RECONSTRUCTING THE WATER NETWORK

- Order of the demands on a segment of the network
  - Demands associated to water inlets, located on the stream, to take into account return flows.

- Flows to the reservoirs [Nassopoulos, 2012]
  - Runoff taken from the outputs of CNRM climate model
  - sub-basin flow-accumulation area of each reservoir based on a Digital Elevation Model [HYDRO1k elevation derivative database]

2. OPERATING RULES OF RESERVOIRS NETWORKS

- Coordinated operation of reservoirs for a better supply-demand balance
- Objective function: maximise economic benefits of the allocated water
- Parameterisation-Simulation-Optimisation approach
  [Nalbantis and Koutsoyiannis, 1997]

Taking into account the value of water

- Priorities among demands

  Give priority to the satisfaction of demands with a high valorisation of water

- Demands of a higher priority can be:
  - Located on different segments
  - Occurring at different time-periods

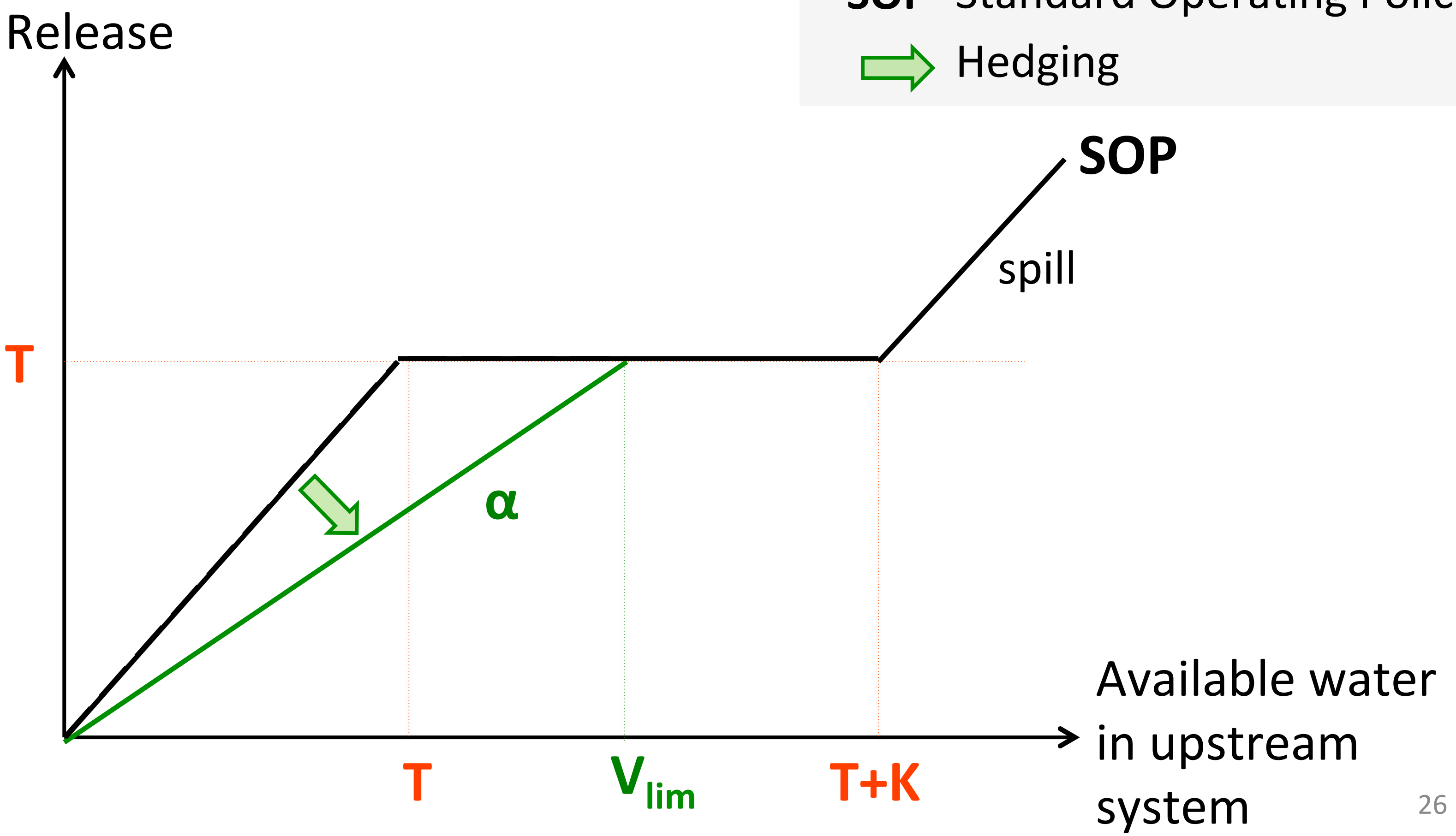
  => Spatial and temporal trade-offs

- Prudential rules

Prudential rule

- 1-point hedging

T Target
K Capacity of reservoir
SOP Standard Operating Policy
Hedging



Operating rules taking into account water value

- Prudential release rules:
  - Prudential parameters, both intertemporal and inter-branch: ***α*** parameters (hedging)

- Other water release rules:
  - Reservoirs in series: release from most downstream reservoir
  - Reservoirs in parallel: parameter **β**

=> 2 parameters for each reservoir (**α** and **β**)

- Parameters are optimised

III. APPLICATION TO ALGERIA

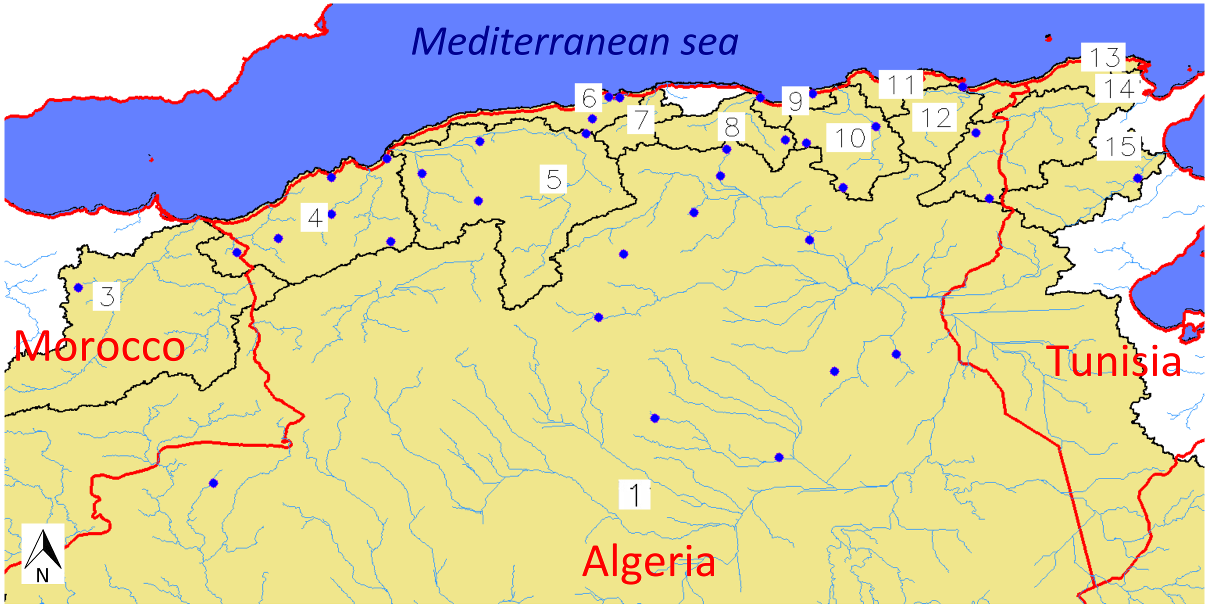
1. DEMAND EVOLUTION

- At country level :

Domestic sector becomes a major sector of water use

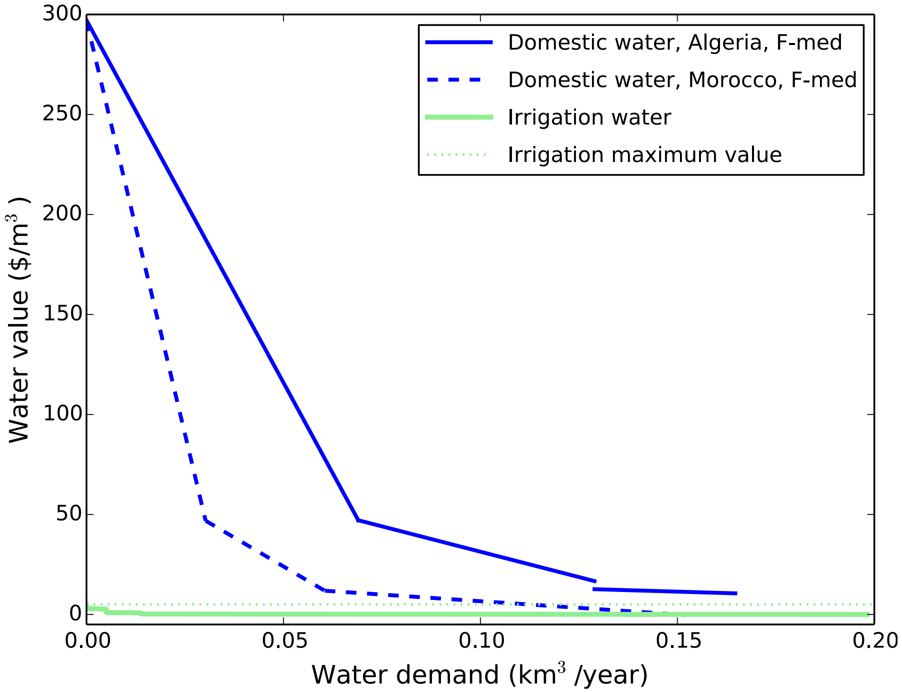
  - Irrigation: +8% by 2050 (A1B SRES scenario, constant irrigated areas)
  - Domestic: [+200;+358]% by 2050; share: 16 % in 2000 -> 35-45% in 2050

- Demands and values in Algerian basins

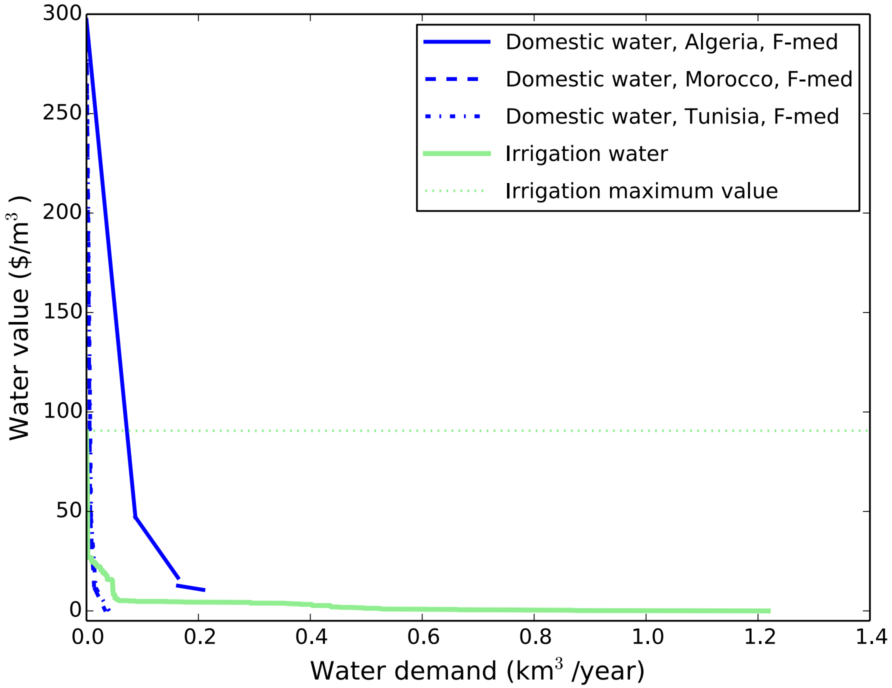


Domestic and irrigation demands in Algerian basins

- Domestic and Irrigation demands in Algerian basins



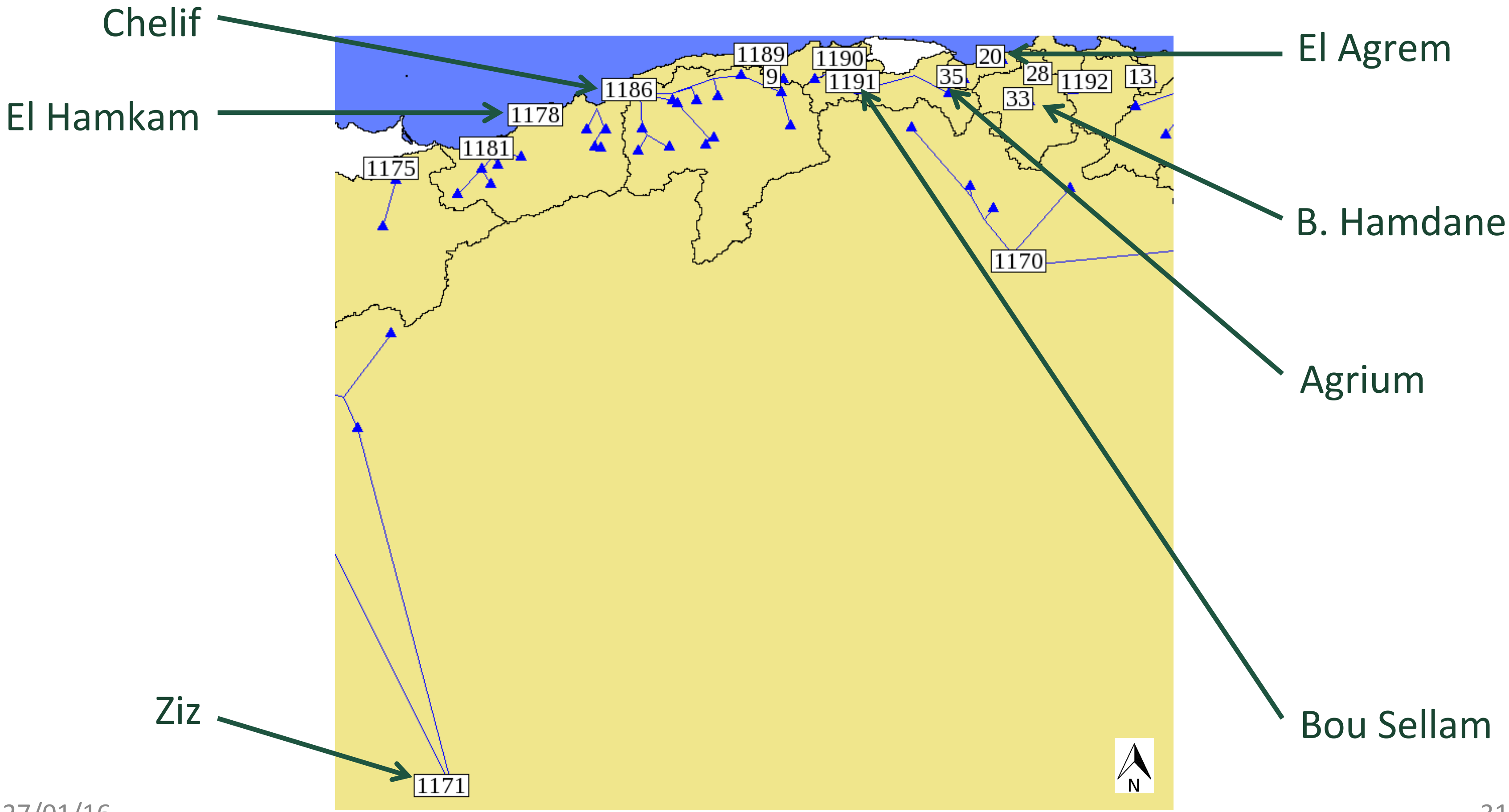
Basin 4



Basin 1

2. DEMAND-SUPPLY GAP

- a system = river catchment network of reservoirs



Demand satisfaction rates

- Evolution under future conditions (2050 horizon)

System	Quantity			Value		
	Past	Future	**Evolution**	Past	Future	**Evolution**
Agrium	72.4 %	84.4 %	**+ 11.9**	99.7 %	99.9 %	**+ 0.2**
Ziz	11.0 %	15.3 %	**+ 4.3**	22.6 %	28.2 %	**+ 5.6**
Bou Sellam	60.3 %	42.3 %	**- 18.0**	72.8 %	56.0 %	**-16.8**
B. Hamdane	31.8 %	17.5 %	**-14.4**	60.0 %	28.6 %	**-31.3**
El Agrem	53.3 %	11.7 %	**- 41.6**	53.3 %	32.1 %	**-21.1**

2 systems: improvement of supply-demand balance in the future

Most catchments: Increase in supply-demand imbalance in the future

Demand satisfaction rates

- Impact of demand prioritisation
  - Prioritisation: value & prudential rules -> maximise economic benefits
  - No prioritisation: no value & no prudential rules -> maximise quantity

System	Quantity		Value	
	Past	Future	Past	Future
El Hamkam	- 3.3 %	+ 1.6 %	+1.4 %	+3.4 %
Bou Sellam	+ 2.0 %	+ 0.8 %	**+ 11.3 %**	+ 6.4 %
El Agrem	+ 2.5 %	+5.5 %	+ 2.4 %	**+20.2 %**
Chelif	- 0.1 %	+ 0.6 %	+ 6.4 %	+ 6.3 %

With prioritisation: lower satisfaction rate in terms of quantity
With prioritisation: better satisfaction rates in terms of quantity
Positive impact of prioritisation on satisfaction rates in terms of economic benefits

CONCLUSION

Conclusions and discussion

- Large-scale hydroeconomic model
  - Anticipate water scarcity issues under global changes
  - Basin scale + Large-scale coverage
  - Quantities + Associated economic losses

- Use of globally available data has its limits
  - There can be errors in reconstruction of reservoirs-demands networks
  - Use of models for crops yields and water demands
  - Assumptions for domestic water willingness to pay, agricultural costs etc.
  - Operating rules could follow other principles

- Not designed to provide a detailed representation of catchments for operational purpose but to **represent heterogenous impacts of global changes at the local scale**
  - Suitable for the representation of inter-basin interactions (virtual water, water transfers, activity relocation)

Perspectives

- Extend to the whole Mediterranean basin
- A screening tool to investigate water management and adaptation policies, at the country or regional scale

- Evaluation of indirect impacts and costs
- Groundwater
- Electricity sector
- Quality ?

- ANR on two major Chinese rivers: validation, hydropower, coupling to Land Surface Models (ORCHIDEE)

Merci de votre attention

Références:

- Nassopoulos, H. (2012). Les impacts du changement climatique sur les ressources en eau en Méditerranée. PhD thesis, Université Paris Est, France.
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- Neverre, N. and Dumas, P. (under review in Water Economics and Policy). Projecting basin-scale distributed irrigation and domestic water demands and values: a generic method for large-scale modeling.

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