Modeling Water Management Options for the Tigris – Euphrates Basin

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Road Map

- Motivation
- Introduction of WATER – MOD
- Building of Scenarios
- Analysis of the Results
- Conclusion
- Further Research

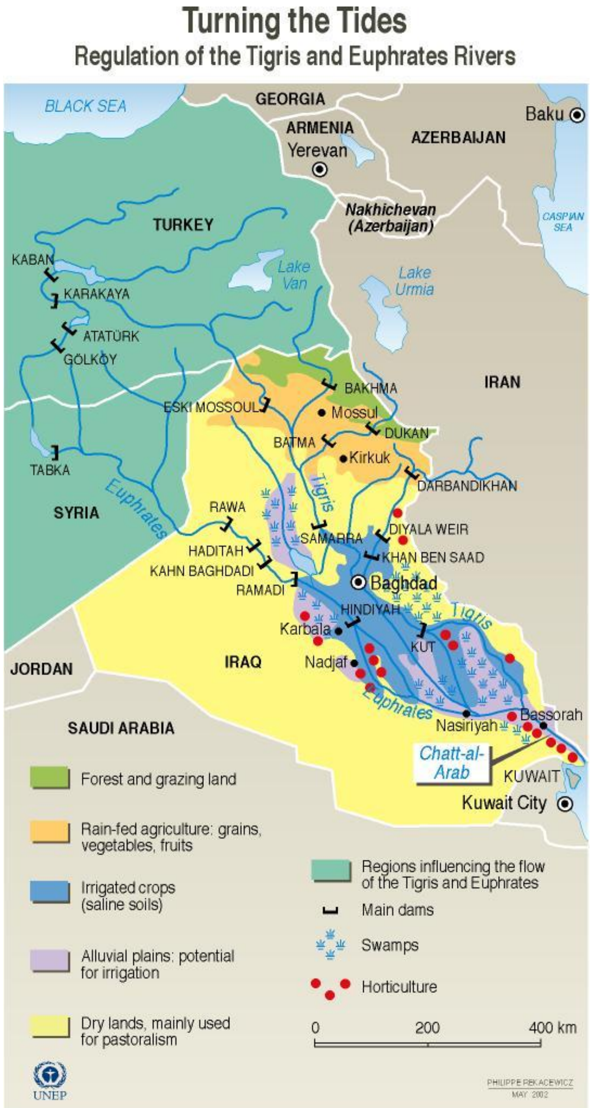
Motivation

- Euphrates and Tigris supply 50 million people from Turkey, Syria and Iraq

- 90 – 98 % of Euphrates and 50 % of Tigris spring in Turkey

- Constant debates how to regulate a fair water distribution

➢ Need to examine different **water management options**



Source: Le Monde diplomatique, Paris, 1994, updated in 2001.

Motivation

"And tell them that water is to be divided between them:

Each one's right to drink being brought forward by turns."

The Koran, Alkamar: 28 iv

"Neither Syria nor Iraq can lay claim to Turkey's rivers any more than Ankara could claim their oil. This is a matter of sovereignty. We have a right to do anything we like. The water resources are Turkey's; the oil resources are theirs. We don't say we share their oil resources, and they cannot share our water resources."

Suleyman Demirel, Prime Minister of Turkey, 1992

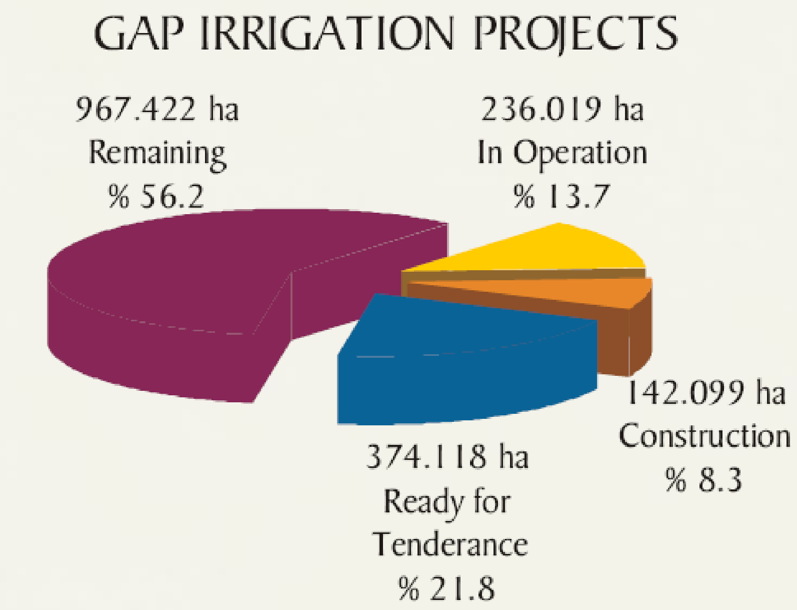
"Southeastern Anatolia Project" (GAP)

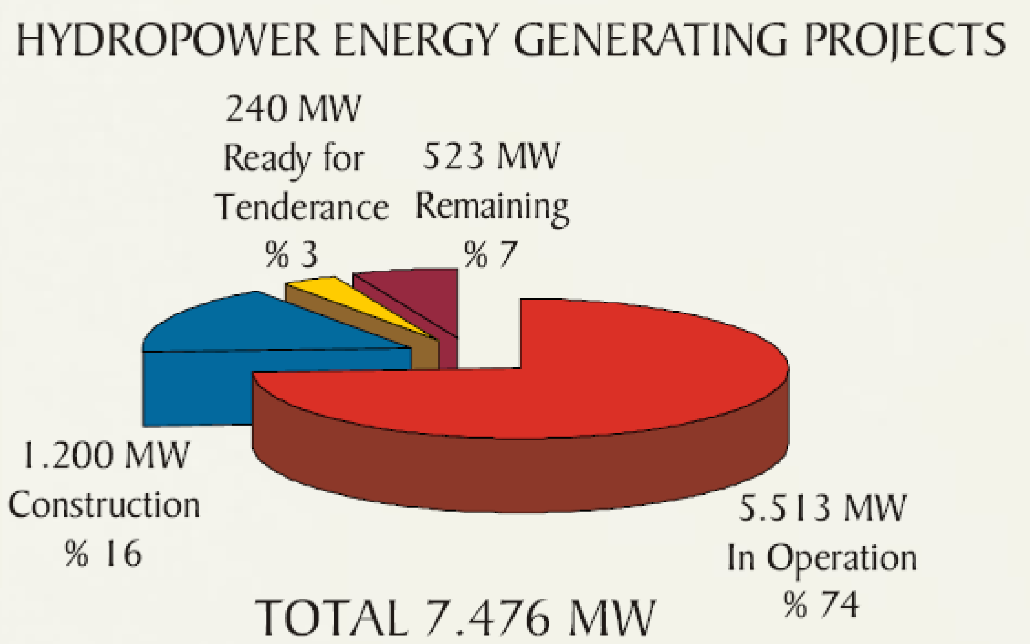
- Turkish investment project
- 9 provinces in the Kurdish South-East
- Original plan to finish by 2010

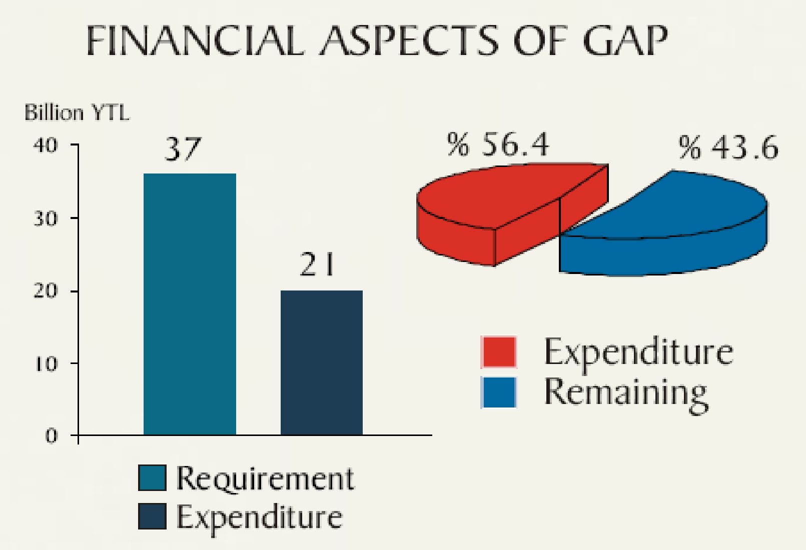
- Irrigate 1.7 million ha
- Produce 27 billion kWh
- Employ 3.8 million people
- Increase per capita income by 209 %

Source: (GAP, 2006)

"Southeastern Anatolia Project" (GAP)







Source: (GAP, 2006)

Literature Overview

- (Li et al., 2006) Yellow River Basin, (McKinney/Karimov, 1997) Aral Sea, (Siehlow et al., 2011) Orange River Basin, (Gohar/Ward, 2010) Nile.

- "Euphrates and Tigris River Basin Model" (ETRBM) (Kucukmehmetoglu, 2002) from Gebze Institute of Technology, Turkey
  The ETRBM is a linear programming model maximizing net economic benefits from the TE-Watershed.

- Later versions focus on potential political and economic impacts of reservoirs in temporal perspective (Kucukmehmetoglu, 2005 and 2009).

Water Allocation of the Tigris-Euphrates Rivershed

- WATER – MOD
- Seasons, Storage, Evaporation & Precipitation
- Water characteristics (back-flow, min water)
- 50 Nodes

- 16 Transport nodes:	Tigris, Euphrates and main tributaries		
- 9 Turkish Demand nodes :	7 mil. people,	1,700,000 ha,	430 mcm^3
- 7 Syrian Demand nodes :	7 mil. people,	1,000,000 ha,	308 mcm^3
- 18 Iraquien Demand nodes:	37 mil. people,	5,500,000 ha,	9700 mcm^3

Figure 3:

Euphrates-Tigris river basin

Legend

- International boundary
- Administrative boundary
- Capital, town
- River basin
- Lake
- Intermittent lake
- Wetland
- Salt pan
- River, intermittent river
- Canal
- Dam (capacity > 1 km^3)
- Zone of irrigation development
- Southeastern Anatolia Project (GAP), ongoing
- Irrigation scheme

0 40 80 160 240 km

Albers Equal Area Projection, WGS 1984

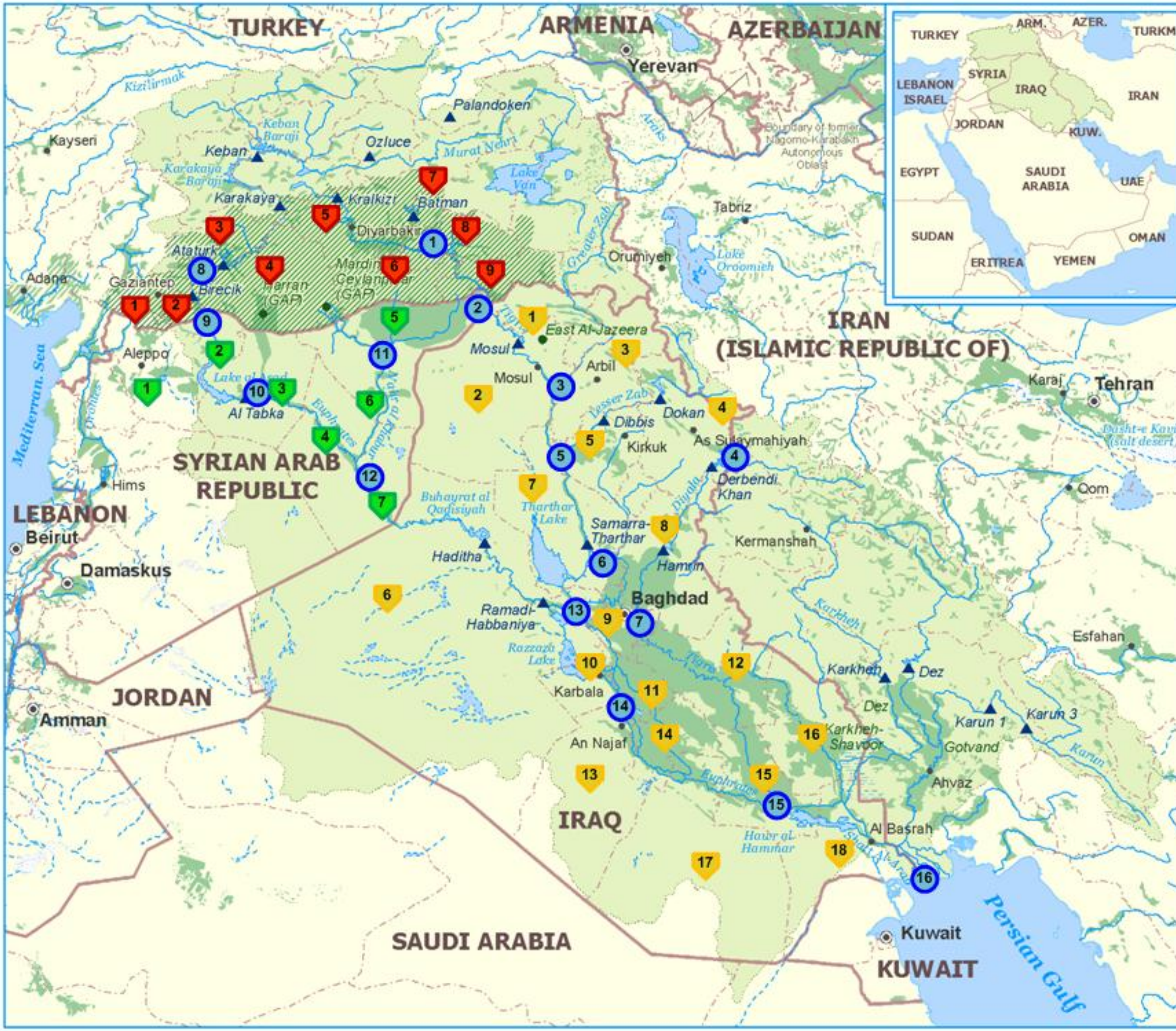
FAO - AQUASTAT, 2009

Disclaimer

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Figure 3:

Euphrates-Tigris river basin



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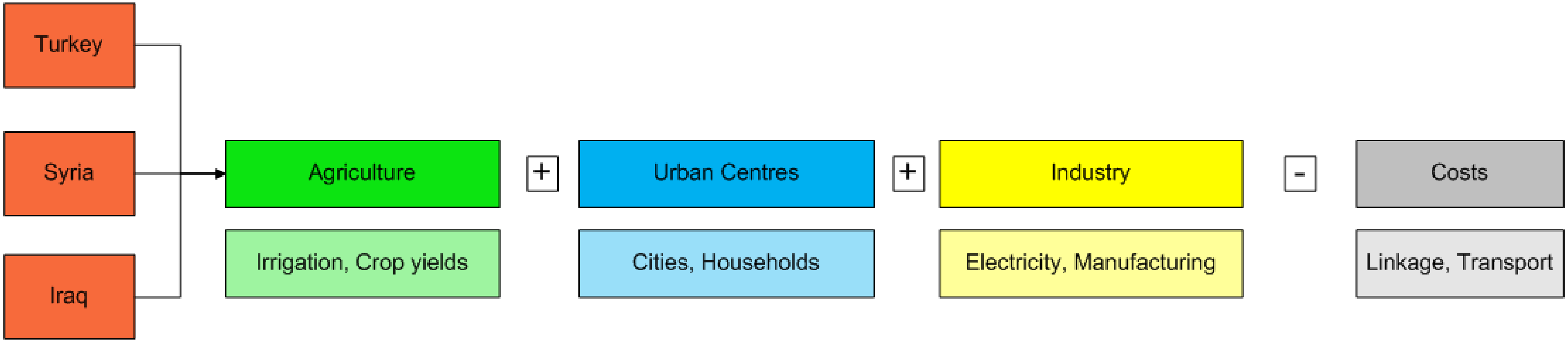
Water Allocation of the Tigris-Euphrates Rivershed

Decision Tree:



Objective Function:

$$\max_{\substack{d_{irga}, stor\_in_{ria}, \\ stor\_out_{ria}, flow_{rija}}} z = \sum_{r,i,g,a} [d\_area_{irga} - d_{irga} \cdot c_{irga} - stor\_in_{ria} \cdot c\_stor_i] \qquad \forall r \tag{25}$$

$$d\_area_{irga} = [0.5 \cdot m_{rg} \cdot (d_{irga})^2 + n_{rg} \cdot d_{irga}] \qquad \forall i, r, g, a \tag{26}$$

Constraints

$$\sum_{r,j} flow_{rija} - \sum_{r,j} flow_{rjia} + \sum_{r,g} d_{irga} - \sum_{r,g} (d_{irga-1} \cdot return_g) - p_{ia} + e_{ia}$$
$$+ \sum_{r} (stor\_in_{ria} - stor\_out_{ria}) = 0 \qquad \perp (\mu_{ia} - free) \qquad \forall i, a$$

$$d_{irga} - d\_min_{iga} \geq 0 \qquad \perp \lambda\_dmin_{irga} \geq 0 \qquad \forall i, r, g, a$$
$$-d_{irga} + d\_max_{iga} \geq 0 \qquad \perp \lambda\_dmax_{irga} \geq 0 \qquad \forall i, r, g, a$$

$$-flow_{rija} + f\_max_{ij} \geq 0 \qquad \perp \lambda\_fmax_{rija} \geq 0 \qquad \forall i, j, r, a$$
$$flow_{rija} - f\_min_{ij} \geq 0 \qquad \perp \lambda\_fmin_{rija} \geq 0 \qquad \forall i, j, r, a$$

$$\sum_{b}^{b \leq a} (stor\_in_{rib} - stor\_out_{rib}) \geq 0 \qquad \perp \lambda\_stor_{ria} \geq 0 \qquad \forall i, r, a$$
$$-\sum_{b}^{b \leq a} (stor\_in_{rib} - stor\_out_{rib}) + stor\_max_i \geq 0 \qquad \perp \lambda\_stormax_{ria} \geq 0 \qquad \forall i, r, a$$

Data: Reference Values and Demand

Regions	Groups	Reference value [$/cm]	Reference demand [mcm]	Elasticity
Iraq	Households	1	4300	- 0.3
Syria	Households	1	738	- 0.3
Turkey	Households	1	620	- 0.3
Iraq	Industry	1.5	9700	- 0.2
Syria	Industry	1.5	308	- 0.2
Turkey	Industry	1.5	430	- 0.2
Iraq	Agriculture	0.0023	52000	- 0.25
Syria	Agriculture	0.057	7335	- 0.25
Turkey	Agriculture	0.066	2960	- 0.25

Two Modeling Approaches

- Sequential three stages approach:
  Every country maximizes its own profit
  in order of their geographic position

- Mixed Complementarity Problem (MCP):
  Maximizing the overall welfare of all countries

Scenarios

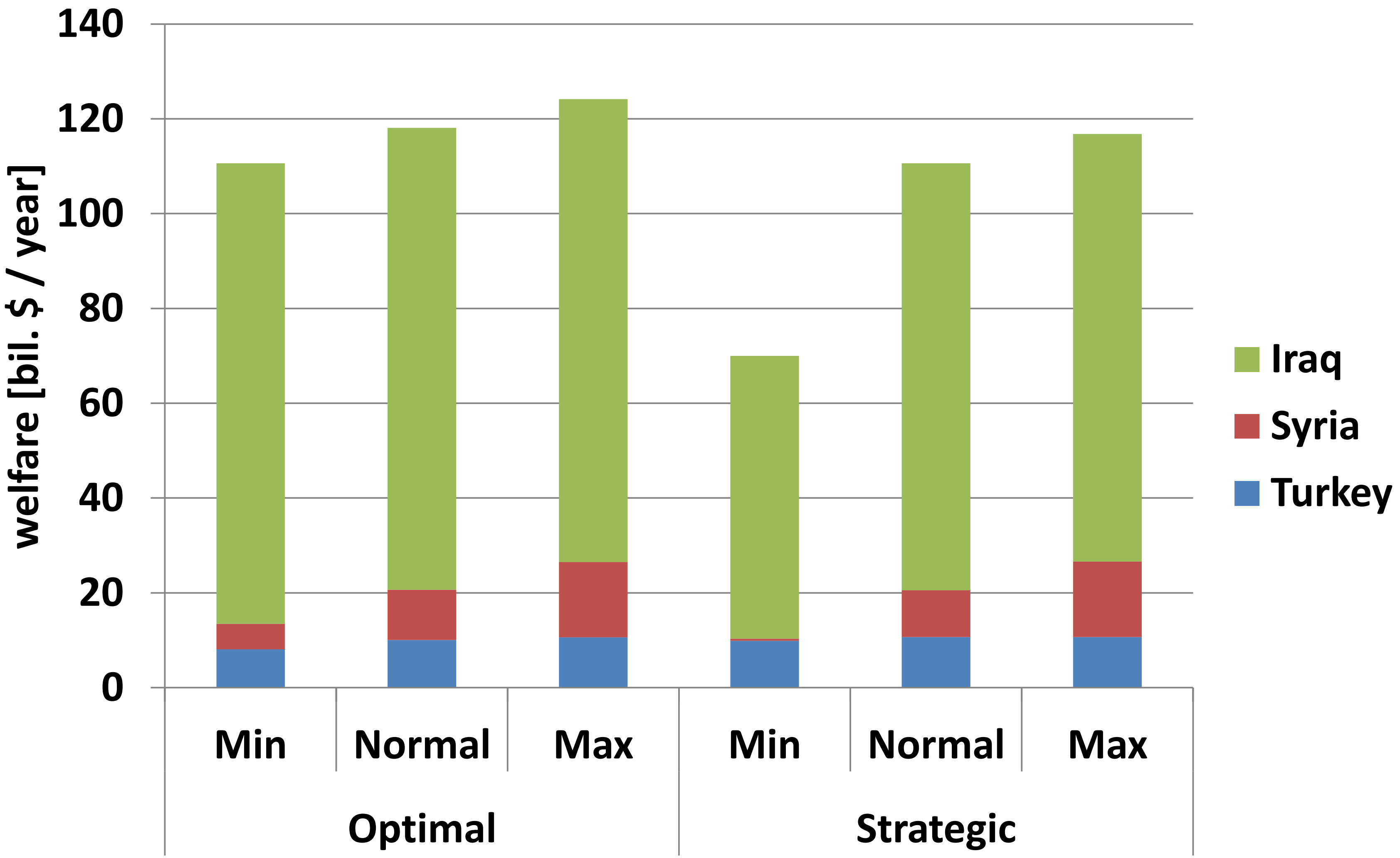
Ecological:

- Different water levels (dry, medium or wet)

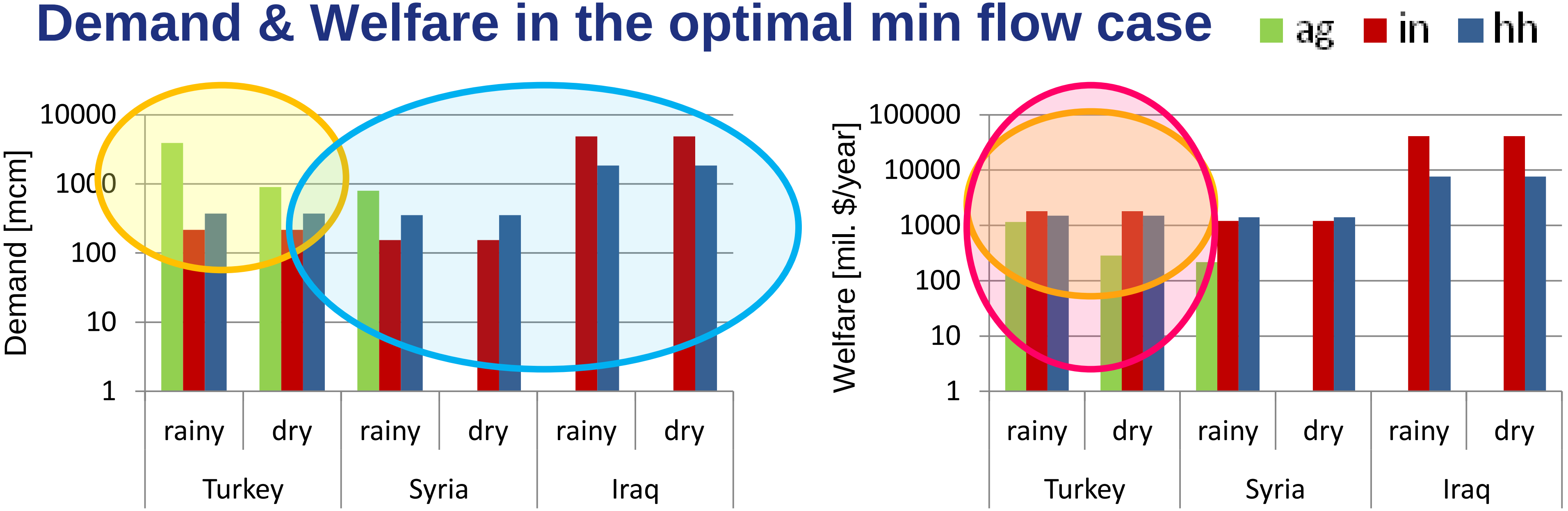
Institutional:

- Building a canal from Tigris to Euphrates in Iraq
- Minimum flow treaties between countries

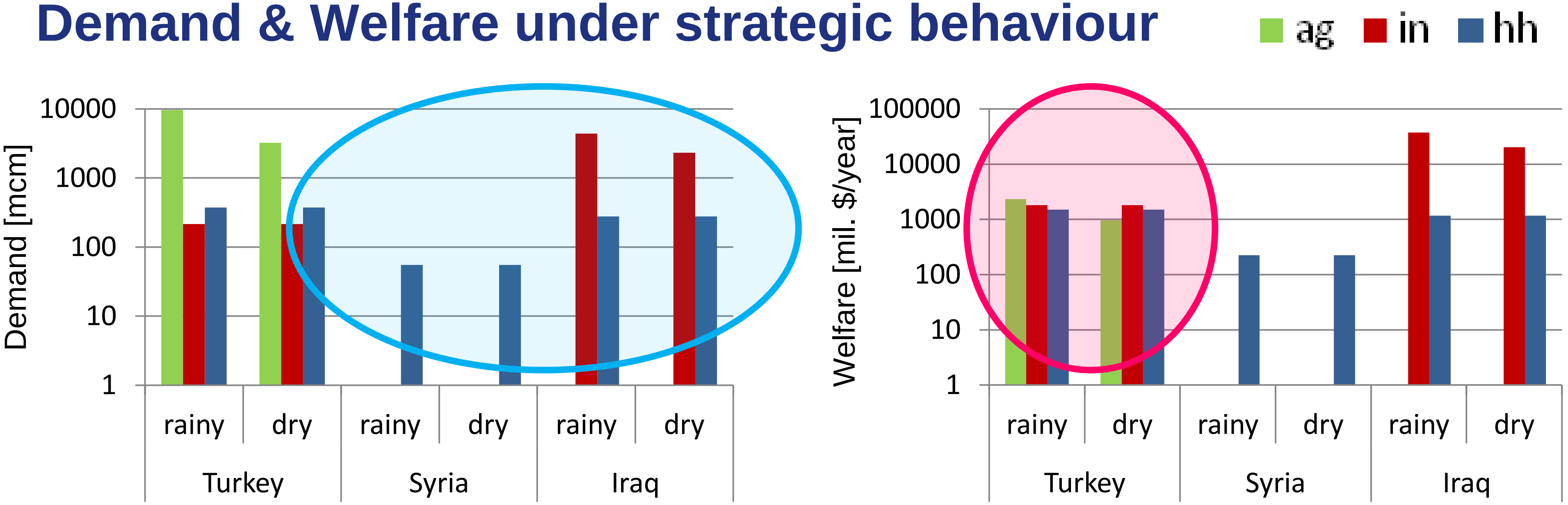
Results: Different water flows



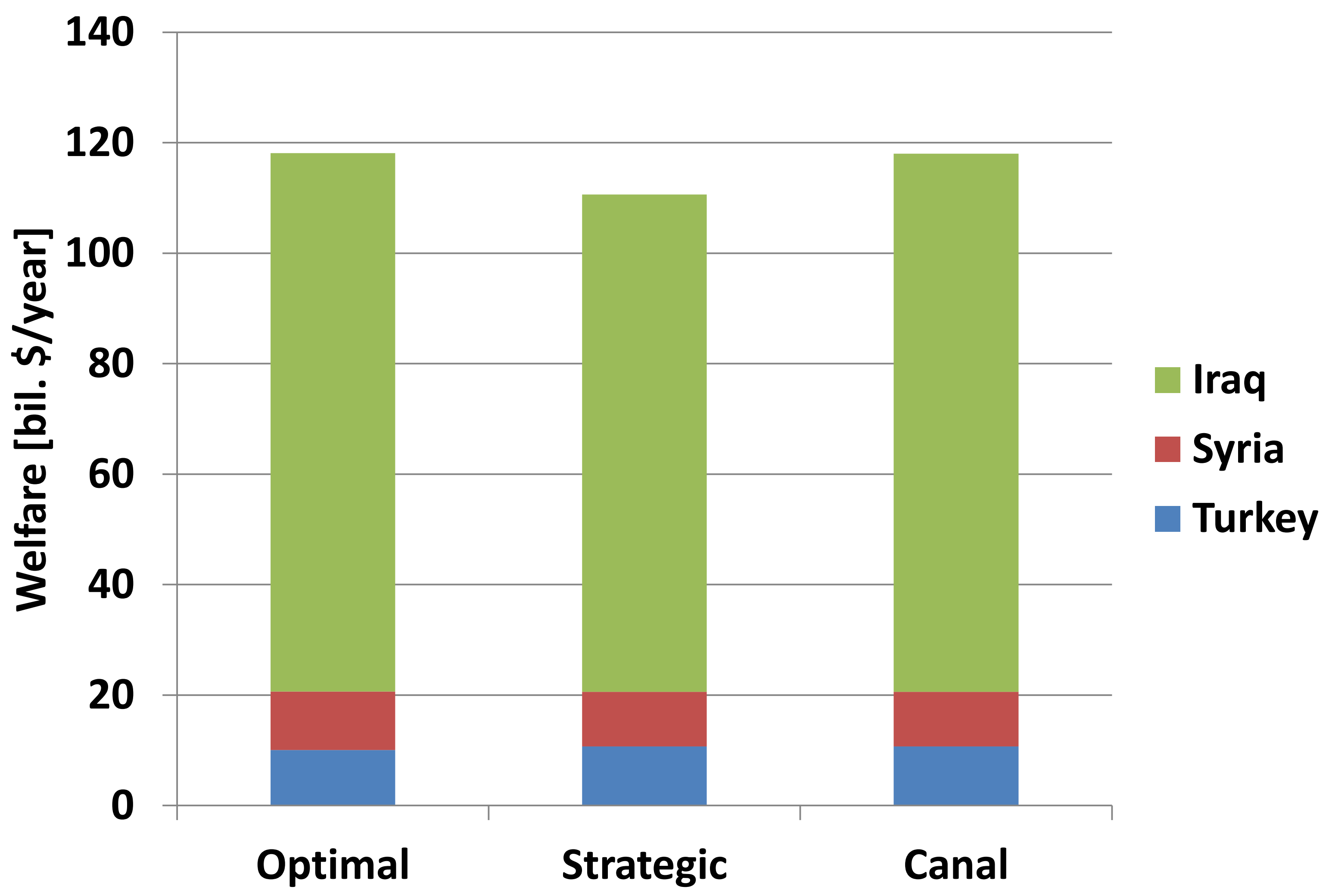
Demand & Welfare in the optimal min flow case



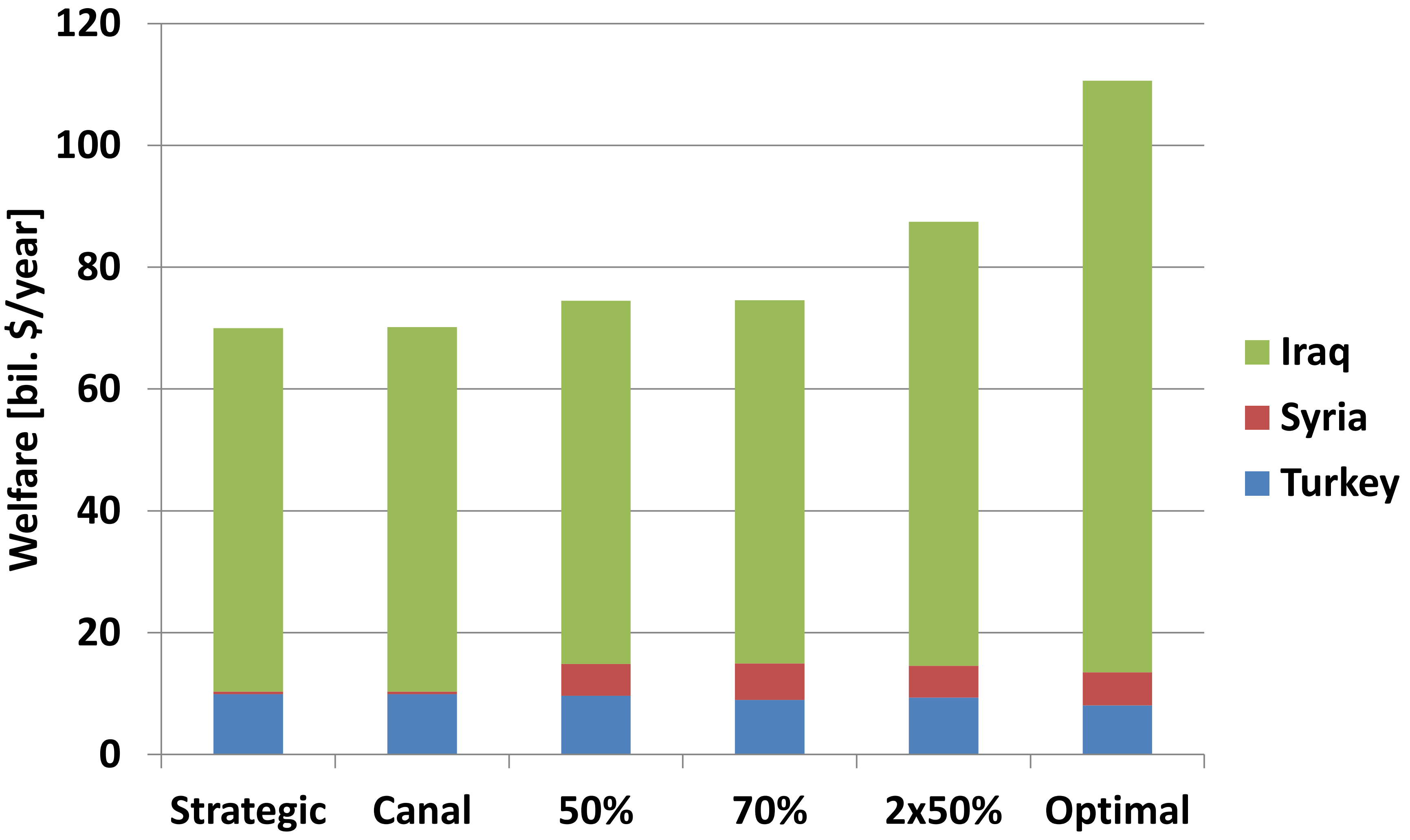
Demand & Welfare under strategic behaviour



Results: Building a canal



Results: Minimum flow treaty



Final Conclusion

- Turkey is able to produce 5 times higher values as Iraq in the agricultural sector per m^3 of water.
- A waterflow reduction by 60% reduces the overall income by 5%.
- Strategic behaviour is causing the overall national income to be reduced by 35%.
- A canal from Tigris to Euphrates increases the Iraquien industrial & domestic usage.
- Minimum flow treaties between countries increase the overall national income by 20%.

Further Research

Water

Allocation of the

Tigris and

Euphrates

Rivershed

WATER – MOD

I am currently working on:

- Ecological constraints
- Hydropower integration

Questions

Water

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WATER – MOD

Thank you very much

for your attention!

Are there any questions?

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Sets	Description
a	periods (rainy, dry)
$f(r)$	follower (Syria, Iraq)
g	groups (industry, agriculture, households)
i	nodes
$l(r)$	leader (Turkey)
r	regions (Turkey, Syria, Iraq)
Parameters	
$evap_{ia}$	evaporation at node i in period a
$prec_{ia}$	precipitation at node i in period a
d_min_{iga}	minimum demand at node i for group g in period a
d_max_{iga}	maximim demand at node i for group g in period a
f_min_{ij}	minimum flow on arc(i,j)
f_max_{ij}	maximum flow on arc(i,j)
$stor\_max_{i}$	maximum storage capacity at node i
v_{irga}	value of consumption at node i in region r for group g in period a
c_{irga}	costs of consumption at node i in region r for group g in period a
s_c_{i}	costs of storage at node i
K	disjunctive constraints constant
p	punishment weighting factor $\in [0;1]$
Variables	
d_{irga}	demand at node i for region in group g in period a
$flow_{rija}$	flow controled by region r on arc(i,j) in period a
$stor\_in_{ria}$	incoming storage controled by region r at node i in period a
$stor\_out_{ria}$	outgoing storage controled by region r at node i in period a
r_d	binary variable for disjunctive constraint on demand
r_f	binary variable for disjunctive constraint on flow
r_si	binary variable for disjunctive constraint on incoming storage
r_so	binary variable for disjunctive constraint on incoming storage
Dual variables	
λ_dmin_{irga}	dual to minimum demand at node i for region in group g in period a
λ_dmax_{irga}	dual to maximum demand at node i for region in group g in period a
λ_fmin_{rija}	dual to maximum flow controled by region r on arc(i,j) in period a
λ_fmax_{rija}	dual to maximum flow controled by region r on arc(i,j) in period a
λ_stor_{ria}	dual to total storage of dam controled by region r at node i in period a
$\lambda\_stormax_{ria}$	dual to storage capacity of dam controled by region r at node i in period a
μ_{ia}	dual to flow balance at node i in period a

Data: Reference Values and Costs

Table 2: Value of $1m^3$ water per country and per sector [US$]

Country/Sector	Agriculture	Households	Industry
Iraq	0.002	1	1.5
Syria	0.057	1	1.5
Turkey	0.066	1	1.5

Source: FAO-Stat (2008), BEAUMONT (1998), own calculations

Table 3: Costs of $1m^3$ water in the agricultural sector per country [US$]

Country	Agricultural Costs
Iraq	0.0017
Syria	0.0075
Turkey	0.0083

Source: OECD (2010), BEAUMONT (1998), INECO (2009), KUCUKMEHMETOGLU (2009), own calculations

Costs for domestic and industrial uses is 0.005 US$/$m^3$/km (Kucukmehmetoglu, 2009)

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