University of Haifa
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THE ECONOMIC IMPACT OF WATER SCARCITY UNDER DIVERSE WATER QUALITIES AND DESALINATION POLICIES

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Israel’s Water Economy

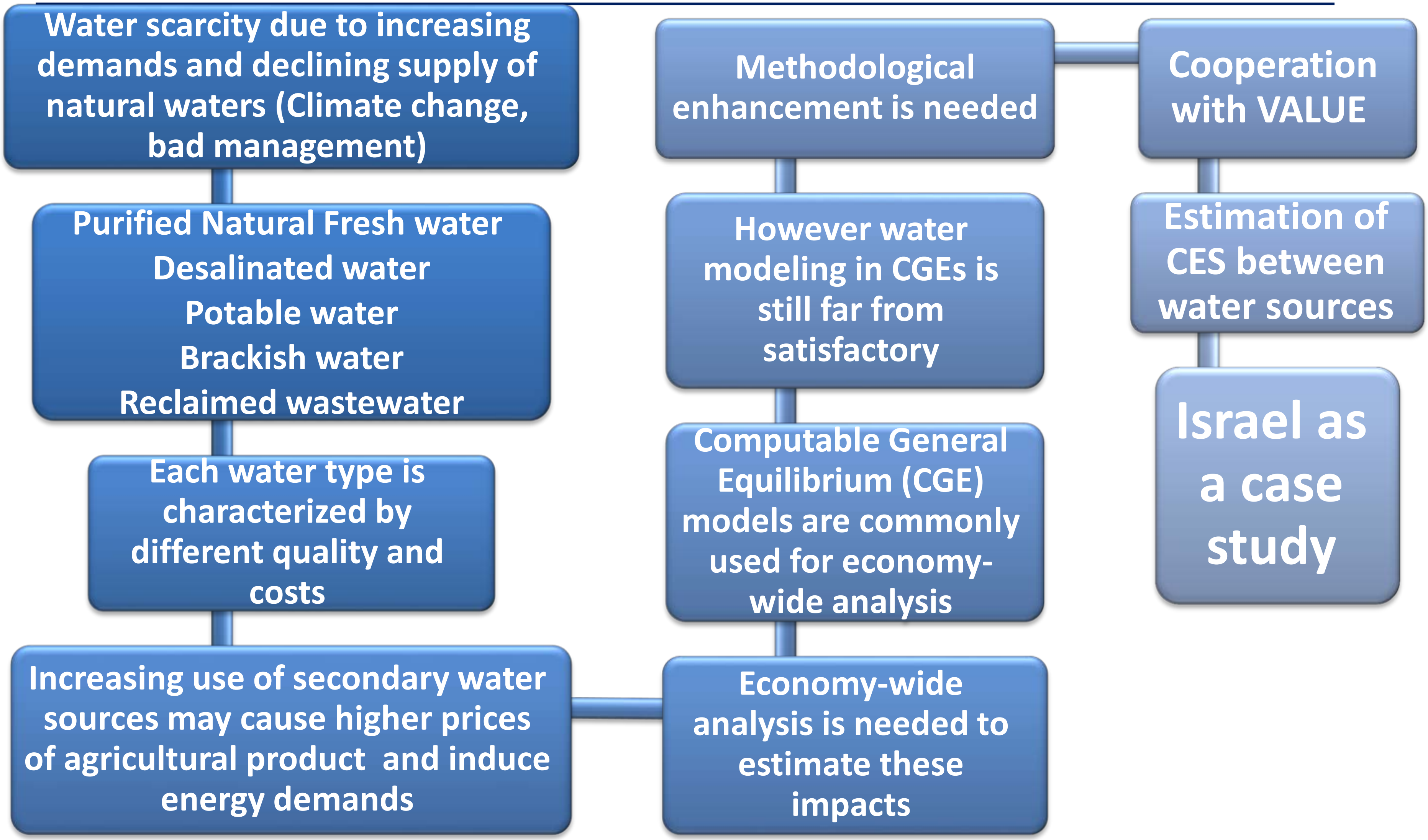
- In recent years, Israel has encountered water scarcity caused by ongoing droughts and low aquifer replenishment rates.
- Extensive investments were made over the years in an integrated water resource diversion/abstraction and conveyance system.
- Rainfall, characterized by yearly variations, is the main natural water resource.
- Alternative water sources include: reclaimed wastewater, desalinated seawater and extracted brackish groundwater.
- Climate change models project worsening water scarcity caused by temperature increase and changes in rainfall quantities and distribution.
- Alternative water sources already play a critical role in coping with the expected shortages.

Israel’s 2010 Water Balance

Water supply sources (MCM)		Water demands (MCM)	
Lake Tiberias	340	Households	764
Galil and Carmel Aquifer	130	Industry	120
Mountain Aquifer	473	Agriculture	500 (freshwater)
Coastal Aquifer	285		544 (reused water)
Desalinated water	303	Palestinian Authority	93
Effluents	400	Jordan	50
Salinated and flood water	200	Nature	60
Total	**2131**	**Total**	**2131**

(*Based on IWA, 2011*)

Research Motivation



Water scarcity due to increasing demands and declining supply of natural waters (Climate change, bad management)

Purified Natural Fresh water
Desalinated water
Potable water
Brackish water
Reclaimed wastewater

Each water type is characterized by different quality and costs

Increasing use of secondary water sources may cause higher prices of agricultural product and induce energy demands

Methodological enhancement is needed

However water modeling in CGEs is still far from satisfactory

Computable General Equilibrium (CGE) models are commonly used for economy-wide analysis

Economy-wide analysis is needed to estimate these impacts

Cooperation with VALUE

Estimation of CES between water sources

Israel as a case study

Purpose of the Study

- Assess the impact of climate change on the Israeli water economy and on the agricultural sector under different desalination policies
- Methodological innovation in modeling water:
  - Evaluating the general structure and values of key water related parameters in production functions.
    - (1) the substitution of irrigation water with different qualities,
    - (2) the link between the consumption of freshwater by domestic and industrial consumers and the amount of treated wastewater to be used in agricultural production.
  - Constructing a consistent economic database, building upon official data of water values in Israel.
- Enhancing the model to better reflect the characteristics and operating principles of the water economy.
- Comprehensive assessment of the impact of climate change.

SAM WATER

- Israel Water Satellite Accounts 2006 (CBS, 2011)
- Provide unique data that allows to introduce detailed representation of water sectors in values (monetary terms)

	Surface water	Ground water	Desalinated water	Recycled effluents	Other water
AFF	3	4	4	1	1
ROIL	13	16	16	6	4
COIL	0	0	0	0	0
COAL	0	0	0	0	0
MNF	279	393	0	0	0
ELE	103	224	299	141	166
CON	27	33	32	11	8
TRD	5	6	5	2	1
ASR	0	0	0	0	0
TRC	7	9	9	3	2
BIF	4	5	5	2	1
BAC	164	267	0	0	0
PAD	22	28	27	10	7
EDU	0	1	1	0	0
HWS	0	0	0	0	0
CSS	1	1	1	0	0
IBS	32	40	38	14	10
Labor	230	787	103	43	0
Capital	1040	1911	86	86	79

IGEM - Israeli General Equilibrium Model

- Static CGE-type model representing the entire Israeli economy.
- Small open economy, 5 energy sectors, 5 water sectors *(potable: natural and desalinated, Shafdan - t*ertiary treated wastewater*, reclaimed and brackish),* 13 other sectors, government, investment agent, foreign agent, single representative household.
- Final demands are determined by market prices.
- Standard assumptions of: market clearing, zero excess profits, balanced budget for each agent.
- The economy is assumed at equilibrium at the benchmark.
- Simulated scenarios are implemented as a ‘counter-factual’ with exogenous shocks. Output represents the state after all markets reach a new equilibrium.

The
Vegetative
Agricultural
Land-
Use
Economic
Model

Main Attributes of VALUE

- A positive mathematical programming model with calibrated revenue and cost functions

- The revenue side incorporates field-level production functions of irrigation water applications

- The production functions incorporate the impacts of both irrigation water quantity and salinity

Input From VALUE To IGEM

- σ^T- Constant Elasticity of Substitution (CES) between water types in agricultural production

- General characteristics:
  - $\sigma^T>0$
  - If σ^T close to 0→substitution between water types is nearly fixed and unresponsive to changes in relative prices.
  - As σ^T ↑ → the easier to substitute from one water type to another

Deriving Constant Elasticity of Substitution (CES)

- VALUE is used to derive an artificial dataset for CES rates between water types in agricultural production.

- The dataset is generated by running VALUE while changing relative prices of water types used as inputs and evaluating the reallocation of overall regional land and water.

Regression Model

- Assuming firms behavior in the neoclassical model with a cost minimization objective, the CES production function of Q (agric output) is presented as:

$$Q = A(\alpha W_1^{\sigma} + (1-\alpha) W_2^{\sigma})^{1/\sigma}$$

α - distribution parameter

W_1 - quantity of water type 1

W_2 - quantity of water type 2

σ - elasticity of substitution between the two water types

- The standard reduced form of the first-order-conditions is:

$$\frac{\alpha}{1-\alpha}\left(\frac{W_1}{W_2}\right)^{\sigma-1} = \frac{Pw_1}{Pw_2}$$

Pw_1 - price of water type 1

Pw_2 - price of water type 2

- Taking logarithm and econometrically estimating parameters:

$$\ln\left(\frac{W_{1i}}{W_{2i}}\right) = \beta + \sigma \ln\left(\frac{Pw_{2i}}{Pw_{1i}}\right) + u_i$$

i – observation, $\beta = \sigma \ln\left(\frac{1-\alpha}{\alpha}\right)$

Hierarchical multi-level structure

- Once CES is determined for the lowest level, composite quantities and prices need to be calculated for estimating CES at the next level.

$$P_{12} = [\alpha_{12}P_1^{((1-\ \sigma12)/\sigma12)} + (1-\ \alpha_{12})P_2^{((1-\ \sigma12)/\sigma12)}\ ]^{(\ \sigma12/(1-\ \sigma12))}$$

$$Q_{12} = [\alpha_{12}Q_1^{((1-\ \sigma12)/\sigma12)} + (1-\ \alpha_{12})Q_2^{((1-\ \sigma12)/\sigma12)}\ ]^{(\ \sigma12/(1-\ \sigma12))}$$

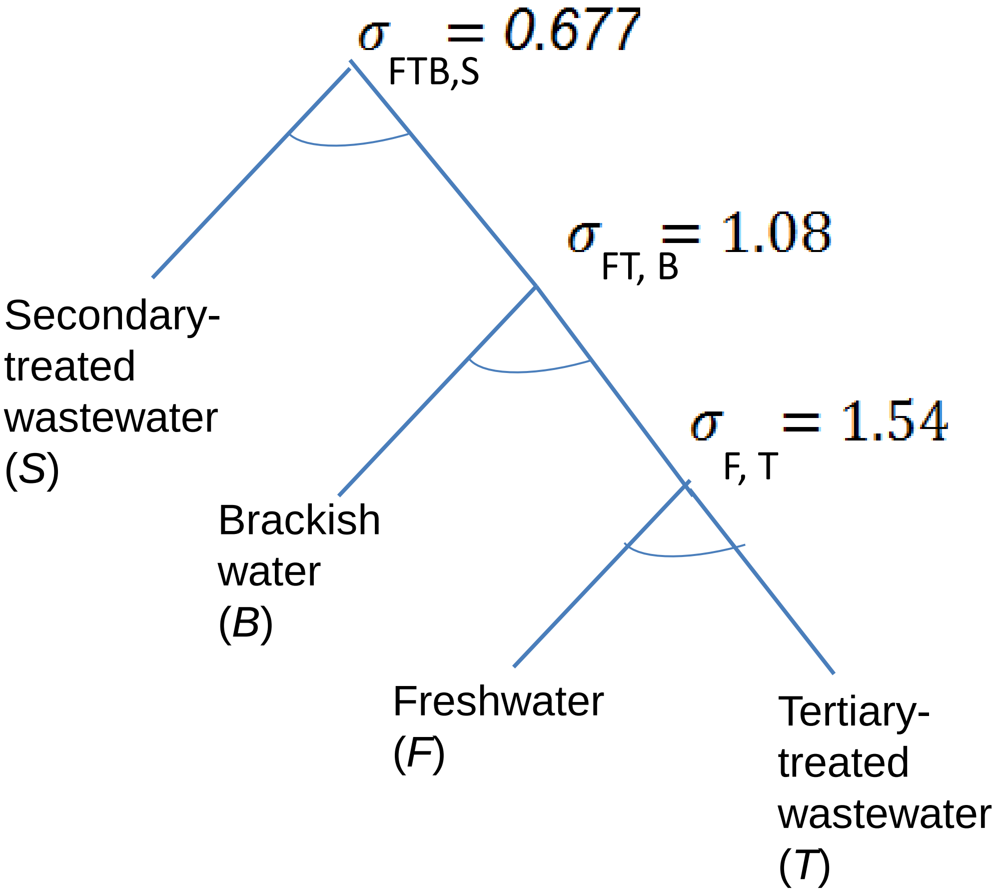
P_{12} – composite price

Q_{12} - composite quantity

α_{12} - relative share of type 1 water out of the entire composite quantity

σ_{12} - elasticity of substitution between the two water types

Estimated nesting CES structure for water inputs



$\sigma_{FTB,S} = 0.677$

$\sigma_{FT, B} = 1.08$

$\sigma_{F, T} = 1.54$

Secondary-treated wastewater (*S*)

Brackish water (*B*)

Freshwater (*F*)

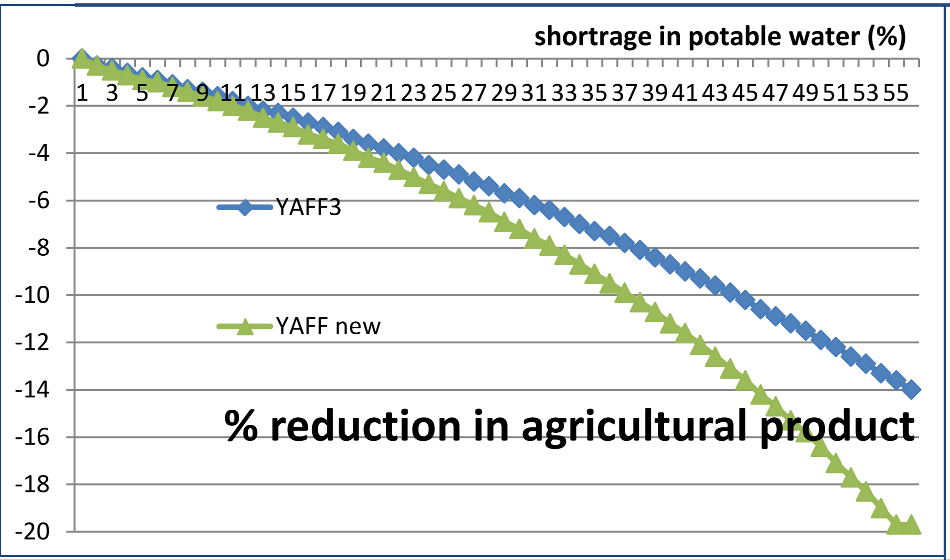
Tertiary-treated wastewater (*T*)

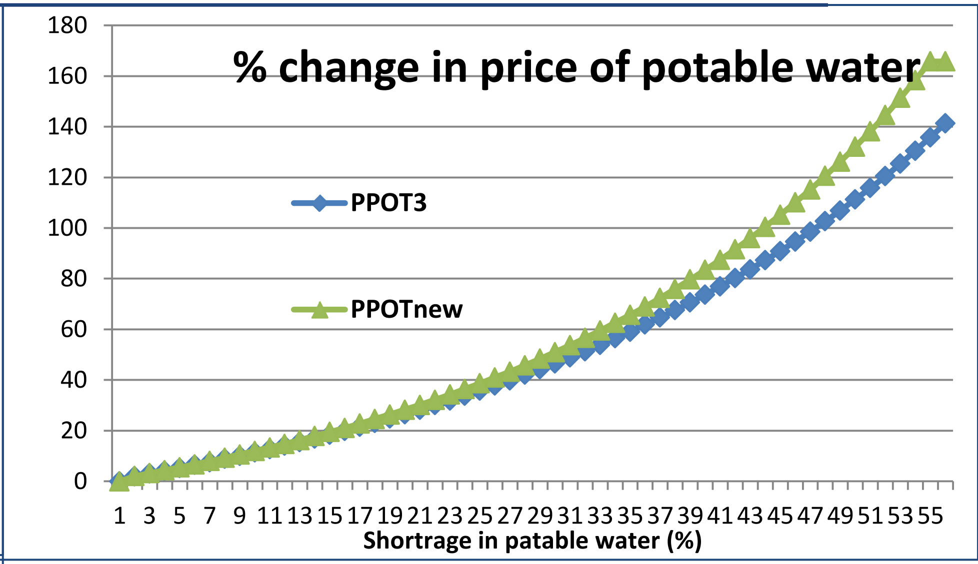
Qualifying the results

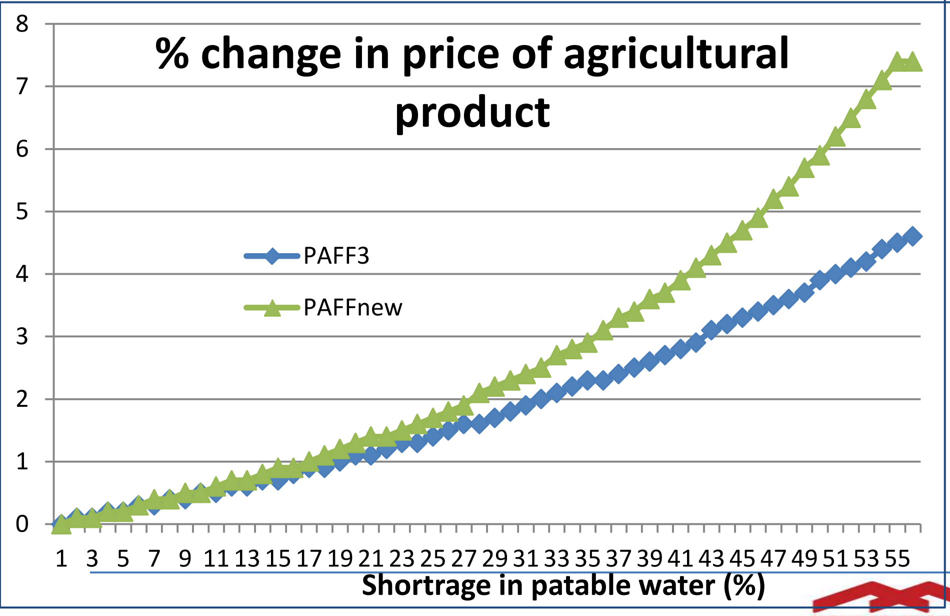
- Unique in the literature in evaluating substitutability between different water types.

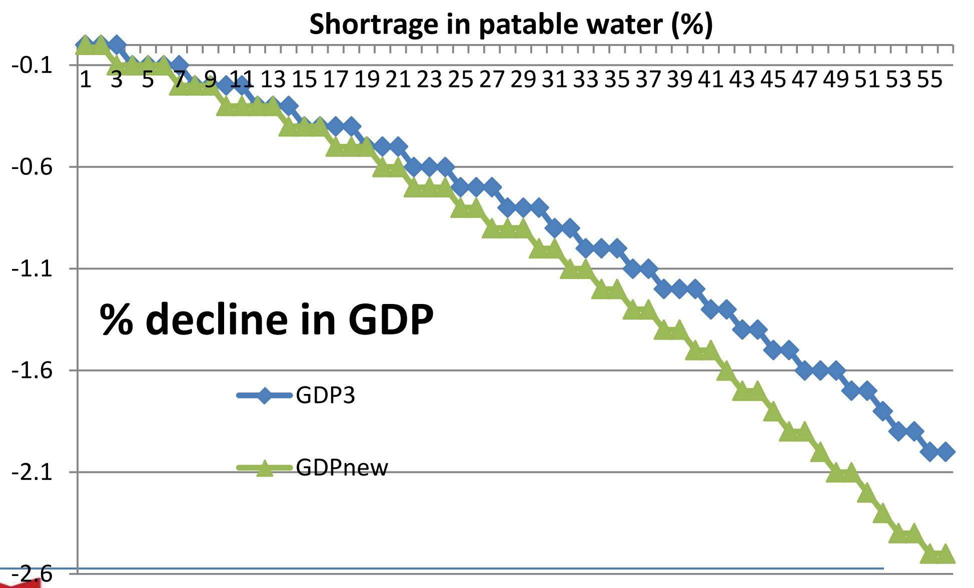
- Contrary to Luckmann et al. (2011) the results provide evidence that:
    - Potable, reclaimed and saline water inputs are not equally substitutable in agricultural production in Israel.
    - Estimated rates of substitution are considerably lower than assumed in Luckmann et al. (2011) .

Qualifying the results









Water Shortage Scenarios (based on Long Term National Master Plan for The Water Economy (IWA, 2011))

Year	Scenario No.	Description	Natural Freshwater	Potable shortage At desired reliability level of 75%		Potable shortage at desired reliability level of 90%		Potable shortage At desired reliability level of 95%		Potable shortage At desired reliability level of 100%	
			MCMY	%	MCMY	%	MCMY	%	MCMY	%	MCMY
2020	1	At current level of desalination	1,140	16	220	16	220	22	320	31	520
2020	2	With approved level of desalination	1,140	-	-	-	-	-	-	4	50
2030	3	At current level of desalination	1,080	28	420	33	520	36	620	40	720
2030	4	With approved level of desalination	1,080	-	-	4	50	12	150	19	250
2050	5	At current level of desalination	1,020	50	1020	52	1120	54	1220	56	1320
2050	6	With approved level of desalination	1,020	35	550	39	650	42	750	45	850

Results for 2020

Scenario No.	Indicator	Desired Supply Reliability Level of Potable Water			
		75%	90%	95%	100%
1	% Decline in agricultural output	-3.2	-3.2	-4.7	-7.6
	% Increase in relative price of agricultural products	0.9	0.9	1.4	2.4
	% Increase in the relative price of potable water	21.1	21.1	32.2	53.7
	% decline in GDP	-0.4	-0.4	-0.7	-1.0
2	% Decline in agricultural output	—	—	—	-0.6
	% Increase in relative price of agricultural products	—	—	—	0.2
	% Increase in the relative price of potable water	—	—	—	4.3
	% decline in GDP	—	-	–	-0.1

Results for 2030

Scenario No.	Indicator	Desired Supply Reliability Level of Potable Water			
		75%	90%	95%	100%
3	% Decline in agricultural output	-6.5	-8.3	-9.5	-11.2
	% Increase in relative price of agricultural products	2.1	2.7	3.1	3.7
	% Increase in the relative price of potable water	45.8	59.5	69	83.5
	% decline in GDP	-0.9	- 1.1	-1.3	- 1.5
4	% Decline in agricultural output	_	-0.6	-2.2	-3.9
	% Increase in relative price of agricultural products	_	0.2	0.7	1.2
	% Increase in the relative price of potable water	_	4.3	14.8	26.4
	% decline in GDP		-0.1	-0.3	-0.5

Results for 2050

Scenario No.	Indicator	Desired Supply Reliability Level of Potable Water			
		75%	**90%**	**95%**	**100%**
5	% Decline in agricultural output	-16.4	-17.7	-19.0	**-19.7**
	% Increase in relative price of agricultural products	5.9	6.5	7.1	**7.4**
	% Increase in the relative price of potable water	132.1	144.6	158.4	**165.8**
	% decline in GDP	-2.1	-2.3	-2.4	**-2.5**
6	% Decline in agricultural output	- 9.1	-10.7	-12.1	**-13.6**
	% Increase in relative price of agricultural products	2.9	3.6	4.1	**4.7**
	% Increase in the relative price of potable water	65.7	79.7	91.6	**105.2**
	% decline in GDP	-1.2	-1.4	-1.6	**-1.8**

Conclusions

In the absence of a suitable solution for the projected shortage in potable water

- there will be, starting in 2030 and steadily growing thereafter, a major impact on agriculture and the water economy:
- Failing to implement the plan for enlarging the desalination capacity to 750 MMY will result, under equilibrium conditions and at the highest desired level of supply reliability:
  - decline in agricultural output of 19.7%,
  - increase in the price of agricultural products of 7.4%,
  - increase in the relative price of potable water of 165.8 %
  - and decline in GDP of 2.5%.

Conclusions

The implementation of the approved plan for enlarging the desalination capacity will mitigate the impact, but there will still remain a sizable shortage in potable water that will result, at the highest desired level of supply reliability:

- in a decline in agricultural output of 13.6%,
- increase in the price of agricultural products of 4.7%,
- increase in the relative price of potable water of 105.2 %
- and decline in GDP ranges of 1.8%.

Thank You for Your Attention
Questions?
Comments?