Water Quality Assessment SAM/CGE and Satellite Accounts Integrated Framework

Rehab Osman
Emanuele Ferrari
Scott McDonald

Contributed Paper prepared for presentation at the 89th Annual Conference of the Agricultural Economics Society, University of Warwick, England
13 - 15 April 2015

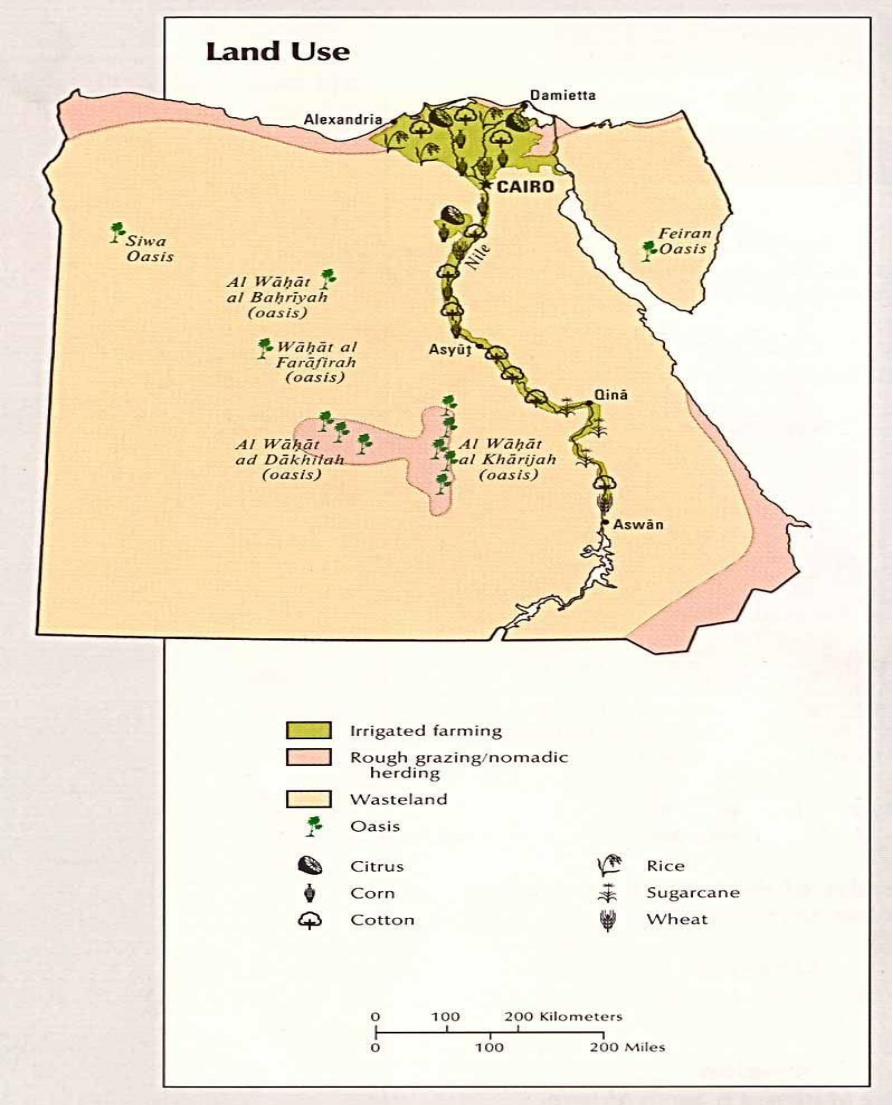
Water Quality Assessment SAM/CGE and Satellite Accounts Integrated Framework

REHAB OSMAN

EMANUELE FERRARI

SCOTT MCDONALD

Table of Contents



Water Quality & Agriculture

Development of agriculture is constrained by low quality water

Semi-arid area Nile a main source of fresh/irrigation water

85% Nile water agriculture

Nile water 80% of irrigation requirements

4% of land agriculture, 85% in Nile Valley and Nile Delta

Total cost of low quality water 1.8% GDP (MWRI)

Irrigation misconduct is, actually, a main cause of water quality deterioration

- Multi-cropping system; 3 irrigation seasons
  - **Winter** (November-May): wheat, fodders & broad beans
  - **Summer** (May-September): cotton & rice
  - **Nili**, i.e. Nile flood (September-November)
- Intensive exploitation of water & land raises salinity level, (RIGW)
- Drainage network discharges wastes into the Nile mainstream, (WB)
- **Empirical Case Studies:**

  WQI is marginal, high values of **EC_e**, reduction in **SPI** by **46%**

Research Objectives & Contributions

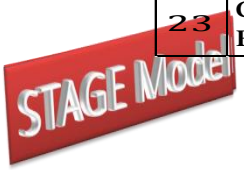
Providing quantitative assessments for the implications of water quality enhancements for agricultural productivity

- Recently constructed SAM for Egypt **2008/09**
- Developed version of **STAGE-WL**
- Scenarios consider **agro-economic features** (i.e. soil properties, water salinity & crop salt-tolerance)

New SAM for Egypt, 2008/2009

- Detailed agricultural/irrigation accounts
  - 54 activities (23 agriculture: 7 winter, 8 summer, 6 Nili, 1 year-round & xAgri.)
  - 16 commodities
  - 18 production factors (8 Nile-dependent & 8 ground-water dependent Irrigation factors)

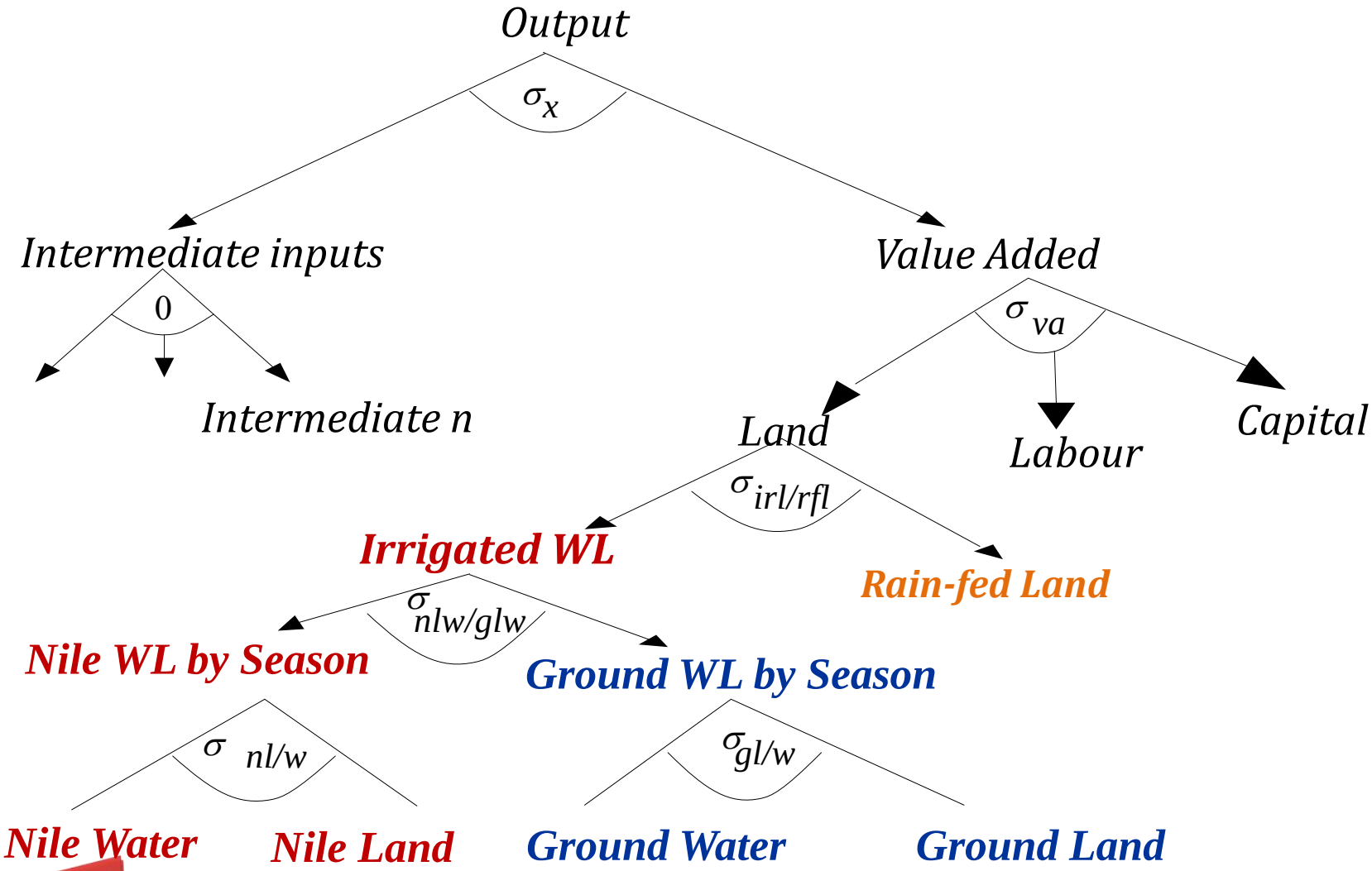
No	SAM Agr. Activity	No	Commodity	No	SAM Factors
1	Winter Wheat	1	Wheat	1	Labour
2	Winter Cereals	2	Cereals	2	Capital
3	Winter Sugar Beet	3	Rice	3	Winter Nile-dependent Land
4	Winter Fodders	4	Vegetables	4	Summer Nile-dependent Land
5	Winter Fibbers	5	Fruits	5	Nili Nile-dependent Land
6	Winter Medical Plants	6	Coffee Tea	6	Year-round Nile-dependent Land
7	Winter Vegetables	7	Other Agriculture Fo	7	Winter Nile Water
8	Summer Rice	8	Ores Minerals Gas	8	Summer Nile Water
9	Summer Other Crops	9	Food Products	9	Nili Nile Water
10	Summer Sugar Cane	10	Other Transportable	10	Year-round Nile Water
11	Summer Cotton	11	Metal machinery equ	11	Winter Groundwater-dependent Land
12	Summer Fodders	12	Construction	12	Summer Groundwater-dependent Land
13	Summer Oily Crops	13	Trade	13	Nili Groundwater-dependent Land
14	Summer Medical Plants	14	Financial Services	14	Year-round Groundwater-dependent Land
15	Summer Vegetables	15	Business Services	15	Winter Ground Water
16	Nili Rice	16	Social Services	16	Summer Ground Water
17	Nili Other Crops			17	Nili Ground Water
18	Nili Fodders			18	Year-round Ground Water
19	Nili Oily Crops				
20	Nili Medical Plants				
21	Nili Vegetables				
22	Fruits				
23	Other Agriculture, Forestry, Fishing				



STAGE-WL CGE Model

- Comp. Static variant of STAGE-WL CGE
- 5 level CES production function
- W & L are mobile across agriculture activities but not across irrigation seasons

Production Flows in STAGE-WL CGE Model



Agro-economic Scenarios
3 Computation Steps

Cost/benefit analysis for governmental project

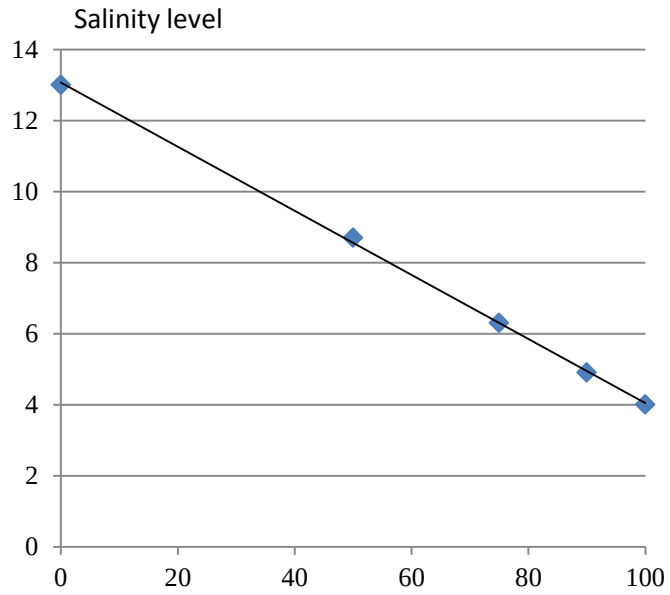
(IWRMP): -10% in water salinity, 9.5 billion LE

annual gov. exp.

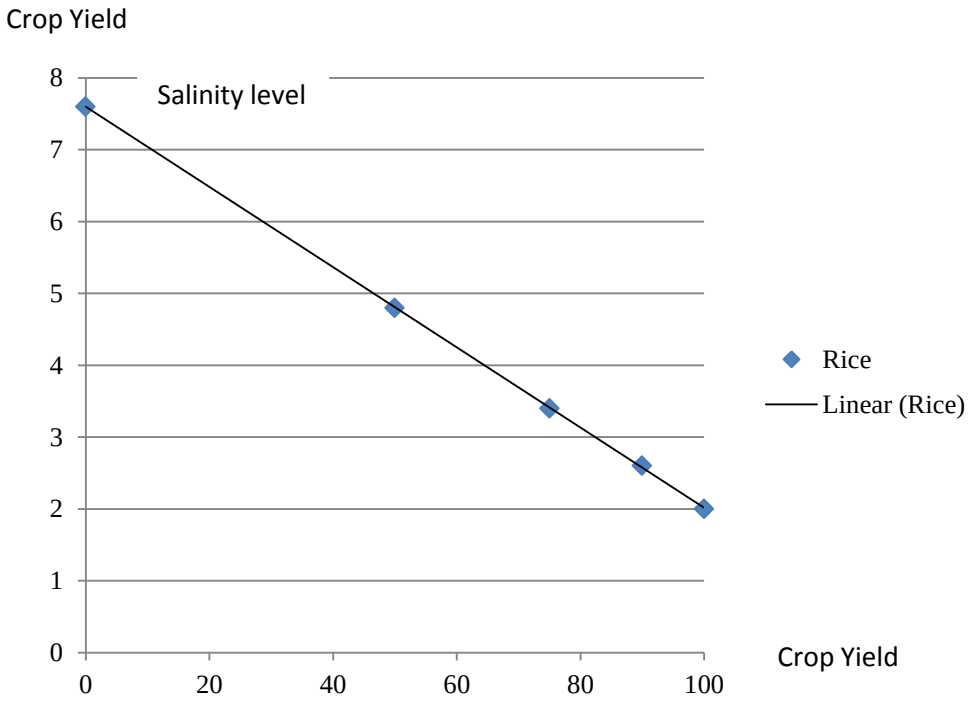
1. Technical agro-economic estimations for crop yields under different water salinity levels, (FAO)
2. Crop yield elasticities to changes in water salinity
3. Potential improvement in water quality is translated into changes in crop yields

	Table 4 CROP TOLERANCE AND YIELD POTENTIAL OF SELECTED CROPS AS INFLUENCED BY IRRIGATION WATER SALINITY (ECw) OR SOIL SALINITY (ECe)										
	YIELD POTENTIAL										
		100		90		75		50		0.00001	
		100%		90%		75%		50%		0% "maximum"	
		EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
FIELD CROPS	Barley (Hordeum vulgare)	8	5.3	10	6.7	13	8.7	18	12	28	19
	Cotton *(Gossypium hirsutum)*	7.7	5.1	9.6	6.4	13	8.4	17	12	27	18
	Sugarbeet (Beta vulgaris)	7	4.7	8.7	5.8	11	7.5	15	10	24	16
	Sorghum *(Sorghum bicolor)*	6.8	4.5	7.4	5	8.4	5.6	9.9	6.7	13	8.7
	Wheat *(Triticum aestivum)*	6	4	7.4	4.9	9.5	6.3	13	8.7	20	13

Ayers, R., & Westcot, D. (1985). Water Quality for Agriculture. *FAO Irrigation and Drainage Paper, 29*(Rev. 1)


Salinity level
14
12
10
8
6
4
2
0
0
20
40
60
80
100


Wheat
Linear (Wheat)


Crop Yield
Salinity level
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
Rice
Linear (Rice)
Crop Yield


STAGE Model

Agro-economic Scenarios

- All scenarios 34% increase in gov. exp.
- H-Yld Full potential increases in crop yields
- P-Yld 70% of potential increases in crop yields
- L-Yld 50% of potential increases in crop yields

Simulated Changes in Crop Yields (% change)

	H-Yld	P-Yld	L-Yld
Winter Wheat	0.04	0.03	0.02
Winter Cereals	0.08	0.06	0.04
Winter Sugar Beet	0.03	0.03	0.02
Winter Fodders	0.26	0.18	0.13
Winter Fibbers	0.29	0.21	0.15
Winter Medical Plants	0.26	0.18	0.13
Winter Vegetables	**0.37**	**0.26**	**0.19**
Summer Rice	0.19	0.13	0.10
Summer Other Crops	0.16	0.12	0.08
Summer Sugar Cane	0.07	0.05	0.04
Summer Cotton	0.10	0.07	0.05
Summer Fodders	0.10	0.07	0.05
Summer Oily Crops	0.15	0.10	0.07
Summer Medical Plants	0.10	0.07	0.05
Summer Vegetables	**0.37**	**0.26**	**0.19**
Nili Rice	0.19	0.13	0.10
Nili Other Crops	0.16	0.11	0.08
Nili Fodders	0.18	0.13	0.09
Nili Oily Crops	0.15	0.10	0.07
Nili Medical Plants	0.18	0.13	0.09
Nili Vegetables	**0.37**	**0.26**	**0.19**
Fruits	**0.59**	**0.31**	**0.14**
Other agri forestry fishing	0.20	0.13	0.09

Macro-economic Indicators

	H-Yld	P-Yld	L-Yld
Private consumption	3.01	2.07	1.45
Government consumption	0.33	0.14	0.05
Investment consumption	2.05	1.27	0.85
Total Absorption	2.55	1.72	1.19
Import demand	3.07	1.41	0.63
Export supply	4.36	2.13	1.06
GDP from expenditure	**2.83**	**1.90**	**1.32**
Total domestic production	3.14	2.17	1.54
Total intermediate inputs	3.16	2.41	1.82

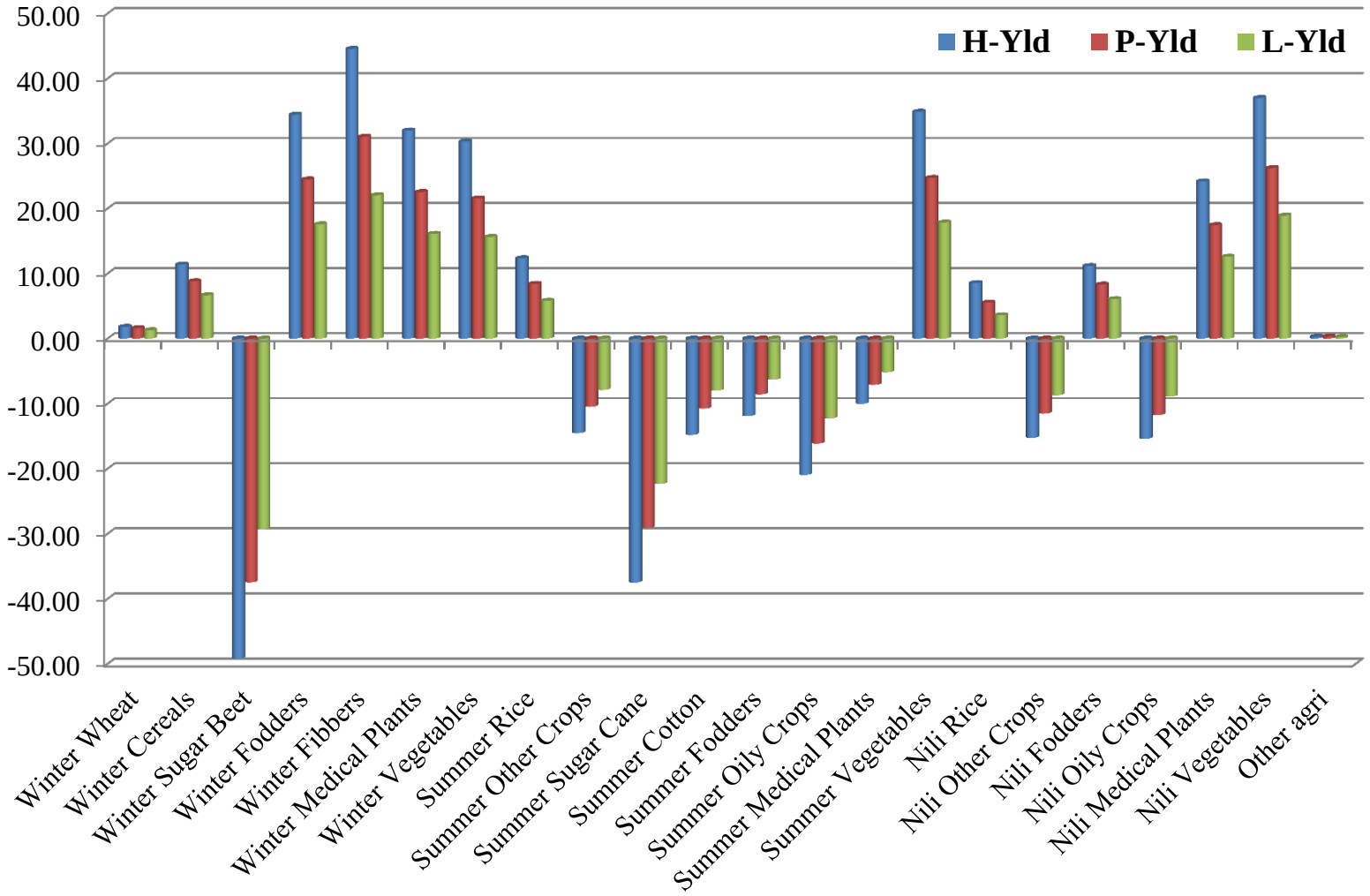
Economy-wide Impacts

- All scenarios strong positive impacts
- H-Yld more than +2.5% in GDP
- P-Yld positive economy-wide impacts
- L-Yld more than +1% in GDP

The planned investments in water quality improvements are worthwhile even with very low generated crop yields

STAGE Model

Domestic Agricultural Production (% change)



Sector-specific Impacts

- Favourable impacts, particularly for winter crops (contribute **36%** BL agricultural output)
- Seasonal veg. **+30%,** veg. & fruits salt-sensitive (seasonal veg. comprise **23%** of BL agricultural output)
- Rice output **+12%** (summer) **+9%** (Nili) (rice **6%** BL agricultural output, **13%** of which is exported)

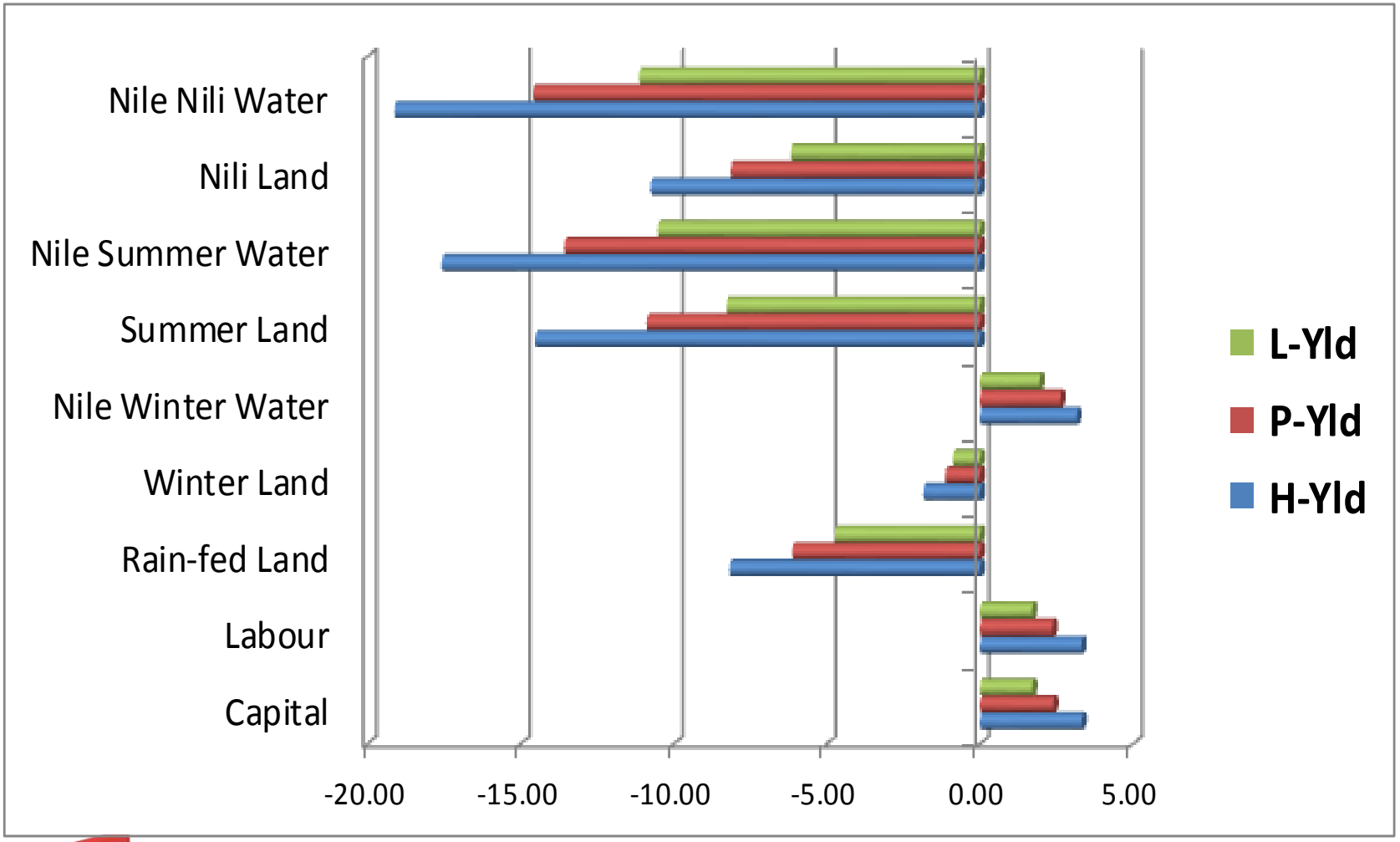
Commodity Exports (% change)

	H-Yld	P-Yld	L-Yld
Wheat	3.35	3.49	2.99
Cereals	22.24	17.10	12.86
Rice	**63.18**	**43.55**	**30.58**
Vegetables	71.13	48.71	33.94
Fruits	319.80	126.09	47.93
Coffee Tea	69.41	47.87	33.57
minerals gas	-9.12	-5.08	-3.08
Food products	**-3.41**	**-0.79**	**-0.01**
Other transportable goods	-1.18	0.06	0.26
Metal machinery	1.23	2.13	2.13
Construction	0.88	2.27	2.91
Trade	-5.76	-3.09	-1.85
Financial services	-4.48	-2.33	-1.33
Business services	-5.43	-2.87	-1.67
Social services	-5.44	-3.07	-1.92

Sector-specific … (cont.)

- Rice exports **+30-60%**
- Decreases food product exports as sugar beet (winter) & sugar cane (summer) shrink
- Summer crops (except rice & veg.) shrink
- Rice & veg. absorb labour and capital & push their prices and incomes to rise
- Summer crops experience increasing production costs

Agricultural Factor Prices (% change)



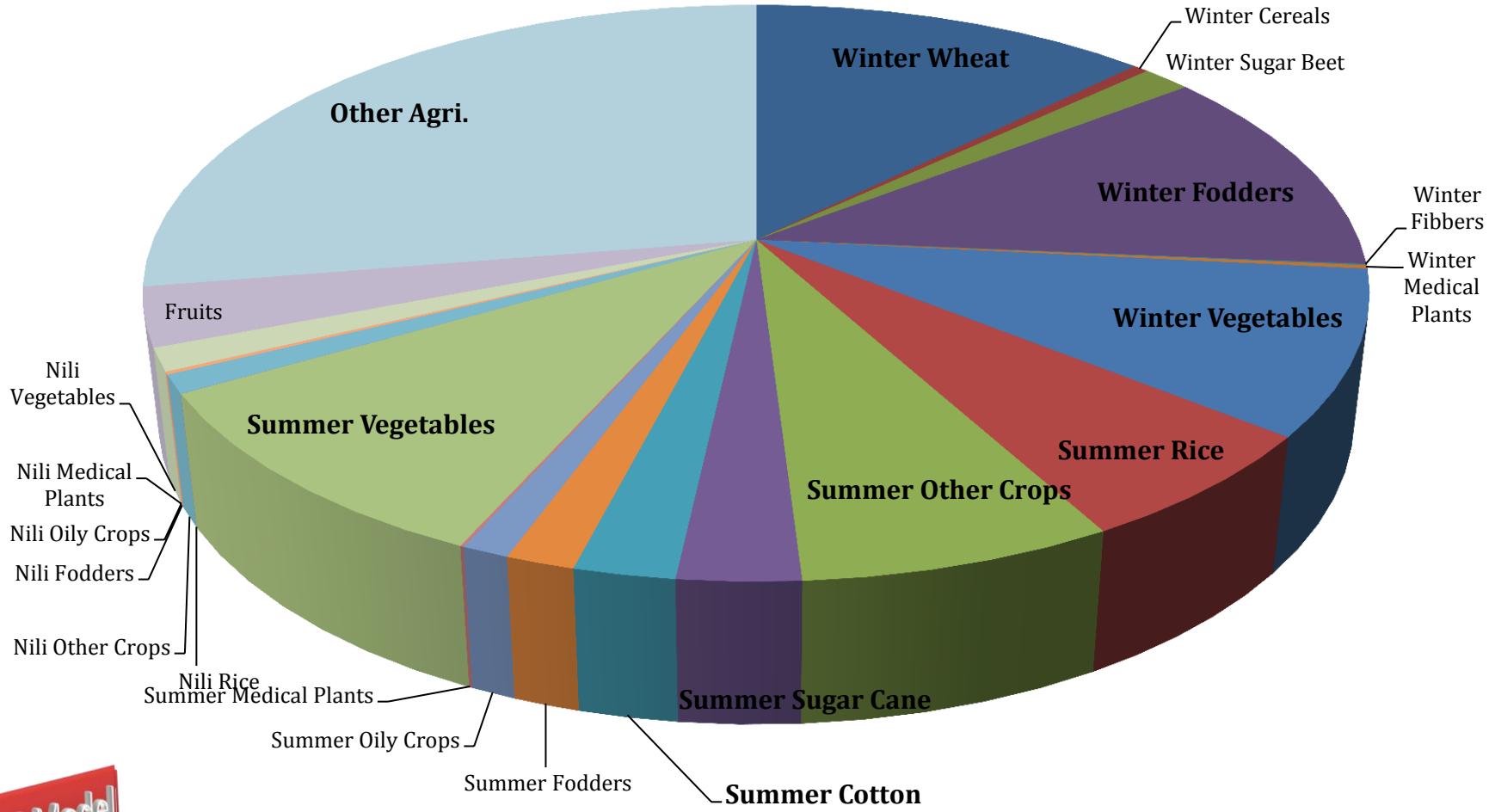
STAGE Model

Concluding Remarks

- Strong positive economy-wide impacts; the planned investments in water quality improvements are worthwhile even with very low generated crop yields.
- Without increasing irrigation water requirements, Egypt can achieve outstanding expansions in rice output and exports.
- This highlights the importance of by investing in improving irrigation water quality for the overall economy.

Thank you – feedback is appreciated!

BL Agricultural Structure



STAGE Model

	Land %	Water %	Water /Land Ratio	Water Intensity (million m3/1000 ton)
Winter Field Crops				
Wheat	20.0	9.7	0.2	0.5
Cereals	1.0	0.4	0.1	0.7
Sugar Beet	2.0	1.1	0.1	0.1
Fodders	13.0	20.0	0.5	0.2
Fibbers	0.0	0.1	0.2	0.7
Medical Plants	0.0	0.1	0.1	0.3
Vegetables	6.0	2.4	0.1	0.1
Summer Field Crops				
Rice	9.0	23.0	0.8	1.9
Other Crops	14.0	13.7	0.3	1.0
Sugar Cane	2.0	5.9	0.9	0.2
Cotton	3.0	2.2	0.2	1.2
Fodders	4.0	3.3	0.2	0.2
Oily Crops	2.0	0.8	0.1	1.2
Medical Plants	0.0	0.1	0.3	0.3
Vegetables	10.0	3.6	0.1	0.1
Nili Field Crops				
Rice	0	0.0	0.04	0.12
Other Crops	2	3.3	0.43	1.56
Fodders	1	0.0	0.00	0.00
Oily Crops	0	0.0	0.06	1.14
Medical Plants	0	0.2	0.18	0.39
Vegetables	1	1.2	0.26	0.26
Year-round Crops				
Fruits	8	8.9	0.3	0.4

BL Factor Intensity by Agricultural Activity (Percent)

	Labour	Capital	Nile-land	Nile-water	Ground-land	Ground-water	Rainfed-land	Total
Winter Wheat	13.8	56.4	20.0	3.4	1.8	0.2	4.5	100
Winter Cereals	22.2	29.8	34.6	4.6	1.3	0.0	7.5	100
Winter Sugar Beet	12.3	64.2	16.9	2.8	0.0	0.0	3.8	100
Winter Fodders	2.5	83.7	6.0	5.1	0.4	0.0	2.2	100
Winter Fibbers	14.4	59.0	18.4	3.8	0.1	0.0	4.3	100
Winter Medical Plants	10.2	68.7	15.3	2.2	0.2	0.0	3.4	100
Winter Vegetables	7.7	84.1	5.8	0.8	0.4	0.1	1.3	100
Summer Rice	13.8	54.1	6.1	20.6	0.1	0.0	5.2	100
Summer Other Crops	23.1	47.0	17.0	7.4	0.6	0.1	4.7	100
Summer Sugar Cane	11.4	70.1	2.3	13.1	0.1	0.0	3.1	100
Summer Cotton	24.7	59.0	10.9	2.7	0.0	0.0	2.6	100
Summer Fodders	4.8	77.8	9.7	2.7	2.2	0.4	2.4	100
Summer Oily Crops	15.1	62.5	15.6	2.4	1.0	0.0	3.4	100
Summer Medical Plants	12.1	64.6	14.6	5.0	0.0	0.0	3.8	100
Summer Vegetables	11.4	74.3	10.4	1.3	0.4	0.1	2.2	100
Nili Rice	11.4	54.3	13.4	0.5	17.6	0.2	2.7	100
Nili Other Crops	23.0	47.2	12.9	9.9	2.3	0.2	4.4	100
Nili Fodders	5.5	76.9	10.9	0.0	4.5	0.1	2.1	100
Nili Oily Crops	18.4	39.7	30.4	1.8	3.6	0.0	6.1	100
Nili Medical Plants	11.8	56.4	5.3	21.2	0.0	0.0	5.3	100
Nili Vegetables	11.4	73.6	8.5	2.9	1.3	0.1	2.2	100
Fruits	14.4	63.2	9.5	4.7	4.8	3.4	0.0	100
Other agri forestry fishing	58.0	42.0	0.0	0.0	0.0	0.0	0.0	100

BL Factor Shares in Agricultural Value Added (Percent)

	Labour	Capital	Nile-land	Nile-water	Ground-land	Ground-water	Rainfed-land
Winter Wheat	12.9	12.6	29.8	10.7	27.2	9.7	25.2
Winter Cereals	0.7	0.2	1.8	0.5	0.7	0.0	1.4
Winter Sugar Beet	1.4	1.8	3.1	1.1	0.1	0.0	2.6
Winter Fodders	2.5	20.1	9.7	17.3	7.4	2.3	13.1
Winter Fibbers	0.1	0.1	0.2	0.1	0.0	0.0	0.1
Winter Medical Plants	0.2	0.3	0.4	0.1	0.1	0.0	0.3
Winter Vegetables	5.9	15.5	7.1	2.0	5.2	2.4	5.8
Summer Rice	6.2	5.8	4.4	30.7	0.9	0.0	14.0
Summer Other Crops	11.2	5.5	13.3	12.1	5.2	2.6	13.8
Summer Sugar Cane	2.2	3.3	0.7	8.5	0.3	0.0	3.6
Summer Cotton	4.0	2.3	2.8	1.5	0.0	0.0	2.5
Summer Fodders	0.7	2.6	2.2	1.3	5.2	3.0	2.0
Summer Oily Crops	1.3	1.2	2.1	0.7	1.3	0.1	1.7
Summer Medical Plants	0.1	0.1	0.1	0.1	0.0	0.0	0.1
Summer Vegetables	8.5	13.3	12.4	3.2	5.0	2.1	10.0
Nili Rice	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Nili Other Crops	1.8	0.9	1.6	2.5	2.9	0.9	2.0
Nili Fodders	0.1	0.3	0.3	0.0	1.2	0.1	0.2
Nili Oily Crops	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nili Medical Plants	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nili Vegetables	1.3	2.0	1.6	1.1	2.4	0.5	1.5
Fruits	6.2	6.5	6.5	6.6	34.1	76.2	0.0
Other agri forestry fishing	32.8	5.7	0.0	0.0	0.0	0.0	0.0
Agr. Value Added	100	100	100	100	100	100	100