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Water Scarcity and Irrigation Efficiency in Egypt

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Abstract

Examining the potential implications of changes in irrigation efficiency associated with improvements in water quality is crucial for the Egyptian economy. This study provides quantitative assessments for the impact of quality enhancements of different types of irrigation water under water scarcity conditions using a single country CGE (STAGE) model that is calibrated using a new SAM for Egypt. The SAM segments the agricultural accounts by season and by irrigation technology; Nile water-dependent and groundwater-dependent agricultural activities. The simulation results show that Egypt should be able to manage the potential reductions in the supply for Nile water with more efficient irrigation practice that secures higher productivity for Nile water, groundwater and irrigated land. *The results however suggests more ambitious plan to boost irrigation efficiency for summer rice in order to overweight any potential shrinkages in its output and exports. Furthermore, the findings show that even doubling all non-conventional water resources is not sufficient to compensate the potential adverse impacts of Nile water losses. This highlights the critical importance of irrigation efficiency for the Egyptian economy.*

Introduction

Water scarcity is problematic in Egypt. Water availability per capita rate is already one of the lowest in the world. This is suggested for further declines. A major challenge is to close the rapidly increasing gap between the limited water resources and the escalating demand for water from various economic sectors.

Nile is the main source of freshwater in Egypt, with a share of more than 95%. The storage reservoir of Nasser Lake provides 56 billion m^3 (hereinafter referred to BCM) per annum. The issue of Egypt's share of Nile waters is under difficult negotiations. In April 2011, Ethiopia has launched the construction of the Grand Ethiopian Renaissance

Dam, GERD. With water storage capacity of 63 BCM and energy generation capacity of 6,000 MW, the GERD is anticipated to be the biggest hydroelectric power plant and one of the largest water reservoirs in the continent. Egyptian experts give indications of 20-34% water reduction when the filling period overcuts the drought period. This is estimated to be 11-19 BCM on average over the Dam's filling period.

Shortage of fresh water resources and/or poor quality of these resources would have outstanding impacts on agricultural activities and the whole economy. Agriculture plays a significant role in the Egyptian economy and it is the main consumer for fresh water resources. Agriculture's share of GDP has been the largest among individual sectors, contributing about 20% of GDP. It absorbs around 34% of employment. The agricultural exports account for 13% of total exports. Agriculture consumes about 85% of the annual total water resource. More than 70% of the cultivated area depends on low-efficiency surface irrigation systems, which cause high water losses, a decline in land productivity, waterlogging and salinity problems. Moreover, unsustainable agricultural practices and improper irrigation management affect the quality of the country's water resources. Reductions in irrigation water quality have, in their turn, harmful effects on irrigated soils and crops.

Water Scarcity and Water Quality in Egypt

Water issue in Egypt is twofold - the increasing gap between demand and supply and the deterioration of water quality. As Claudia Bürkin explains, Egypt faces two main challenges: water loss and poor water quality.[2] "Egypt loses about 50% of its freshwater through poor maintenance of supplies and distribution problems, and the water is polluted," she says, stressing that a significant number of diseases are water borne. Polluted water also affects the ecosystems' balance, the soil quality, and seeps into the aquifers. "Egypt needs to set up strong standards for water quality and control the drainage nutrients, pesticides and waste found in the water." (Sarant, 2013)

It is worth noting here that water loss and deteriorating water quality are interlinked. Water available for specific purposes is constrained by its quality, on one

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[2] Claudia Bürkin is the Water Sector Coordinator for the German Development Cooperation and Senior Programme Manager at KfW Development Bank.

hand, and increasing demand for limited water resources might cause degradation in quality. Growing population and slum areas, industrial activities, urbanization, pollution and climate changes adversely affect water quality. Furthermore, higher water quality implies less risk of water shortage at a given level of output. Besides, higher water quality leads to higher marginal productivity of other agricultural factors, land in particular.

It is thus crucial for Egypt to form comprehensive strategy that aims at enhancing water supply from both conventional and non-conventional resources as well as preserving water quality. There is an urgent need to gain more insights into water quality and its implication for agricultural productivity.

"… one of the main components of the agricultural development strategy is to achieve a gradual improvement of the efficiency of irrigation systems to reach 80 per cent in an area of 8 m feddans, and to reduce the areas planted to rice from 1.673 m feddan (2007) to 1.3 m feddan by 2030 in order to save an estimated 12 400 million cubic meters of water", (FAO, 2013, p. 13).[3]

The study aims at examining the potential implications of changes in irrigation efficiency associated with improvements in water and land quality. It provides quantitative assessments for the impact of quality enhancements of different types of irrigation water under water scarcity conditions. The simulation results inform answers for several research questions. How significant are potential effects of Nile water reductions on the agricultural sector and the whole economy likely to be? What are the sufficient enhancements in irrigation efficiency required to compensate the potential losses of Nile water? Is investing in securing non-conventional water resources, actually, a viable alternative strategy to the irrigation efficiency strategy?

Irrigation Water Map

This section portrays the irrigation water state in Egypt.

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[3] Feddan is a non-metric measurement unit of land area used in Egypt, inter alia. A feddan is equivalent to 1.037 acres, 0.420 hectares or 4,220 m2.

Table 1 portrays different sources for irrigation water whereas Figure 1 locates land irrigated by these water sources.

Conventional Water Resources

1. Nile Water

Nile is the main source of freshwater in Egypt, with a share of more than 95%. Nile water accounts for virtually 80% of irrigation requirements. This water source mainly serves irrigated land in Nile Valley and Nile Delta, which together constitute 85% of total irrigated land. In 2008/09, total water resources reach 74.2 BCM and total irrigated land was 8.7 million feddans.

> "Egypt's Nile Valley irrigation system (NVIS) is an excellent example of a multiple use-cycle system with a high global efficiency but low local efficiencies. Egypt is interested in expanding the area irrigated by Nile River waters without reducing the high productivity of the present irrigated areas. To accomplish this will require an aggressive conservation program. However, directing conservation efforts toward areas where multiple use-cycles are possible, and thus [Effective efficiency] is already quite high, will result in little real water savings", (Keller & Keller, 1995, p. 6).

Table 1: Available and Potential Irrigation Water Resources

Source	**Usage**		**Availability**	
	Billion m3/Annum	%	Billion m3/Annum	%
Nile Water	51.7	82.59	55.5	75.2
Groundwater	5.2	8.3	11.3	15.3
Drainage Water	3.7	5.91	5	6.8
Treated Sewage Water	1.5	2.4	1.5	2.03
Rain	0.5	0.8	0.5	0.67
Total	**62.6**		**73.8**	

2. Ground Water

Ground water is the second largest water source available for irrigation. It accounts for 8% of the total irrigation water. Groundwater-dependent agricultural activities attributes to 11% of total irrigated agricultural production. Moreover, it is effectively the sole source of water in areas like Sinai, Western North Coast (Matruh) and Western Desert and the New Valley. Table 2 shows groundwater usage and land irrigated by groundwater in Aresh – North Sinai.

Egypt has large potentials for groundwater estimated to be 7.5 BCM in 2009 (UNSTAT Database). The volume of groundwater entering the country on an annual basis from Sudan is estimated at 1 BCM. The main source of internal recharge is percolation from irrigation water, and its quality depends mainly on the quality of the irrigation water. The groundwater in the shallow Nile aquifer cannot be considered an independent resource of water as it is renewed only by seepage loses from the Nile, irrigation canals and drains, and deep percolation from irrigated lands. Deep groundwater is found in large aquifers in the Western Desert. However, it is found at great depths and is generally considered a non-renewable resource.

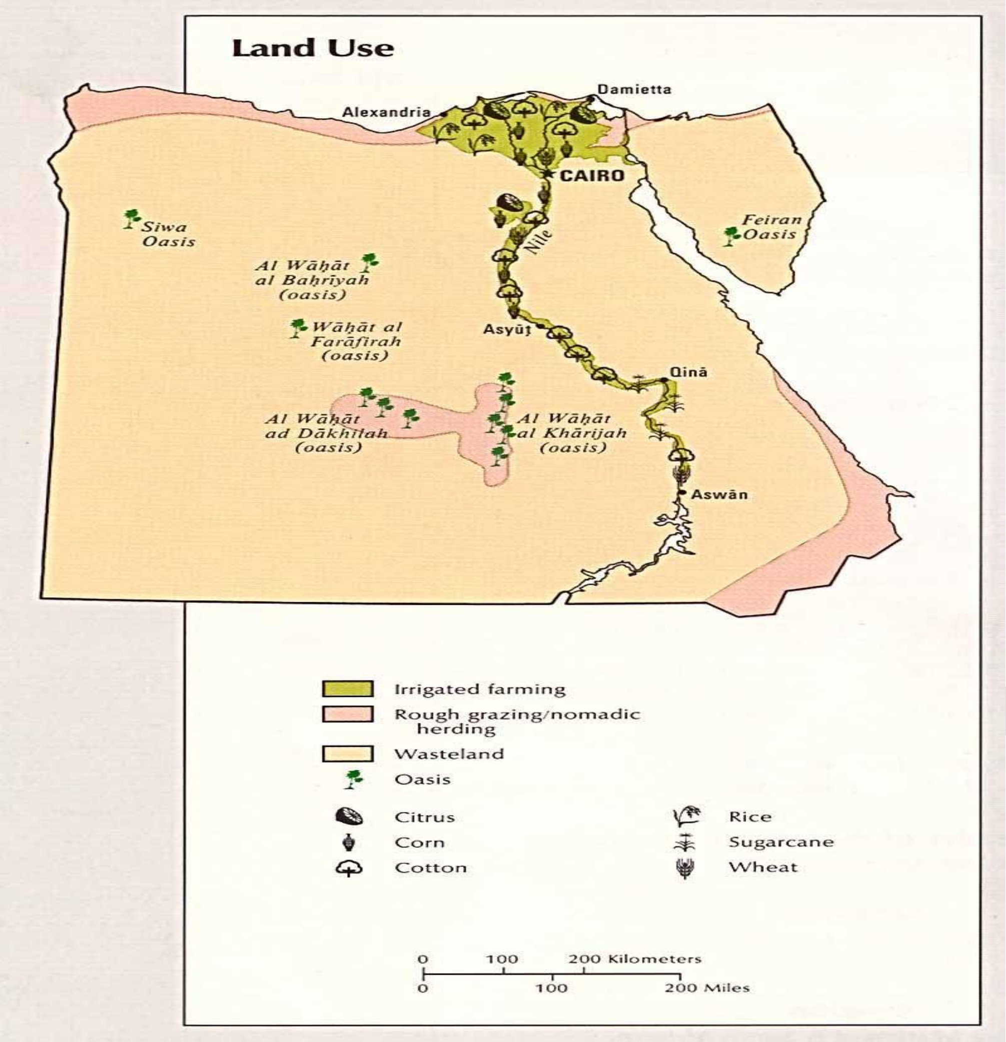
3. Rainfall Water

Egypt has no effective rainfall except for a narrow strip along the northern coastal area where the average rainfall does not exceed 200 mm (about 1.5 BCM/year). This amount of rainfall cannot be considered a reliable source of water due to its spatial and temporal variability.

Land irrigated by rainfall water locates mainly alongside the Mediterranean shore between Al-Salloum in the west, near the Libyan border, and Rafah in the east, along the border with the Palestinian Territories. Besides, 251,000 feddans are irrigated in Sinai depending on seasonal rains.

Around 150 thousand feddan in the Western North Coast irrigated by rainfall is cultivated in cereals, legume, vegetables and fruits. The Northern coastal region depends mainly on winter rainfall. This area is extremely vulnerable to drought and thus supplementary irrigation is required to improve the crop productivity in this region, Abdrabbo et al. (2012, pp. 29-33). One suggestion to secure the required irrigation water for the region is by saving 5 BCM of the Nile water wasted in the sea (M., 2011). For detailed explanation of water harvesting and supplemental irrigation, see (Oweis, Hachum, & Kijne, 1999, pp. 19-26).

Figure 1: Irrigated Land Use



Source: (El-Nahrawy, 2011)

Non-conventional Water Resources

1. Recycled Drainage Water

Annual drainage water utilized in agriculture is estimated to be 4.7 BCM in 2008/09 with impressive potentials to reach 10 BCM over a span of ten-years. Drainage water is evenly mixed by Nile water and reused in irrigating 450 thousand feddan in North Sinai (East Suez Canal).

2. Treated Sewage Water

Treated sewage water used in irrigation is 1.67 BCM in 2000 with estimations to reach 2.4 BCM in 2027.

Table 2: Groundwater Usage

Area	Number of Wells	Salination	Usage		Withdraw m3/day	Current Cultivated Area (feddan)		
			Drinking Water	Irrigation Water		Field Crops	Vegetables	Fruits
East Aresh	403	2500	69	394	60855	31800	23046	17979
Aresh Delta	151	3000-4000			81800	20416	23210	25185
West Aresh	662	2500-3000			38000	28950	2832	3129

Irrigation Water Quality and Land Productivity

It is worth noting here that the conventional definition of efficiency for a given input is measured by the generated output. Keller and Keller (1995) demonstrate that the classical definition of irrigation water efficiency is applicable to examining irrigation design and management but is not precise in the case of studying water allocation. Failure to consider the inevitable water discharge, which occurs during irrigation in form of runoff or seepage, and the recycled drainage water leads to ill-defined measure of efficiency. For the purpose of this study, it is appropriate to use productivity as an approximate for efficiency.

Agricultural activities and the associated drainage network contribute to water quality deterioration in Egypt. Covering the whole Nile Valley and Delta, the drainage network discharges wastes into the Nile mainstream or the northern lakes and sea coast. This irrigation misconduct affects water quality through three channels: changing salinity level, adding chemical fertilizers and pesticides to irrigation water and eutrophication of water bodies. ((RIGW), 1996). The various pollution loads led to significant water quality degradation, Table 3.

Table 3: Recycled Drainage Water in the Nile Delta 2000/2001

(BCM per annum)

Salinity Level	**East Delta**	**Middle Delta**	**West Delta**	**Delta**
< 750	0.664	0.085	0.575	1.324
750-1000	0.422	0.458	0	0.88
1000-1500	0	1.416	0.067	1.483
1500-2000	0.744	0	0	0.744
2000-3000	0	0	0.416	0.416
Total	**1.83**	**1.959**	**1.058**	**4.847**

Source: Drainage Research Institute (2004)

“In Egypt, perhaps the most critical factor in predicting, managing, and reducing salt-affected soil is the quality of irrigation water being used (The main sources of the salinity in the Delta soils are irrigation water, Mediterranean saline water and the high level water table). Besides affecting crop yield and soil physical conditions, irrigation water quality can affect fertility needs, irrigation system performance and longevity, and how the water can be applied. Therefore, knowledge of irrigation water quality is critical to understanding what management changes are necessary for long-term productivity”, (Noureldeen, 2013, pp. 1-2). Table 4 provides quantitative estimations for potential yield reductions due to increases in salinity level of irrigation water.

Table 4: Potential Yield Reduction from Saline Water

Crop	Yield Reduction (%)			
	0%	10%	25%	50%
	EC_w			
Barely	5.3	6.7	8.7	12
Wheat	4	4.9	6.4	8.7
Sugarbeet*	4.7	5.8	7.5	10
Alfalfa	1.3	2.2	3.6	5.9
Potato	1.1	1.7	2.5	3.9
Corn (grain)	1.1	1.7	2.5	3.9
Corn (silage)	1.2	2.1	3.5	5.7
Onion	0.8	1.2	1.8	2.9
Dry Beans	0.7	1	1.5	2.4

Updated SAM for the Egyptian Economy

A new Social Accounting Matrix (SAM) for Egypt in 2008/2009 is developed and updated as part of this project. Data are mainly based on the most recent (Central Agency for Public Mobilization and Statistics (CAPMAS), 2010). In addition, data for institutional sector accounts are collected from (Ministry of Planning (MOP), 2011). Data for detailed agricultural crops by irrigation seasons are compiled from the most recent issues of Bulletin of Agricultural Statistics. In addition, data on agricultural cost and return is the most recent issues of Bulletin of Agricultural Prices, Costs and Net Returns. Data on water requirements are compiled from (The Central Agency for Public Mobilisation and Statistics, December 2009). It is worth noting here that water requirement refers to blue water only.

Table 5: SAM Accounts, Egypt 2008/2009

No	SAM Activity	No	SAM Activity	No	SAM Activity
1	Winter Wheat	19	Nili Oily Crops	37	Education
2	Winter Cereals	20	Nili Medical Plants	38	Social Services
3	Winter Sugar Beet	21	Nili Vegetables	39	Arts Entertainment
4	Winter Fodders	22	Fruits	40	Other Services
5	Winter Fibbers	23	Other Agriculture, Forestry, Fishing	41	Financial Services
6	Winter Medical Plants	24	Mining	42	Insurance
7	Winter Vegetables	25	Manufacturing	43	Public Services
8	Summer Rice	26	Electricity gas	44	Defence
9	Summer Other Crops	27	Water Supply	45	Public Safety
10	Summer Sugar Cane	28	Construction	46	Economic Affairs
11	Summer Cotton	29	Trade	47	Environmental Protection
12	Summer Fodders	30	Suez Canal	48	Housing and Community Amenities
13	Summer Oily Crops	31	Transportation	49	Health
14	Summer Medical Plants	32	Accommodation Services	50	Recreation, Culture and Religion
15	Summer Vegetables	33	Information Communication	51	Education
16	Nili Rice	34	Real Estate	52	Social Protection
17	Nili Other Crops	35	Professional Services	53	Non-profit Activities Serve HH
18	Nili Fodders	36	Administrative Services	54	Subsistence HH Activities
No	**SAM Commodity**	**No**	**SAM Commodity**	**No**	**SAM Factors**
1	Wheat	9	Food Products	1	Labour
2	Cereals	10	Other Transportable Goods	2	Capital
3	Rice	11	Metal machinery equipment	3	Winter Nile-dependent Land
4	Vegetables	12	Construction	4	Summer Nile-dependent Land
5	Fruits	13	Trade	5	Nili Nile-dependent Land
6	Coffee Tea	14	Financial Services	6	Year-round Nile-dependent Land
7	Other Agriculture Forestry Fi	15	Business Services		
8	Ores Minerals Gas	16	Social Services		
No	**SAM Factors**	**No**	**SAM Factors**	**No**	**SAM Factors**
7	Winter Nile Water	11	Winter Groundwater-dependent Land	15	Winter Ground Water
8	Summer Nile Water	12	Summer Groundwater-dependent Land	16	Summer Ground Water
9	Nili Nile Water	13	Nili Groundwater-dependent Land	17	Nili Ground Water
10	Year-round Nile Water	14	Year-round Groundwater-dependent Land	18	Year-round Ground Water

Data on agricultural trade are compiled from (Ministry of Industry and Foreign Trade & Egyptian International Trade Point (EITP), 2008-2009). It is worth mentioning that agricultural trade data is sourced from Central Agency for Public Mobilization and Statistics (CAPMAS).

Cross entropy method is used to balance the original SAM and then to disaggregate the agricultural activity and commodity. Aggregates from national accounts and supply/use tables are used to control the transaction values for the disaggregated SAM. Final SAM includes 54 activity accounts, 16 commodity accounts and 18 production factor accounts. Table 5 portrays the basic account in the Egyptian SAM.

Single Country STAGE CGE Model

This study uses a comparative static variant of the single-country CGE STAGE model.[4] In this version (i.e. STAGE-WL) of the model, a CES nest is added to the production function representing derived demand for Nile water and land as well as other sources of irrigation water.

Production Specification

As depicted in Figure 2, production relationships for agricultural activities are specified through five level CES function. At the top level, value added and intermediate demand are combined using a CES aggregator. At the second level of the nest, a CES production technology specifies the aggregate value added as a function of primary inputs demand in each activity. The primary inputs are capital, labour and aggregate water/land for agriculture. By maximizing profit, farmers determine the optimal supply level of crops output according to the production technology prevailing in each activity. This *per se* specifies their derived demand levels for production factors. Farmers demand a production factor at the level that equalizes the value of its marginal product with its wage rate in each activity.

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[4] STAGE model, described in detail in McDonald S. (2007), is a descendant of the USDA ERS model (Robinson, Kilkenny, & Hanson, 1990).

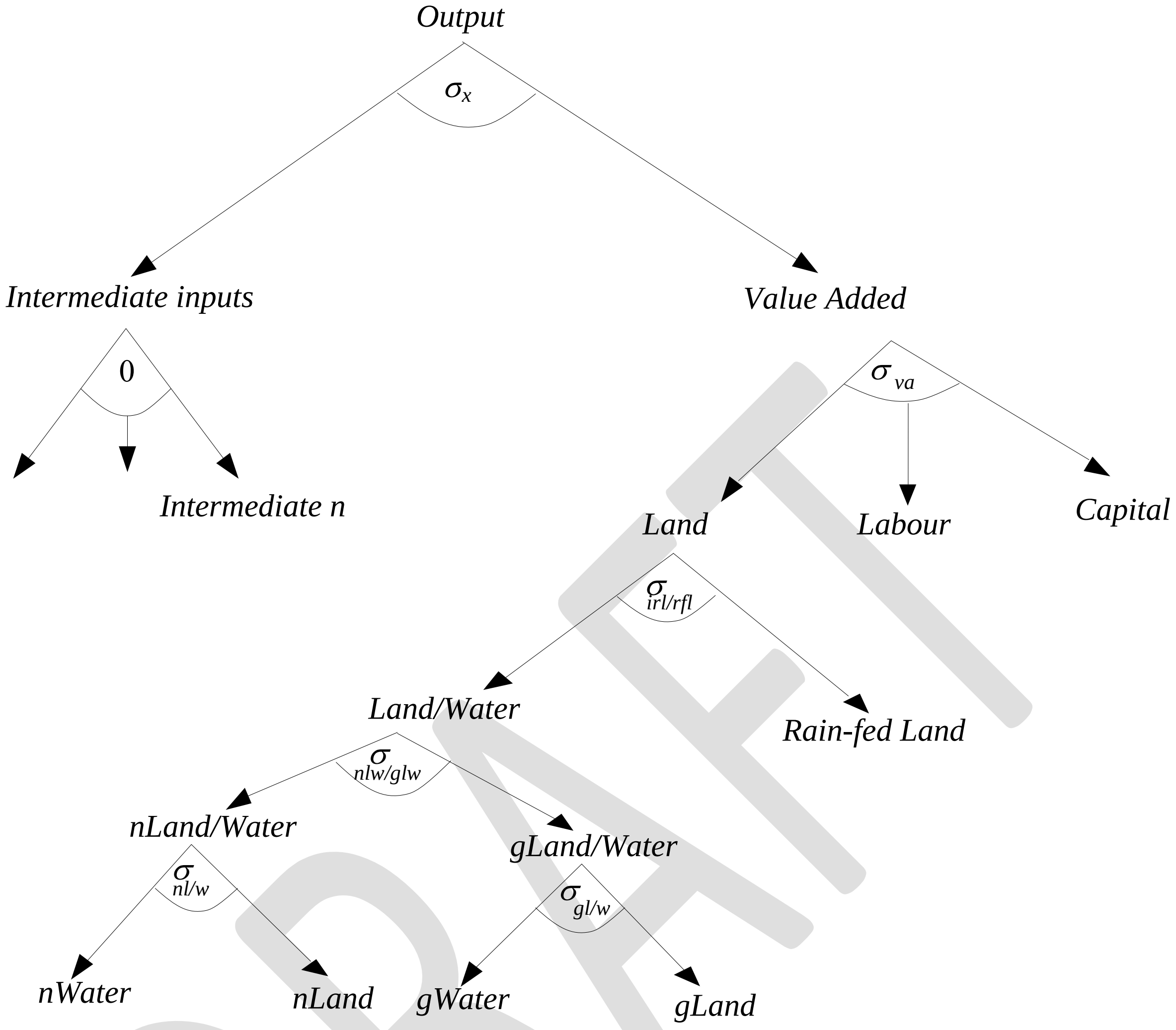
For the purposes of this study, aggregate land for agriculture is composite of irrigated land and rain-fed land. At the third level of the agricultural production function, rain-fed land and composite irrigated land are combined through a CES aggregator. Composite irrigated land is land irrigated by either Nile water or groundwater.

The model is developed to segment groundwater-dependent agricultural activities from Nile water-dependent agricultural activities. At the fourth level of the agricultural production function, Nile land/water composite and groundwater land/water composite are combined through a CES aggregator. This allows for specifying different levels of substitutability between these two types of irrigated land. Both types of irrigated land are mobile across crops subject to changes in the ratios for land rent in each activity to the average land rent.

At the bottom level, water and land are combined according to two CES aggregators – each for Nile water-dependent and for groundwater-dependent activities. The greater the irrigation water quality available for specific activities, the lower is the water price, and the higher is the land rent. The price for composite irrigated land/water changes depending, *inter alia*, on the prevailing irrigation technology. The latter is measured by factor intensity for irrigated land and water. The activities with increasing irrigated land/water price withdraw irrigated land/water from other activities according to the elasticity of substitution between the two types of irrigated land: Nile water-dependent land and groundwater-dependent land. Excess irrigated land supply pushes irrigated land rent to drop in order to clear the market. The farmers utilize irrigated land at the level that equalizes the value of its marginal product with its rent rate in each activity. This *per se* specifies the optimal level of derived demand for irrigated land.

Three points worth highlighting here. Firstly, the model is flexible in the sense that it allows for specifying Leontief fixed coefficient at the different levels of the water/land production nest. Secondly, the model specifies physical supply constraints for water and the two types of land. Demand volume transactions for both land (by thousand feddan) and water by agricultural activities are employed as upper limits for total supply of water and land. Also, water supply activity deals with non-agricultural uses of water.

Figure 2: Agricultural Production Flows in STAGE-WL CGE Model



The model assumes no distribution cost of irrigation water. Under an additional closure rule, the model sets production volumes to be fixed at their baseline levels. This is applied at the third level of the CES production function for all agricultural activities except 'Other Agriculture Forestry Fishery'. This specification allows endogenously quantifying changes in efficiency required to offset the water losses keeping agricultural output unchanged. Under different levels of water loss, generated changes in efficiency are measured for the land/water composite production factor.

<u>Model Closure Rules</u>

Egypt is a small country in the world market. It is, thus, plausible to fix world prices for exports and imports. The model assumes that current account balance is fixed at its initial benchmark level. To clear the external balance, real exchange rate is allowed to adjust.

The model adopts investment-driven closure in the sense that saving rate adjusts to generate the required savings to finance the baseline investment. Foreign saving is, exceptionally, specified as exogenous.

Capital is specified to be mobile and fully employed. Labour is mobile, albeit under employed. Water and land, for both Nile water-dependent and groundwater-dependent activities, are fully employed, but season-specific. For the purposes of this study, water and land supply are set to be fixed for each irrigation season. Thus, water and land are allowed to be mobile across agricultural activities within each irrigation season but not across different seasons.[5] This specification implies that water and land would have seasonal prices.

Simulation Scenarios

The simulation scenarios distinguish irrigation systems according to different levels of irrigation efficiency. For agricultural activities producing the same crop, water quality and, hence, land productivity varies according to the employed irrigation system: Nile water-dependent versus groundwater-dependent. This paper reports four main simulation scenarios:

1. N-Wtr Loss: Nile Water Loss

The first scenario simulates the Nile water loss in isolation, which reflects the upper limit of potential reductions of Egypt's share of Nile water. It assumes a 34% reduction in Nile water supply evenly spread across irrigation seasons.

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[5] The elasticity of substitution between water and land are based on estimations (provided by Calzadilla et al. (2011)) for Middle-East countries which are equal to 0.06.

2. Irrg-Eff: Irrigation Efficiency

The second scenario considers improvements of irrigation efficiency. An external shock of 30% increase in irrigation efficiency is simulated. For better interpretation of the determinants of the results, this scenario is decomposed into two components according to the source of the simulated irrigation efficiency: Nile water-dependent irrigation (Nile Irrg-Eff) and groundwater-dependent irrigation (Ground Irrg-Eff).

The point to mention here is that the model does not specify the underlying source for funding the simulated improvements in irrigation efficiency. That is to say, government expenditure on R & D, for example, is not explicitly specified by the model.

3. N-Wtr Loss & Irrg-Eff: Nile Water Loss & Irrigation Efficiency

The third scenario combines the simulated 34% reduction in Nile water with the 30% improvement in irrigation efficiency. This comprehensive scenario provides quantitative assessments for the impact of quality enhancements of different types of irrigation water under water scarcity conditions.

4. X-Wtr Gain: Non-conventional Water Gain

The last scenario assumes *ceteris paribus* more non-conventional water resources are secured to compensate the simulated reductions in Nile water. It implicitly represents the case in which Nile water loss is compensated by increases in recycled drainage water and treated sewage water. As discussed earlier, the potential average increase in these two water resources is estimated to be 95%.[6] Due to lack of data, an increase in ground water is simulated as a proxy for potential increases in all other non-conventional water resources. Ground water used in irrigation is roughly equivalent to both recycled drainage and treated sewage water combined, see

Table 1. This scenario thus represents a 95% increase in ground water supply across different irrigation seasons.

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[6] This is weighted according to their current shares of total irrigation water.

Table 6: Macroeconomic Indicators (Real percentage change)

	N-Wtr Loss	Efficiecny			N-Wtr Loss & Irrg-Eff	X-Wtr Gain
		Nile Irrg-Eff	Ground Irrg-Eff	Irrg-Eff		
private consumption	-0.30	0.53	0.03	0.55	0.26	0.02
government consumption	0.03	-0.06	0.00	-0.06	-0.03	0.00
investment consumption	-0.13	0.22	0.01	0.23	0.10	0.02
absorption	-0.23	0.41	0.02	0.43	0.20	0.02
import demand	-0.16	0.11	0.00	0.10	-0.07	0.04
export supply	-0.25	0.23	0.00	0.24	-0.03	0.06
GDP from expenditure	-0.26	0.45	0.02	0.47	0.22	0.02
total domestic production	-0.32	0.56	0.03	0.59	0.27	0.02
total intermediate inputs	-0.42	0.72	0.04	0.75	0.34	0.02

Source: model results.

Simulation Results

Macro-economic Impacts

At the economy-wide level, slight negative impact is reported under the N-Wtr Loss scenario, Table 6. The simulated irrigation efficiency generates around 0.5% increases in GDP and total absorption. Potential increases in non-traditional water resources induce trivial positive economy-wide impacts.

The reported positive effects generated under the Irrg-Eff scenario imply that the simulated 30% improvement in irrigation efficiency is virtually sufficient to offset the potential 34% loss in Nile water supply. The results are primarily driven by the simulated enhancement in Nile water-dependent irrigation efficiency. This is attributed to the major importance of the Nile water-land for agriculture as a whole and irrigated agricultural in particular. Nile water/land accounts for virtually 15% of total agricultural value added and 90% of total irrigated agriculture. Ground water and land irrigated by ground water have small shares in total agricultural value added (less than 2%) and in total irrigated agriculture (8%).

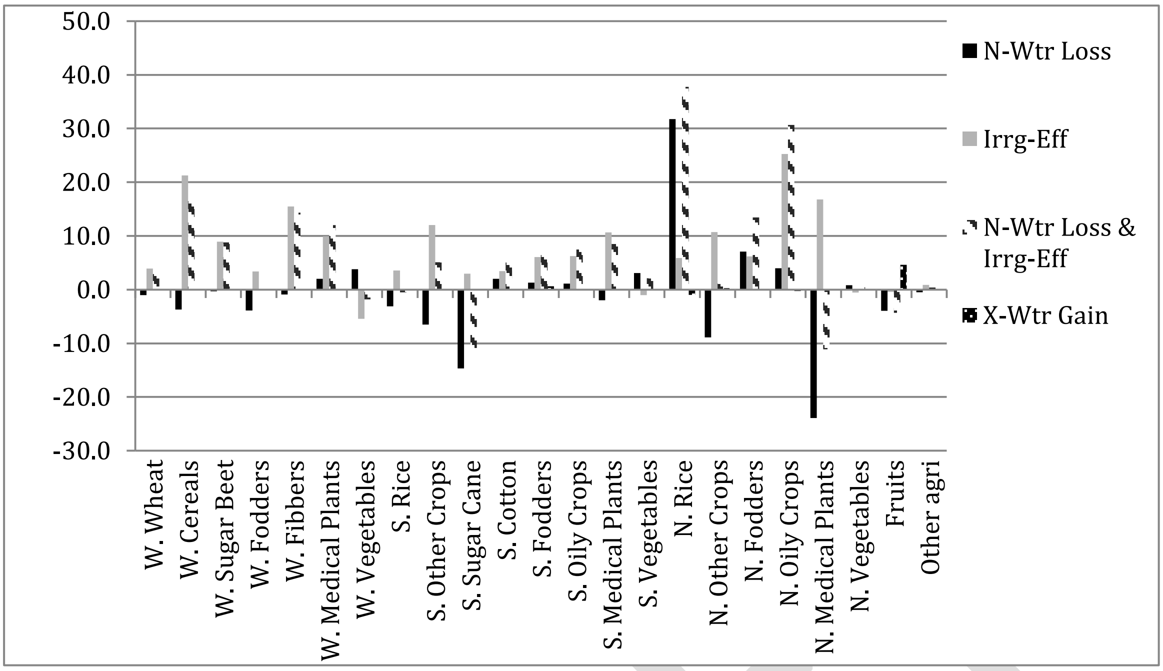
Sector-specific Impacts

At the sectoral level, reductions in Nile water availability have noticeable adverse impacts on summer agricultural production, Figure 3. This is particularly the case for rice, other crops and sugar cane. Other sectors expand (e.g. winter and summer vegetables) under the N-Wtr Loss scenario. Improving Nile water-dependent irrigation efficiency generates positive effects for sectors like winter cereals and summer other crops whereas all seasonal vegetables sectors shrink. The simulated increases in non-conventional water resources boost the fruits sector.

Rice is of a great importance to the Egyptian economy. This sector solely contributes more than 6 percent of total agricultural production. Furthermore, it is one of the main exporting sectors. Rice is cultivated mainly in the summer season with only 0.4% of total rice output grows in the Nili season. This water-intensive crop solely consumes more than 30% of annual irrigation Nile water and more than half of summer Nile water.

The N-Wtr Loss scenario has a strong negative impact (-20%) on rice exports. Under the comprehensive N-Wtr Loss & Irrg-Eff scenario, rice exports drop by only 4%. Improving Nile water-dependent irrigation efficiency boosts rice output (by 4% in the summer and 6% in the Nili seasons) without increasing irrigation water requirements. Furthermore, combining irrigation efficiency with Nile water loss mitigates the negative impacts on rice exports, Table 7. Doubling all other non-conventional water resources has negligible impact on summer rice. From this perspective, more ambitious plan to boost irrigation efficiency for this sector is recommended in order to overweight any potential shrinkage in rice output and exports.

Figure 3: Domestic Agricultural Production (Percentage change)



Vegetables comprise 23% of agricultural output evenly circulated over the winter and summer seasons. It roughly consumes 6% of Nile water used in each of the irrigation seasons. Interestingly, winter and summer vegetables output rise under the N-Wtr Loss scenario. According to the factor market clearing conditions, water and land are allowed to move across activities within each irrigation season, but not across seasons. Reduction in water availability pushes the agricultural structure to be more concentrated in less hydro-water crops. As such, the winter and summer vegetable sectors attract excess Nile water and land leading to expansions of 3-4%.

Improving Nile water-dependent irrigation efficiency adversely affects the vegetables sectors in all irrigation seasons. These negative impacts are worse under the comprehensive irrigation efficiency scenario.

Clearly, interpreting these findings requires more detailed analyses for production technology prevailing in the baseline scenario as well as changes in factor prices and rents under the simulation scenarios. The next sub-section addresses these effects.

Table 7: Commodity Exports (Percentage change)

	N-Wtr Loss	Efficiency			N-Wtr Loss & Irrg-Eff	X-Wtr Gain
		Nile Irrg-Eff	Ground Irrg-Eff	Irrg-Eff		
Wheat	-3.95	16.87	1.22	18.16	13.70	0.19
Cereals	-7.18	44.42	1.74	46.82	36.19	0.00
Rice	-19.46	19.78	0.35	20.16	-3.58	-0.05
Vegetables	-3.42	8.81	0.39	9.20	5.46	0.01
Fruits	-6.57	-1.09	-0.06	-1.14	-7.62	7.99
Coffee Tea	-6.26	10.12	0.60	10.71	4.03	0.03
minerals gas	0.56	-0.82	-0.05	-0.86	-0.30	-0.16
Food products	-0.20	0.46	0.02	0.47	0.32	-0.11
Other transportable goods	-0.31	0.60	0.03	0.62	0.35	-0.06
Metal machinery	-0.41	0.75	0.04	0.78	0.42	-0.04
Construction	0.19	-0.29	-0.02	-0.31	-0.11	-0.05
Trade	0.33	-0.49	-0.03	-0.52	-0.18	-0.11
Financial services	0.25	-0.36	-0.02	-0.38	-0.11	-0.08
Business services	0.33	-0.48	-0.03	-0.51	-0.17	-0.10
Social services	0.44	-0.72	-0.04	-0.75	-0.31	-0.09

Source: model results.

Water and Irrigated Land Prices

Under the Nile Irrg-Eff scenario, Nile water and Nile water-dependent land rents drop as they become more efficient.[7] The expanding activities (e.g. winter cereals, summer rice, summer other crops and cotton) withdraw the mobile factors (i.e. labour, capital, year-round Nile water and year-round Nile-water dependent land) from other activities and push their prices and incomes to raise, Table 8.[8]

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[7] Increasing production factor productivity implies higher effective factor endowment, which consequently affects factor demand and price. Within this multi-sector modelling framework, changes in productivity of specific factors/sectors affect demand and price for other factors/sectors through different transmission channels. The higher the factor productivity, the lower is its effective price. Consequently, producers substitute other factors/intermediate inputs by the cheaper factor. Changes in factor productivity entails also lower production cost and, hence, lower price. Consumers gain and their demand increases, which consequently boosts production.

[8] In this general equilibrium framework, the causal relationship between factor demand and factor rents works in two directions. Excess demand for a production factor pushes its average rent to rise in order to clear the market. Simultaneously, producers substitute this factor, which became relatively more expensive, for other factors according the elasticity of substitution at the fourth level of the CES production function.

Table 8: Income Factors (Percentage change)

	N-Wtr Loss	Efficiency			N-Wtr Loss & Irrg-Eff	X-Wtr Gain
		Nile Irrg-Eff	Ground Irrg-Eff	Irrg-Eff		
labour	-0.42	0.78	0.04	0.81	0.41	0.03
capital	-0.40	0.72	0.04	0.75	0.37	0.03
fRfLnd	7.60	-12.18	-0.68	-12.74	-6.15	-0.16
	Nile water-depenent Factors					
winter Nile land	-1.35	-2.52	-0.77	-3.23	-4.51	-0.19
summer Nile land	-2.12	-0.65	-0.45	-1.07	-3.21	-0.11
nili Nile land	-4.13	-0.73	-0.51	-1.22	-5.39	-0.10
Nile land year-round crops	-3.78	0.13	0.01	0.14	-3.57	4.25
winter Nile water	9.91	-2.27	-0.67	-2.88	6.89	-0.17
summer Nile water	6.12	-2.31	-0.30	-2.57	3.27	-0.05
nili Nile water	4.25	1.40	-0.28	1.12	5.49	-0.06
Nile water year-round crops	6.75	0.13	0.01	0.14	6.99	4.25
	Ground water-depenent Factors					
winter Ground land	4.17	-10.95	8.27	-3.55	0.54	3.89
summer Ground land	4.76	-8.98	8.58	-1.14	3.55	4.73
nili Ground land	5.27	-8.85	8.74	-0.89	4.21	2.39
Ground land year-round crops	-3.78	0.13	0.01	0.14	-3.57	4.25
winter Ground water	4.20	-11.57	8.22	-4.26	-0.17	-16.65
summer Ground water	3.60	-8.33	8.51	-0.49	3.14	-15.10
nili Ground water	1.79	-7.61	8.63	0.40	2.45	-17.34
Ground water year-round crops	-3.78	0.13	0.01	0.14	-3.57	-11.78

Source: model results.

Table 10 and Table 11 present factor intensity and factor allocation respectively. The former reflects the prevailing technology in different activities while the latter represents factor usage across activities. These two indicators are essential for understanding any potential change in factor rents and the consequent changes in factor allocation after a policy shock.

Among the agricultural sectors, vegetables have the lowest Nile water/land intensity ratios. Nile water/land intensity ratios for the seasonal vegetables sectors range 6-12%. As such, the vegetables sectors are relatively less Nile water/land-intensive compared to other sectors. Besides, the vegetables sectors occupy small shares of total Nile-water (6.3%) and Nile-land (21%).

The experienced increases in factor prices under the Nile-Irrg Eff scenario entail higher production costs for sectors that are relatively more dependent on these factors.

As such, the seasonal vegetables sectors experience increasing production cost. Hence, these explain the reported shrinkages.

Conclusions and Discussion

The simulation results suggest that Egypt should be able to manage the potential reductions in the supply for Nile water with more efficient irrigation practice that secures higher productivity (30%) for Nile water, groundwater and irrigated land. The results however suggests more ambitious plan to boost irrigation efficiency for summer rice in order to overweight any potential shrinkages in its output and exports. Furthermore, the findings show that even doubling all non-conventional water resources is not sufficient to compensate the potential adverse impacts of Nile water losses. This highlights the critical importance of irrigation efficiency for the Egyptian economy.

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Table 9: Domestic Agricultural Production (Percentage change)

	N-Wtr Loss	Efficiency			N-Wtr Loss & Irrg-Eff	X-Wtr Gain
		Nile Irrg-Eff	Ground Irrg-Eff	Irrg-Eff		
Winter Wheat	-1.03	3.64	0.28	3.90	2.90	0.04
Winter Cereals	-3.72	20.25	0.87	21.26	16.66	0.00
Winter Sugar Beet	-0.30	8.84	0.06	8.90	8.79	0.01
Winter Fodders	-3.87	3.28	0.10	3.38	-0.54	-0.04
Winter Fibbers	-0.92	15.31	0.14	15.48	14.36	-0.01
Winter Medical Plants	2.02	9.81	0.11	9.93	12.05	-0.07
Winter Vegetables	3.78	-5.37	-0.08	-5.45	-1.82	0.00
Summer Rice	-3.13	3.55	0.03	3.59	-0.48	0.00
Summer Other Crops	-6.51	11.72	0.31	12.03	5.09	0.11
Summer Sugar Cane	-14.70	3.25	-0.27	2.98	-11.66	-0.11
Summer Cotton	2.01	3.72	-0.32	3.42	5.45	-0.12
Summer Fodders	1.27	4.72	1.46	6.10	7.46	0.63
Summer Oily Crops	1.14	5.86	0.40	6.23	7.69	-0.15
Summer Medical Plants	-1.98	10.85	-0.21	10.64	8.52	-0.09
Summer Vegetables	3.08	-0.96	-0.07	-1.04	2.15	-0.02
Nili Rice	31.73	-4.02	10.93	5.90	37.78	-0.96
Nili Other Crops	-8.92	9.46	1.26	10.74	1.11	0.29
Nili Fodders	7.05	3.53	2.77	6.16	13.45	-0.11
Nili Oily Crops	3.99	22.63	2.32	25.27	30.66	-0.25
Nili Medical Plants	-23.93	16.95	-0.14	16.81	-11.09	-0.08
Nili Vegetables	0.83	-0.98	0.49	-0.54	0.45	0.02
Fruits	-3.94	-0.38	-0.02	-0.40	-4.28	4.64
Other agri	-0.48	0.84	0.04	0.88	0.43	0.02

Source: model results.

Table 10: 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	100.0
Winter Cereals	22.2	29.8	34.6	4.6	1.3	0.0	7.5	100.0
Winter Sugar Beet	12.3	64.2	16.9	2.8	0.0	0.0	3.8	100.0
Winter Fodders	2.5	83.7	6.0	5.1	0.4	0.0	2.2	100.0
Winter Fibbers	14.4	59.0	18.4	3.8	0.1	0.0	4.3	100.0
Winter Medical Plants	10.2	68.7	15.3	2.2	0.2	0.0	3.4	100.0
Winter Vegetables	7.7	84.1	5.8	0.8	0.4	0.1	1.3	100.0
Summer Rice	13.8	54.1	6.1	20.6	0.1	0.0	5.2	100.0
Summer Other Crops	23.1	47.0	17.0	7.4	0.6	0.1	4.7	100.0
Summer Sugar Cane	11.4	70.1	2.3	13.1	0.1	0.0	3.1	100.0
Summer Cotton	24.7	59.0	10.9	2.7	0.0	0.0	2.6	100.0
Summer Fodders	4.8	77.8	9.7	2.7	2.2	0.4	2.4	100.0
Summer Oily Crops	15.1	62.5	15.6	2.4	1.0	0.0	3.4	100.0
Summer Medical Plants	12.1	64.6	14.6	5.0	0.0	0.0	3.8	100.0
Summer Vegetables	11.4	74.3	10.4	1.3	0.4	0.1	2.2	100.0
Nili Rice	11.4	54.3	13.4	0.5	17.6	0.2	2.7	100.0
Nili Other Crops	23.0	47.2	12.9	9.9	2.3	0.2	4.4	100.0
Nili Fodders	5.5	76.9	10.9	0.0	4.5	0.1	2.1	100.0
Nili Oily Crops	18.4	39.7	30.4	1.8	3.6	0.0	6.1	100.0
Nili Medical Plants	11.8	56.4	5.3	21.2	0.0	0.0	5.3	100.0
Nili Vegetables	11.4	73.6	8.5	2.9	1.3	0.1	2.2	100.0
Fruits	14.4	63.2	9.5	4.7	4.8	3.4	0.0	100.0
Other agri forestry fishing	58.0	42.0	0.0	0.0	0.0	0.0	0.0	100.0

Table 11: 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	100.0	100.0	100.0	100.0	100.0	100.0	100.0