# International Trade and the National Water Balance
# - An Egyptian Case Study[♣]

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***Draft – not for quotation!***

***Abstract***

*One of the general determinants for a country's participation in international trade is the country's relative factor endowment. CGE analyses of international trade have traditionally accounted for the production factors land, labor, and capital. However, irrigation water is also highly important for agricultural production in many countries. Egypt is one of the countries, which is highly dependent on irrigation water for agricultural production, and water scarcity is likely to materialize in the near future in Egypt due to the growing population and the government's plans to reclaim large amounts of desert land for agricultural cultivation.*

*The present paper will analyze the implications for Egyptian international trade of accounting for the national water constraint. The analysis is based on a modified version of the ORANI-G CGE model and the IFPRI disaggregated 1997 SAM for Egypt. The model and database have been extended to cover the use of water in agriculture, and the national water constraint has been specified to take account of the recycling of water from irrigation activities.*

*The analysis features two scenarios in which the Egyptian agricultural land area is expanded. The first scenario takes account of the Egyptian national water constraint and places a tax on water diversions to ensure that Egyptian water use does not exceed Egypt's current allotment of fresh water. The expansion of the agricultural area results in the national water constraint becoming binding in this scenario. In the second land-expansion scenario, on the other hand, the national water constraint has been relaxed. The results show that the highly trade-exposed agricultural sectors tend to dominate the agricultural supply response following the expansion of the agricultural land area. Furthermore, the analysis demonstrates how accounting for the water constraint is particularly important in the case of the highly trade-exposed and water-intensive rice sector.*

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## 1. INTRODUCTION

One of the general determinants for a country's participation in international trade is the country's relative factor endowment, and this is especially the case for trade in primary agricultural commodities. CGE analyses of international trade have traditionally accounted for the production factors land, labor, and capital. However, there is a fourth factor of production, which is also highly important for agricultural production in many countries. This production factor is irrigation water.

Egypt is one of the countries, which is highly dependent on irrigation water for agricultural production, as Egyptian crop production covers virtually 100% of its water requirements through irrigation. In 2005, the Egyptian population had reached 74 million people and was growing at an annual rate of 1.9% (World Bank 2007). The growing economy and the demands for rising income can in-and-of-itself be expected to increase the demand for water. However, the implications of the growing population are further compounded by the fact that although Egypt is a large country, only a small fraction of the land is cultivable. In 1997 agricultural land holdings thus amounted to approximately 8 million feddan,[1] which corresponds to less than 5% of the total land area.

The need to accommodate and feed the growing Egyptian population early on led the Egyptian government to adopt a strategy of expanding the country's limited agricultural area by reclaiming large amounts of low-quality desert land (Hvidt 1998). The Land Master Plan of 1986 estimated Egypt's additional reclaimable lands at approximately 3.4 million feddan (Hellegers and Perry 2004). According to the Integrated Water Resources Management Plan from 2005, the irrigated areas are forecasted to increase from 7.985 million feddan in 1997 to approximately 11.026 million feddan in 2017 (Ministry of Water Resources and Irrigation 2005). Although progress in land reclamation has generally been much slower than planned (Mohamed 2001), the land reclamation plans remain very ambitious, as they still aim to increase agricultural land by 38% compared to the 1997 level. If implemented these land reclamation plans will consequently require substantial amounts of irrigation water.

While Egypt's demand for water is increasing significantly, Egypt only has limited options for augmenting its supply of water. The Nile supplies more than 95% of Egypt's annual

[1] A "feddan" is the Egyptian area measurement unit. One feddan corresponds to 0.420 hectares (or 1.037 acres) (World Bank 1993).

renewable water resources, and Egypt is not likely to be able to augment its supply of Nile water. While Egypt also has some non-Nile related water sources, including fossil ground water, which may provide some additional amounts of water in the future, the increasing water demands may nonetheless result in the country facing significant water scarcity within a foreseeable future. As the agricultural sector is the major water user in the Egyptian economy, accounting for more than 80% of water diversions in Egypt, agricultural production will in turn be noticeably affected by the binding national water constraint.

The present paper will analyze the linkage between Egyptian crop production, the ensuing national water constraint, and international trade by exploring, how the national water constraint affects Egypt's international trade and production patterns when the Egyptian agricultural area is expanded. The analysis features two scenarios. In the first scenario the amount of land is expanded by 10%, while the Egyptian supply of water is assumed to remain fixed. The expansion of the agricultural area results in the national water constraint becoming binding. In the second land-expansion scenario, the water constraint is relaxed so that water does not become scarce following the land expansion. The implications of the water constraint for the Egyptian economy and the Egyptian trade balance can then be assessed by comparing the outcomes of the two scenarios.

The analysis is undertaken in a national CGE model for Egypt. The national CGE model is based on a modified version of the so-called ORANI-G CGE model using the International Food Policy Research Institute (IFPRI)'s 1997 disaggregated Social Accounting Matrix (SAM) for Egypt. Neither the ORANI-G model nor the IFPRI SAM features water use. The model has consequently been extended in order to capture crop water use and the national water constraint, and the SAM has been supplemented with additional data on land and water use. Section 2 will outline how water use, land use, and the national water constraint is incorporated into the model and section 3 will present key aspects of the data work and parameter assumptions. Section 4 subsequently presents the simulation scenarios and results, while section 5 comprises discussion and conclusion of the analysis.

## 2. Incorporating irrigation water into the ORANI CGE model

The version of the ORANI-G model, which forms the basis of the present analysis, is the static multiple households model with no margins and no regional extensions.[2] The ORANI-G model is implemented using the GEMPACK software package (cf. Harrison and Pearson 1996).

The ORANI-G model is characterized by a multi-input, multi-output production structure. The model consequently allows each sector to produce multiple commodities using domestic and imported intermediates, different types of labor, as well as capital and land. Furthermore, the model also allows for commodities for export markets to be distinguished from commodities for local markets.

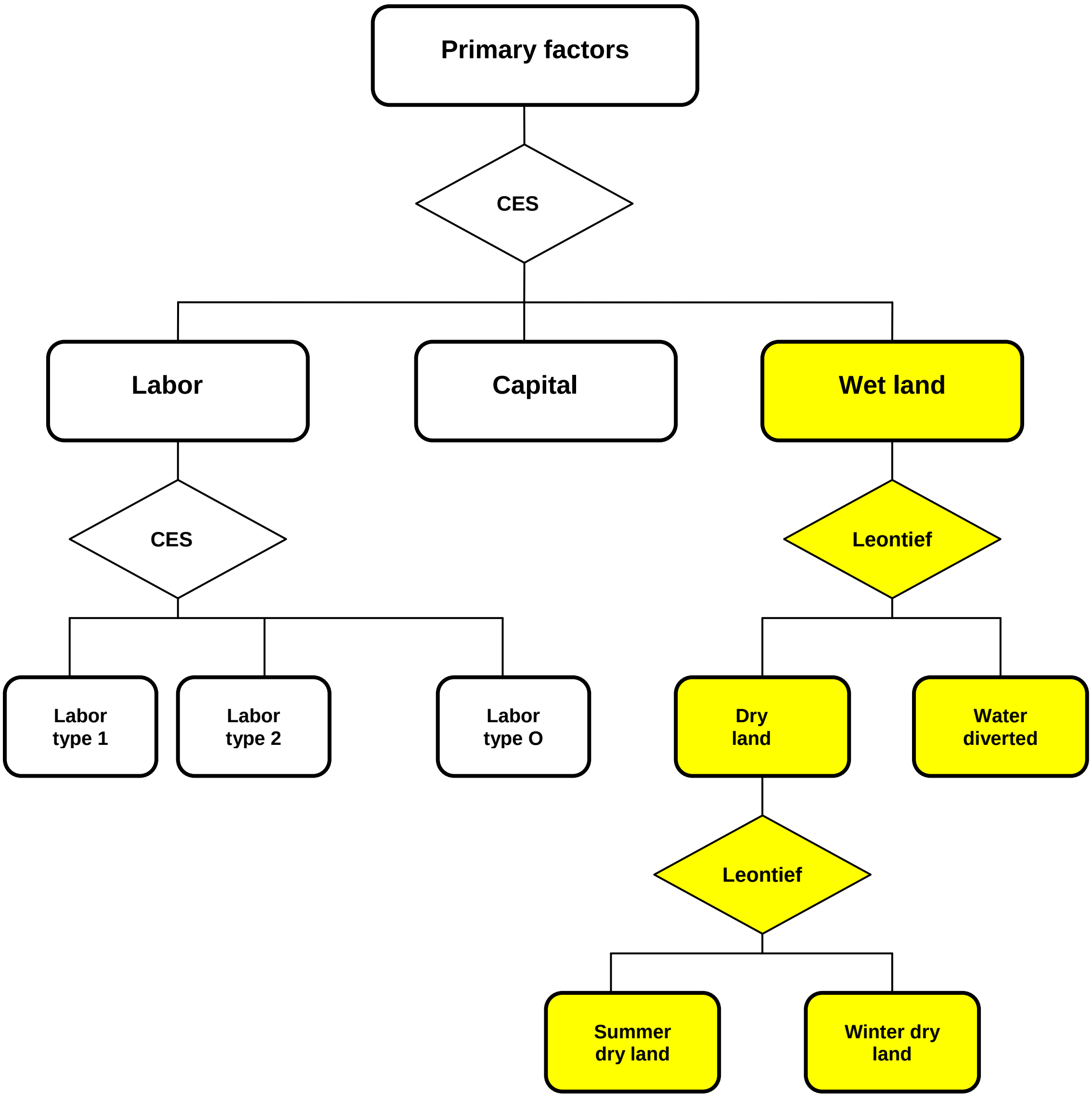
The input side of production in the ORANI-G model is characterized by intermediates being combined with the primary factor aggregate and the "other costs" item[3] through a Leontief function. The primary factor aggregate consists of a labor aggregate as well as capital and land, which are combined through a CES function. The labor aggregate may in turn consist of different types of labor, which are also aggregated through a CES function.

As mentioned in the introduction, water does not enter the production structure of the ORANI-G model. In order to analyze the impact of the irrigation water constraint, it is thus necessary to first introduce irrigation water into the production structure of the model. The question is then, into which nest of the production structure water should be incorporated, and what functional form should be used? The approach adopted in this paper is to interpret the existing land variable as being land-with-water (or "wet land"). Wet land is assumed to be a function of dry land and water, which are used in fixed, crop-specific proportions to produce wet land. Water is consequently incorporated into the production structure by adding a land-water nest with Leontief technology to the existing land variable in the primary factor nest. The notion of incorporating water into the production structure by introducing a land-water nest with Leontief technology is similar to the modeling of irrigation water in the works of Löfgren and El-Said (1999) and Robinson et al (2002), which also feature single-country

[2] This version of the ORANI-G model, which is dated September 2004, can be found at the ORANI website: http://www.monash.edu.au/policy/oranig.htm.
[3] The "other costs" item covers miscellaneous taxes on the firm like e.g. municipal taxes or charges (Horridge 2003).

CGE studies of Egyptian agriculture.[4] The present specification of the model, only allows for crops to be produced using the optimal amount of water per land unit, meaning that the model does not account for the option of producing crops using deficit irrigation. The structure of the expanded primary factor nest is presented in figure 1. The details pertaining to the modeling of water and dry land will be presented in the following subsections.

FIGURE 1: PRIMARY FACTOR NEST AFTER INCLUSION OF LAND-WATER NEST




Source: Adapted and extended from diagram in Horridge 2003 p 18.

[4] Incorporating water into the production structure by adding a land-water nest at the bottom of the production structure seems like the most appropriate solution for Egypt, as land in Egypt cannot be used for agricultural production without provision of irrigation water. However, there are examples of CGE models for other countries, where water is not incorporated into the production structure in this manner. One such example is the TERM model for Australia in which water is combined with a composite of all other inputs in irrigation sectors in a CES-nest at the very top of the production structure (Wittwer 2003). Another example is the GTAP-W model, where water is also included in the top industry nest along with the value-added-energy composite and intermediary inputs (Berrittella et al 2005).

## 2.1 Modeling the use of water and the water constraint

Water is a resource, which possesses special characteristics, and these characteristics need to be taken into consideration when modeling the national water constraint. According to Perry et al, "[o]ne of the most important, yet least appreciated, facts about water is that in a basin, a substantial amount of it is recycled" (Perry et al 1997 p 10). In irrigated agriculture, the recycling of water stems from the fact that not all water applied to a field ends up being consumed (/ evapotranspired) by the crops.[5] The part of the applied water, which is not consumed, either returns to the basin water system or ends up in sinks like saline aquifers or the sea (Hellegers and Perry 2004). While these latter types of return flows imply a non-recoverable loss of fresh water, the former types of irrigation return flows are recoverable. After returning to the basin system, the recoverable return flows thus become available for yet another diversion cycle "at another time, another place, and at another quality" (Perry et al. 1997 p 10).[6]

In order to model the national water constraint, it is important to account for return flows and the extent to which these are recoverable. What matters for the national water constraint is thus not how much water farmers apply to their fields but rather how much water ends up being consumed by the crops or irretrievably lost, as the recoverable return flows can be reused for irrigation or other purposes, provided the quality of these return flows has not deteriorated too much in the course of the diversion cycle.

The notion of recoverable return flows is highly relevant to in some regions of Egypt, notably the so-called Old Lands, which encompass the Nile Valley and Delta. In the Nile Valley, drainage water is thus returned to the Nile or the main irrigation canals, while in the Delta drainage water is either pumped back into the irrigation canals for reuse or pumped into the northern lakes or the Mediterranean Sea (FAO 2005). In most of the Delta and Nile Valley, water, which percolates into the ground, either returns to the river or recharges the shallow Nile aquifer from where it can be recovered (Keller et al 1996).[7] Return flows from the Nile

[5] In this study crop water consumption is equated with crop evapotranspiration. Evapotranspiration is defined as the "the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration" (Allen et al 1998 p 1).

[6] The term "return flow" is in the present analysis used as referring to the entire amount of water applied, which is not evapotranspired, regardless of whether these water flows are recoverable or not.

[7] In the Northern part of the Delta, drainage and groundwater salinity levels are quite high and these water flows are therefore of limited value for reuse (Keller et al 1996).

Valley are thus almost fully recoverable, while return flows from the Delta are partially recoverable. However, this is not the case in the so-called New Lands, which are the desert areas that have been reclaimed for cultivation since 1953. Here excess water percolating into the ground is lost, as the New Lands are located at the ends of the irrigation system and mostly outside the Nile's drainage basin. (FAO 2005 and Hellegers and Perry 2004).

In order to adequately capture these aspects of water use, the present incorporation of water into the ORANI-G model features a clear distinction between water applied to the field and water actually consumed or lost. The water variable, which enters the production function, is water diverted, as this is the water measure, which the farmer is assumed to have direct control over. The amount of water diverted is determined based on the knowledge of the annual crop evapotranspiration coefficients, the field irrigation efficiency, and the amount of land used for production of each crop. Field irrigation efficiency is defined as the fraction of water applied to the field, which is consumed by the crops. This parameter is assumed to be identical for all crops except rice as traditional rice cultivation requires extra water for soaking the paddy fields, which in turn lowers the field irrigation efficiency for this crop.

The national water constraint, on the other hand, is specified in terms of the total amount of water consumed or lost in order to capture return flow recoverability. While the ORANI-G model is generally specified in terms of linearized equations, the national water constraint is specified in levels. The use of levels variables allows for specifying the water constraint as a complementarity constraint, meaning that the water constraint can not only be binding but also non-binding. This is necessary, as the IFPRI SAM for Egypt pertains to the year 1997, and the national water constraint was most likely not strictly binding in Egypt in 1997.

In order to adequately capture the initial non-binding water constraint, the initial shadow price of water must be zero. The shadow price of water is captured by the basic price of water diverted.[8] As linear variables specified in percentage change terms cannot equal zero, the

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[8] In the terminology of the ORANI-G model, "basic prices" is normally the price received by producers or importers. "Purchaser's prices", on the other hand, are the prices paid by users. The difference between basic prices and purchaser's prices is the indirect taxes and as well as the cost of margin services, if the model includes margins (Horridge 2003). However, in the present model the basic prices on water and land resources are interpreted as resource rents accruing to the private agents, which own these resources. As the government can place taxes on these resources, the total costs to farmers of using the resource are given by the purchaser's price of the resource. Purchaser's prices of water and land are thus comprised of the opportunity cost of using the resource as well as any taxes associated with using the resource.

basic price of water diverted is specified as an absolute change linear variable (rather than a percentage change linear variable).

Although the water constraint is not binding initially, expansion of the agricultural area will eventually result in the water constraint becoming binding. When this happens, the cost to farmers of water diversions must become strictly positive in order to ensure that the water constraint is not breached. This could in principle be achieved by allowing the shadow price of water to increase. However, the shadow price of water is specified as a resource rent, which implicitly accrues to private agents. In stead of implicitly having a market for water, the present study will assume that water demand is regulated through a tax mechanism. The tax instrument, which will be used to ensure that the water constraint is not breached, is a uniform tax on water applied.[9] The tax instrument is thus used as the complementarity variable for the complementarity constraint on water. The uniform tax on water applied is modeled as a quantity (as opposed to an ad valorem) tax on water applied. The farmer's purchaser's price of water thus consists of the shadow price of water, which is kept exogenous and equal to zero in the simulations, and the uniform tax on water diverted, which is endogenous and varies to ensure that the complementarity constraint on the total amount of water consumed or lost is not violated.[10]

### 2.2 Modeling the use of dry land and the land constraint

As outlined in the introduction, arable land is a scarce resource in Egypt. In 1997 the Egyptian agricultural sector thus faced a binding land constraint. In the present analysis, Egyptian crop production is divided into winter crops, summer crops, as well as perennial crops. In order to adequately capture the Egyptian land constraint, the land constraint must therefore be specified separately for the winter season and the summer season. The dry land variable in the

[9] For a discussion of the extent to which taxes on water applied can in fact be implemented in Egypt see Gersfelt (2007).

[10] In the ORANI-G model the households and the government do not have explicit budget constraints, which link the total expenditures of the institution to its income. In stead, total household consumption and total government consumption is determined at the macro level through the closure of the model (cf. below on the closure used for the different simulations). The real production and consumption results from the simulations with a uniform tax on water applied would thus be identical to the results from simulations with optimal quotas on water applied. The only difference between these two sets of simulations would be for the variables capturing factor rents and tax revenue, as in the quota scenario the quota rents would accrue to the farmers, while in the tax scenario the tax revenue accrues to the government. However, this would not make a difference for real production and consumption as long as there is no direct link between expenditures and income for households and the government. The production results from the simulations in this paper could thus also have been produced through a set of optimal quotas on water applied. In earlier versions of the model I have also experimented with modeling of crop-specific land taxes as an instrument to regulate farmers' water use. However, it has not yet been possible to achieve a satisfactory implementation of these taxes.

land-water nest is consequently split into winter dry land and summer dry land. This is done by adding a seasonal land nest with Leontief technology to the dry land variable. The use of Leontief technology ensures that summer land cannot be substituted for winter land or vice-versa. Furthermore, the Leontief technology ensures that any changes in the amount of land used for perennial crops in one season translates into an equal change in the amount of land used for these crops in the other season.[11]

As was the case for the national water constraint, the land constraint for each season is specified in levels rather than linearized terms. However, unlike the water constraint, the seasonal land constraints are specified as binding at all times. The variables, which ensure that the seasonal land constraints remain binding, are the seasonal shadow prices of land.

Computing the land rents from the SAM shows that rents vary significantly across crops. Land rents may vary across crops due to e.g. agronomic constraints. According to Löfgren and El-Said (1999), land rents may also differ across crops due to differences in required skills or monitoring for producing these crops, differences in riskiness of crops, and differences in crop impact on soil fertility. However, none of these features are captured in the model, and the model can thus not in-and-of-itself explain the difference in land rents across crops. The question is then whether land rents should be homogenized across crops through some kind of data work, or whether the model should be extended to explicitly allow land rents to differ across crops. Following the approach of Löfgren and El-Said (1999), the latter option is chosen for the present model, and land rents are consequently modeled as differentiated across crops on the basis of fixed ratios calculated from the base year data.

The differentiated land rents are implemented by setting a base land rent for each season. For the winter season, the base land rent is equated with the land rent of wheat, while the base land rent for the summer season is equated with the land rent of maize. The total land rents per area unit for each crop are then modeled as consisting of the base rent land rent, which is uniform across crops, and a crop-specific land rent wedge. The crop-specific land rent wedge is modeled in a similar fashion as an ad valorem tax, except that the “revenue” from this wedge is implicitly modeled as accruing to the land owner rather than the government. The

[11] While land use must be considered on a seasonal basis, water use is calculated on an annual basis. The crop evapotranspiration coefficients for the perennial crop thus capture the annual crop water requirements of these crops. This in turn explains why water use and the water constraint can be separated from the seasonal aspects of land use.

ratios of land rents across different crops are then preserved by making the rent wedges exogenous (except in the cases described below).

In addition to the overall seasonal restrictions on total land availability, certain restrictions on individual crop land use have also been introduced in the model. The first of these restrictions takes the form of a crop rotation restriction. The most prevalent crop rotations in Egypt are cotton crop rotations, which entail cultivation of short berseem in the winter followed by cotton in the summer. This restriction is included in the model by requiring the percentage change in area cropped with short berseem to equal the percentage change in area cropped with cotton. To enable the model to meet this constraint, the land rent wedge for short berseem is endogenized.[12]

The other crop land use restrictions, which are introduced, relates to the crop categories "other winter crops" and "other summer crops". These crop categories are residuals and in order to prevent them from potentially dominating the simulation results, the amount of land allocated to these crops is specified as being exogenous. To enable the model to meet these sectoral land use constraints, the land rent wedges for other summer crops and other winter crops are endogenized.

## 3. PREPARING THE DATA FOR THE SIMULATIONS.

The data work undertaken for the present analysis includes adjustments to the SAM data format, choosing elasticities for the model, and data work and parameters related to the land-water nest. The following sub-sections will consider each of these areas in turn.

### 3.1 ADJUSTMENTS TO THE SAM

The SAM, which constitutes the core part of the data set for this analysis, is IFPRI's 1997 disaggregated SAM for Egypt.[13] The original SAM features 12 institutions (5 rural

[12] It should be noted that the total initial short berseem area is smaller than the total initial cotton area. However, the present modeling of the crop rotation constraint ensures that the ratio of the total berseem area to the total cotton area remains unchanged. The introduction of the cotton-short berseem crop rotation in the model allows for the crop sectors long and short berseem to produce the same commodity berseem, which is in accordance with the input-output structure in the SAM. If the implied perfect substitutability between the outputs of the two berseem activities were to be maintained without introduction of some kind of restriction on one of the berseem sectors, it becomes difficult for the model to allocate berseem production between the two crop sectors in long run simulations, where all factors are mobile across sectors (cf. also Horridge 2003). Incorporating the crop rotation constraint solves this problem, as the production of short berseem is now linked to the production of cotton.

[13] Information about the SAM can be found at the following website: http://www.ifpri.org/data/egypt06.htm

households, 5 urban households, the government, and the rest of the world), 5 factors of production (agricultural and non-agricultural labor, agricultural and non-agricultural capital, and land), 28 activities / sectors (including 13 crop production activities), and 36 commodities (including 19 crop commodities). The SAM also includes information on the capital account, as well as indirect and direct taxes, tariffs, and commodity subsidies.

The original SAM has been adjusted in several ways for the purpose of present analysis. In order for the data format to fit the ORANI-G model imports have been disaggregated across users of imports, investments have been disaggregated across sectors, commodity sales taxes have been disaggregated across sources of the commodities and taxpayers, and agricultural and non-agricultural capital has been aggregated into one type of capital. In addition to this the database has been made more manageable by aggregating all households into one single household[14] as well as aggregating up certain sector and commodity accounts and transferring subsidies, which appear on the commodity accounts of the SAM, into income transfers to the households. The resulting sector and commodity aggregation is presented in appendix A.

### 3.2 Elasticities and parameters for the ORANI-G model

The ORANI-G model also requires a number of elasticities related to production, consumption, and trade respectively.

*Elasticities related to production*

The elasticities related to production include the CES elasticities for substitution between the factors of production in the primary factor nest and the commodity-specific CES elasticities controlling the degree of substitution between the outputs from two industries producing the same commodity. The values for the first of these elasticities are taken from the Löfgren and El-Said CGE study of food subsidies in Egypt (cf. Löfgren and El-Said 1999 p 36). These sector-specific elasticities range from 0.1 in oil production, over 0.3 in all agricultural sectors, to 0.6 for most manufacturing and non-governmental services, implying a rather low degree of substitutability between the different factors of production in the primary factor nest. With respect to the latter set of elasticities, these are only relevant for the commodities vegetables

[14] As mentioned previously, the households and the government in the ORANI-G model do not have explicit budget constraints, which link the total expenditures of the institution to its income. If the distributional implications of the water policies (like e.g. the direct implications of changing factor remuneration for household consumption) were to be analyzed, the model would need to be extended through inclusion of household and government budget constraints.

and berseem. In the case of berseem, there is no immediate reason to assume that the two winter crop activities short berseem and long berseem should produce outputs, which are imperfect substitutes. The CES elasticity for berseem is consequently set equal to 100 (an arbitrary high elasticity implying almost perfect substitutability). The vegetable commodity, on the other hand, is produced by the two crop activities winter vegetables and summer vegetables. As it does not seem reasonable to assume that winter vegetables and summer vegetables are perfect substitutes, the CES elasticity for vegetables is set equal to 5.

*Elasticities related to household demands*

In the ORANI-G model, the commodity composites of household demands are aggregated by a Klein-Rubin function, resulting in a linear expenditure system (Horridge 2003). This specification of household demands requires commodity- and household-specific expenditure elasticities and household-specific Frisch LES parameters. However, due to lack of data on such elasticity and parameter values for Egypt, the linear expenditure system is collapsed to a Cobb-Douglas function by setting household expenditure elasticities equal to 1 and the Frisch parameter equal to -1 (cf. ORANI-G short course 2005 slides). While a Cobb-Douglas representation of household demands is rather simplistic, the focus of the present study is on agricultural production and not household consumption as such.

*Elasticities related to international trade*

The elasticities related to international trade can be divided into elasticities pertaining to imports and elasticities pertaining to exports. Starting with the Armington elasticities governing the substitution between imports and domestically produced commodities, the values for these elasticities are taken from Löfgren and El-Said’s CGE study of Egypt (Löfgren and El-Said 1999 p 36). The Armington elasticities are relatively low for all commodities (ranging from 0.3 for most commodities to 2 for oil), except in the case of wheat. Löfgren and El-Said assume that imported and domestically produced wheat are perfect substitutes, and the Armington elasticity for wheat is consequently set equal to 100.

With respect to exports, the ORANI-G model allows for two different ways of modeling exports – perfect substitution between commodities destined for domestic and foreign markets combined with less than perfectly elastic export demand curves or alternatively imperfect substitution between commodities destined for domestic and foreign markets typically combined with perfectly elastic export demand curves. Following Löfgren and El-Said’s approach, the latter option is adopted here, and the CET elasticities governing the production of commodities for local and export markets as well as the export demand elasticities are taken from their study of Egypt (Löfgren and El-Said 1999 p 36). Löfgren and El-Said assume that rice and oil destined for domestic and export markets are perfect substitutes implying an infinite CET elasticity for these commodities. For all other commodities, output destined for domestic and export markets is assumed to be imperfectly substitutable with CET elasticities ranging from 2.0 for all non-agricultural exports, over 0.8 for most agricultural exports, to 0.5 for legumes. As for the export demand elasticities, Egypt is assumed to face perfectly elastic export demand curves for all commodities except vegetables, for which the export demand elasticity is 3.0, and transportation and other services, for which the export demand elasticity is 1.0. In the case of export demands, the perfectly elastic demand is approximated by an elasticity of 50 (rather than 100 as usual), as the model has difficulties solving for export demand elasticities of 100. Although a demand elasticity of 50 does not entail perfectly elastic export demand, it nonetheless implies highly elastic export demand, and is thus judged to be sufficient for the present study.

### 3.3 Data work and parameters for the land-water nest

Apart from the SAM data and the parameters, the model also requires data on land and water use. Water use by each crop is calculated based on the cropping pattern as well as the water parameters for crop evapotranspiration, field irrigation efficiency, and return flow recoverability. The present sub-section will first outline the data work undertaken with respect to the cropping pattern and secondly present the data for the water parameters.

*Cropping pattern.*

There are several ways in which the cropping pattern implicitly underlying the SAM may be derived. One approach would be to calculate it based on the land rents in the SAM. However, land rents do in reality differ across sectors (due to e.g. crop rotations or differences in riskiness across crops), and this makes it difficult to derive a cropping pattern simply based on the land rents in the SAM. Furthermore, land rents are notoriously difficult to estimate, as they will typically have to be imputed. Given the general challenges of reconciling many different types of data in a SAM, as well as the need to allocate production costs over a limited number of factors and inputs in the SAM, SAM land rents are consequently not likely to be a good tool for deriving the crop land allocation.

Another more promising approach is to derive the land allocation based on the value of sector output and knowledge of crop prices and yields. Using crop prices as well as actual national yields for 1997,[15] a cropping pattern is derived from the SAM values of sector output. Comparing the resulting SAM cropping pattern to the cropping pattern derived from the complete FAOSTAT data set on land use (cf. previous footnote) shows almost identical land allocations for the two large cereal sectors wheat and maize as well as for the perennial fruit sector. However, there are minor deviations between the two cropping patterns with respect to the sectors sugar cane, cotton, and legumes and more significant deviations with respect to the sectors rice, summer and winter vegetables, short and long berseem, as well as other summer and other winter crops.

Using the cropping pattern produced by the original SAM values for sector outputs in combination with the aforementioned prices and yields is not reasonable, as this implies a significant increase in the amount of winter and summer land compared to the FAOSTAT cropping pattern. On the other hand, simply using the FAOSTAT cropping pattern with the original SAM values for sector outputs would amount to implicit assumptions about changes in either crop prices or yields. Rather than implicitly changing prices and yields in order to arrive at the FAOSTAT cropping pattern, the approach adopted for the present analysis assumes that the crop prices and actual yields are correct and that the value of sector output should consequently be adjusted in order to produce the FAOSTAT cropping pattern.

SAM values of sector output are adjusted by using a special levels version of the ORANI-G model designed for updating or balancing complex CGE databases.[16] This levels version of the ORANI-G model uses a proportional scaling approach to adjust database values to specified targets (Horridge 2004). The value of each sector's output is consequently shocked to the level producing the desired cropping pattern, except in the case of other summer and other winter crops, as the amount of land allocated to these crops is specified exogenously (cf. section 2.2). Once the value of sector output have been adjusted, the cropping pattern implicit

[15] Price and yield data are obtained from the Agricultural Sector Model for Egypt (ASME) presented in Mohamed 2001 and from FAOSTAT core production data. The complete FAOSTAT core production data set on area usage in Egypt in 1997 (cf. http://faostat.fao.org/site/340/DesktopDefault.aspx?PageID=340) is also used in combination with ASME data on area use in 1997 to produce a reference cropping pattern for Egypt for 1997.

[16] This model and its documentation can be found at the following website: http://www.monash.edu.au/policy/archivep.htm item TPMH0058. The model is designed for another type of ORANI-G database with margins and a single household. As outlined in section 4.1, the database for the present analysis has been aggregated to one single household, but it contains no margins. The model for adjusting the database is consequently modified to disregard margins.

in the new SAM is calculated by dividing the values of sector outputs with the 1997 crop prices and actual yields for the different crops. The resulting cropping pattern is presented in appendix B.

The land rents are also calculated by dividing the SAM value of land for each crop with the land allocations for each crop. The resulting land rents for summer and winter vegetables are significantly higher than land rents for the other crops, and so are the land rents for long berseem, while land rents for legumes are noticeably lower than land rents for other crops.[17] According to Löfgren and El-Said differentiating land rents across crops is "a reflection of real-world phenomena that are not modeled explicitly" (Löfgren and El-Said 1999 p 8). However, as the result section will demonstrate, these differences in land rents across crops do have implications for simulation results.

*Water parameters*

The water parameters needed for the land-water nest and for calculating initial water use are crop-evapotranspiration coefficients, crop-specific field irrigation efficiency coefficients, and return flow recoverability coefficients. These parameters are largely calculated based on the regional ASME data presented in Mohamed 2001, and aggregated across regions to produce national averages. This results in national field irrigation efficiency coefficients of 0.79 for all crops except rice for which the field irrigation efficiency coefficient is 0.553. The national return flow recoverability coefficient is 0.51. The national evapotranspiration coefficients are shown in appendix C. The final water parameter needed for the model and data work is the total amount of water available for crop water consumption and irretrievable losses from irrigation, which is set equal to 47 billion cubic meters (BCM) (cf. Gersfelt 2007).

## 4. SIMULATION SCENARIOS AND RESULTS.

In order to examine the implications of the water constraint for international trade, two land expansion scenarios are run. In the first scenario, the amount of water available for consumption or loss in irrigation is 47 BCM. In this scenario, increasing the amount of summer and winter dry land by 10% results in the water constraint becoming binding. In the second scenario, summer and winter dry land is also increased by 10%, but the amount of

[17] The land rents for other winter and other summer crops are also very high compared to the land rents for the other crop categories. This is not surprising given the fact that values of industry output were not adjusted for these crops. However, as mentioned above, steps have been taken to minimize the effect of these crops on simulation results, as the land allocation for these crop categories is kept fixed.

water available to agriculture is set so high as to ensure that the water constraint does not become binding. As the only difference between the two scenarios is the water availability for agriculture, the implications of the water constraint for Egyptian agricultural production and international trade can be assessed by comparing the results from these two scenarios.

The model closure used for the two land expansion scenarios is a long run closure. While there is no standard ORANI-G long run closure, the model documentation does provide a possible long run closure, which is used in the present study with a few modifications. The long run closure presented in the ORANI-G model documentation implies the assumption of an open capital market, where sectoral capital stocks adjust to maintain fixed rates of return in each sector. Aggregate employment (which is aggregated across sectors using wage bill weights)[18] is fixed and the real wage is endogenous. Labor is thus implicitly assumed mobile between agricultural and non-agricultural sectors. Sectoral land allocation is assumed to be fixed. On the expenditure side of the economy, the nominal balance of trade as a fraction of GDP is assumed to be exogenous, as the rest of the world is not likely to be willing to fund an increased trade deficit in the long run. Household expenditure and government expenditure move together to accommodate the trade balance constraint, while aggregate investment follows the aggregate stock of capital (Horridge 2003). Demand curves for exports are fixed, as are also foreign prices of imports. The nominal exchange rate is the numeraire.

The long run closure used in the present analysis corresponds to the ORANI-G long run closure except for the fact that land is assumed to be mobile across crop sectors. As it may take 10 or 20 years to reach a long run equilibrium (Horridge 2003), it would not make sense to assume that farmers would not adjust their cropping pattern in the course of this time span. Total amount of summer dry land, winter dry land, and water available for irrigation is assumed to be exogenous. As outlined earlier, the basic price of water diverted is set to be exogenous, while the uniform tax on water diverted is endogenized to ensure that the water constraint is not breached. The base land rents on summer land and winter land are also endogenous, whereas the land rent wedges are exogenous for all crops except short berseem, “other winter” crops, and “other summer” crops (cf. section 2.2 on restrictions on land use for

[18] Using wage bill weights reflects different workers’ relative marginal product. Other options for aggregating employment across sectors include using number of workers or hours worked as weights (Horridge 2003). Considering that agriculture accounted for 31% of total employment in 1997 but – according to the SAM – only 14.6% of total labor costs, there appears to be significant differences between wages in agricultural and non-agricultural employment. Using numbers of workers instead of wage bill wage may thus be more appropriate. However, this would require additional data on employment in Egypt.

these crops). The percentage changes in land rents for all summer crops will thus be identical (with the exception of the land rent for “other summer” crops). The same is true for all winter crops (with the exception of the land rents for short berseem and “other winter” crops) as well as for all perennial crops. The consumer price index is used as numeraire in stead of the nominal exchange rate, as this provides for a more intuitive interpretation of the trade related results.

*Results for water-constrained land-expansion scenario.*

The results for the scenario in which the expansion of the summer and winter dry land area by 10% results in the water constraint becoming binding are presented in tables 1 to 4. Table 1 shows the percentage changes in output and input quantities in the different sectors, while table 2 shows the percentage changes in the corresponding input and output prices. Note that the results for tax on water diverted in table 2 are specified as absolute changes rather than percentage changes. Table 3 presents the percentage changes in quantities and prices for household demands, imports and exports, while table 4 presents the macro results for the scenario.

Land and water is only used by the agricultural sectors, and these are therefore the sectors most immediately affected by the increase in the amount of summer and winter dry land. As shown in table 4, an increase in the amount of summer and winter dry land by 10% results in an increase in agricultural employment of 3.74%. Total employment in the economy is assumed to be fixed in the long run and this pull of labor into the agricultural sector thus results in rising wages. The agricultural capital stock also increases by 4.00%. In the long run, the capital market is assumed to be open and rates of return on capital are fixed for each sector. With the expansion of land and labor employed in agriculture, it is thus not surprising that the agricultural capital stock increases in order to maintain the fixed rates of return to capital in each sector.

The amount of irrigation water consumed or irretrievably lost also increases following the increase in the amount of summer and winter dry land. However, while the amount of dry land was increased by 10%, the amount of water consumed or lost can only increase by 5.41% due to the water constraint. As the water constraint becomes binding, the uniform tax is levied on water diverted in order to assure that the water constraint is not violated (cf. column 5 in table 2).

The increase in the amount of dry land and the onset of water scarcity results in declining land rents. Summer dry land rents decline more than winter dry land rents, which is partly attributable to the fact that summer crops tend to be more water intensive than winter crops. This is shown in column 4 in table 2. The first six crops in the table are winter crops, while the five subsequent crops are summer crops, and the last two crops are perennial crops. For all winter crops (except short berseem and other winter crops) the dry land rents decline by 49.86%, while for all summer crops (except other summer crops) the dry land rents decline by 67.73%. The reason why the changes in dry land rents for short berseem, other winter crops, and other summer crops differ from the general changes in seasonal land rents is that these crops are subject to land allocation restrictions as outlined in section 2.2. Perennial dry land rents decline by 59.08%, which is basically the average of the changes in summer and winter dry land rents.

The increases in total amount of summer and winter dry land and the ensuing changes in factor rents have differing impacts of the cropping sectors depending in part on the water intensity of the crop and the magnitude of the land rents in the crop sector. The first column of table 1 shows the percentage changes in sectoral activity levels, and the impact on agricultural production clearly centers around four sectors: the winter crops wheat and winter vegetables and the summer crops rice and summer vegetables.

TABLE 1: CHANGES IN PRODUCTION AND INPUT QUANTITIES IN WATER CONSTRAINED SCENARIO (PERCENTAGE CHANGE)

| | Sector activity level | Effective labor input | Capital stock | Dry land | Water diverted | Wet land |
|---|---|---|---|---|---|---|
| Wheat | 33.01 | 31.83 | 32.53 | 33.64 | 33.64 | 33.64 |
| Legumes | -2.60 | -1.64 | -1.12 | -4.03 | -4.03 | -4.03 |
| LongBerseem | 2.40 | -1.78 | -1.26 | 3.00 | 3.00 | 3.00 |
| ShortBerseem | 3.38 | -0.78 | -0.25 | 4.37 | 4.37 | 4.37 |
| WinVeg | -46.45 | -50.47 | -50.21 | -44.09 | -44.09 | -44.09 |
| OthWinCrp | 0.04 | -0.08 | 0.45 | 0.00 | 0.00 | 0.00 |
| Cotton | 1.26 | -1.13 | -0.61 | 4.37 | 4.37 | 4.37 |
| Rice | -17.78 | -11.24 | -10.78 | -21.94 | -21.94 | -21.94 |
| MaizeSorg | 3.60 | 1.14 | 1.67 | 5.14 | 5.14 | 5.14 |
| SumVeg | 77.76 | 50.19 | 50.98 | 87.66 | 87.66 | 87.66 |
| OthSumCrp | -0.01 | -0.16 | 0.37 | 0.00 | 0.00 | 0.00 |
| Fruit | 1.98 | 0.57 | 1.10 | 3.68 | 3.68 | 3.68 |
| SugarCane | 0.01 | 5.76 | 6.32 | -4.67 | -4.67 | -4.67 |
| AnimalAgr | 2.56 | 2.13 | 2.67 | - | - | - |
| | | | | | | |
| FoodProcess | 0.00 | -0.81 | 0.24 | - | - | - |
| Oil | -8.14 | -8.29 | -8.13 | - | - | - |
| CottonGin | 1.23 | 0.80 | 1.86 | - | - | - |
| Textiles | 0.29 | -0.30 | 0.75 | - | - | - |
| OthIndustry | -0.23 | -1.06 | -0.01 | - | - | - |
| | | | | | | |
| Electricity | -0.16 | -0.67 | 0.03 | - | - | - |
| Construction | -0.31 | -1.03 | 0.02 | - | - | - |
| GovServ | 0.74 | 0.74 | - | - | - | - |
| Transport | -0.27 | -1.11 | -0.07 | - | - | - |
| OthServ | -0.47 | -1.20 | -0.15 | - | - | - |

TABLE 2: CHANGES IN OUTPUT AND INPUT PRICES IN WATER CONSTRAINED SCENARIO (PERCENTAGE CHANGE)

| | Average input / output price | Price of labor composite | Rental price of capital | Dry land rents | Tax on water diverted (absolute change) | Cost of wet land |
|---|---|---|---|---|---|---|
| Wheat | -0.33 | 2.54 | 0.76 | -49.86 | 0.17 | -2.01 |
| Legumes | 4.83 | 2.54 | 0.76 | -49.86 | 0.17 | 11.30 |
| LongBerseem | -10.37 | 2.54 | 0.76 | -49.86 | 0.17 | -12.49 |
| ShortBerseem | -10.38 | 2.54 | 0.76 | -44.44 | 0.17 | -13.38 |
| WinVeg | -19.64 | 2.54 | 0.76 | -49.86 | 0.17 | -31.52 |
| OthWinCrp | 1.86 | 2.54 | 0.76 | -4.91 | 0.17 | 2.28 |
| Cotton | -4.51 | 2.54 | 0.76 | -67.73 | 0.17 | -14.41 |
| Rice | 28.38 | 2.54 | 0.76 | -67.73 | 0.17 | 57.30 |
| MaizeSorg | -4.58 | 2.54 | 0.76 | -67.73 | 0.17 | -9.90 |
| SumVeg | -36.78 | 2.54 | 0.76 | -67.73 | 0.17 | -51.20 |
| OthSumCrp | 1.73 | 2.54 | 0.76 | -12.23 | 0.17 | 2.00 |
| Fruit | -1.90 | 2.54 | 0.76 | -59.08 | 0.17 | -7.34 |
| SugarCane | 19.28 | 2.54 | 0.76 | -59.08 | 0.17 | 44.96 |
| AnimalAgr | -1.90 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| FoodProcess | 0.72 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| Oil | 0.87 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| CottonGin | -3.15 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| Textiles | 0.39 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| OthIndustry | 0.92 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| Electricity | 1.09 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| Construction | 1.02 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| GovServ | 2.01 | 2.54 | 0.00 | 0.00 | 0.00 | 0.00 |
| Transport | 1.03 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |
| OthServ | 1.14 | 2.54 | 0.76 | 0.00 | 0.00 | 0.00 |

TABLE 3: CHANGES IN QUANTITIES AND PRICES OF HOUSEHOLD DEMANDS, IMPORTS AND EXPORTS FOR WATER CONSTRAINED SCENARIO (PERCENTAGE CHANGE)

| | Household use of domestic / imported composite | Household price of domestic / imported composite | Total supplies of imported goods | Duty-paid, basic price of imported goods (local currency) | Export basic demands | Purchaser's price of export goods (local currency) |
|---|---|---|---|---|---|---|
| Wheat | 0.74 | 0.00 | -40.90 | 0.54 | - | 0.00 |
| Legumes | -2.77 | 3.61 | -1.73 | 0.54 | -4.57 | 0.64 |
| Berseem | 0.00 | 0.00 | 0.00 | 0.54 | - | 0.00 |
| OthWinCrp | 0.00 | 0.00 | 0.00 | 0.54 | - | 0.00 |
| Cotton | 0.00 | 0.00 | 0.00 | 0.54 | - | 0.00 |
| Rice | -21.53 | 28.38 | 0.00 | 0.54 | -100.00 | 28.38 |
| MaizeSorg | 5.58 | -4.58 | 0.00 | 0.54 | - | 0.00 |
| OthSumCrp | 0.00 | 0.00 | 0.00 | 0.54 | - | 0.00 |
| Vegetables | 51.66 | -33.57 | 0.00 | 0.54 | 66.31 | -15.14 |
| Fruit | 2.69 | -1.90 | 1.17 | 0.54 | 3.94 | 0.46 |
| SugarCane | 0.00 | 0.00 | 0.00 | 0.54 | - | 0.00 |
| AnimalAgr | 2.57 | -1.79 | 1.46 | 0.54 | - | 0.00 |
| | | | | | | |
| FoodProcess | 0.03 | 0.72 | 0.06 | 0.54 | -0.34 | 0.55 |
| Oil | 0.00 | 0.74 | 0.16 | 0.54 | -14.99 | 0.87 |
| CottonGin | 0.00 | 0.00 | 0.00 | 0.54 | 8.73 | 0.37 |
| Textiles | 0.36 | 0.38 | 0.21 | 0.54 | 0.57 | 0.53 |
| OthIndustry | -0.02 | 0.77 | -0.03 | 0.54 | -0.95 | 0.56 |
| | | | | | | |
| Electricity | -0.34 | 1.09 | 0.00 | 0.54 | - | 0.00 |
| Construction | -0.27 | 1.02 | 0.00 | 0.54 | - | 0.00 |
| GovServ | 0.00 | 0.00 | 0.00 | 0.54 | - | 0.00 |
| Transport | -0.30 | 1.05 | -0.01 | 0.54 | -0.41 | 0.96 |
| OthServ | -0.36 | 1.11 | -0.27 | 0.54 | -0.55 | 1.10 |

TABLE 4: MACRO ECONOMIC RESULTS FOR WATER CONSTRAINED SCENARIO (PERCENTAGE CHANGE)

| | | | |
|---|---|---|---|
| Agricultural winter land | 10.00 | Nominal GDP | 0.83 |
| Agricultural summer land | 10.00 | Real GDP | 0.44 |
| Consumption or loss of irrigation water | 5.41 | GDP price index (expenditure side) | 0.39 |
| | | | |
| Agricultural employment | 3.74 | Aggregate real household consumption | 0.74 |
| Non-agricultural employment | -0.54 | Aggregate consumer price index | 0.00 |
| Total employment (wage bill weights) | 0.00 | Aggregate real government demands | 0.74 |
| | | | |
| Agricultural capital stock | 4.00 | Nominal trade balance as share of nominal GDP (absolute change) | 0.00 |
| Non-agricultural capital stock | -0.82 | Nominal exchange rate | 0.54 |
| Total capital stock | -0.65 | Terms of trade (export price index - import price index) | 0.35 |
| | | Real devaluation (import price index - GDP price index) | 0.15 |
| | | Export volume index | -3.15 |
| | | Import volume index | -2.22 |

Wheat and rice are both very trade-exposed, as wheat imports and rice exports are assumed to be perfectly substitutable with domestically produced wheat and domestically produced rice for the local market. Wheat is not a water intensive crop, and the decline in winter dry land rents consequently dominates the increase in water taxes for this crop. As the sixth column of table 2 shows, the cost of wet land (i.e. the combined price / opportunity cost of dry land and water) consequently drops by 2.01% for wheat. Despite the increases in labor and capital costs (cf. column 2 and 3 in table 2), the total unit costs of production in the wheat sector thus declines by 0.33% (cf. column 1 of table 2).[19] As domestically produced wheat is assumed to be a perfect substitute for imported wheat, this drop in domestic wheat production costs is accompanied by an increase in domestic wheat production of 33.01%, while imports of wheat decline by 40.90% (cf. column 3 in table 5).

Rice, on the other hand, is a highly water intensive crop, partly because crop water consumption is high for rice and partly because rice production requires extra water for soaking the paddy fields.[20] Despite the decline in summer dry land rents, the cost of wet land for rice production consequently increases by 57.30% due to the water taxes. This results in a relative increase in the labor and capital intensity of the sector (cf. column 2-5 in table 1 how the use of labor and capital in the rice sector only declines by 11.24% and 10.78%, while land and water use declines by 21.94%). However, the unit cost of production in the rice sector still increases by 28.38%. This in turn results in rice production declining by 17.78%, while direct sales of rice to households decline by 21.53% (cf. column 1 in table 1 and column 1 in table 3). Furthermore, as rice for the domestic market and rice for export markets are perfect

[19] The variable capturing the unit costs of production, which are shown in the first column of table 4, is labeled the “average input / output price” in the ORANI-G model code. The reason for this terminology is that the model’s constant returns to scale in production imply that the percentage change in unit costs is also the percentage change in marginal costs. Furthermore, the competitive “zero pure profits” condition is enforced by assuming that the percentage change in marginal (and unit) costs is equal to the average price received by each sector (Horridge 2003).

[20] The extra water required for soaking the paddy fields implies a lower field irrigation efficiency for rice than for other crops and hence also a relatively larger generation of return flows. Return flows are assumed to be partially recoverable in the present analysis, and the lower field irrigation efficiency for rice consequently also implies that rice cultivation produces a relatively larger amount of recoverable return flows than cultivation of other crops. However, a uniform tax an water applied can only account for the average recoverability of return flows and this policy instruments will therefore result in rice getting taxed more heavily than what is actually socially optimal.

substitutes and as export demands for rice are highly elastic, this increase in unit costs of production results in a complete collapse of rice exports (cf. column 5 of table 3).[21]

Rice is one of the major summer land crops and the combination of a 10% increase in total summer land and a decline in the area devoted to rice of 21.94% implies that other summer crops sectors will be expanding considerably. As table 1 shows, the summer vegetable sector expands significantly as production increases by 77.76% and the area devoted to summer vegetable production increases by 87.66%. Part of the explanation for the large increase in the production of summer vegetables is that vegetables are water extensive. The other part of the explanation is that in the present data set land rents for summer vegetables are substantially higher than land rents for other crops. The combination of these two features implies that the decline in summer dry land rents strongly dominates the increase in water taxes for the summer vegetable sector. As shown in table 2, the cost of wet land for the summer vegetable sector consequently declines by 51.20%. This large decline in land-water costs for the summer vegetable sector results in a substitution away from the more expensive labor and capital inputs towards the less expensive land-water input. As shown in table 1, labor and capital inputs into the summer vegetable sector thus only increase by 50.19% and 50.98% respectively, while land and water use increase by 87.66%. All in all, unit costs for the summer vegetable sector declines by -36.78%.

The increase in the amount of land devoted to wheat production is larger than the increase in the total amount of winter land, and other winter crop sectors thus have to contract not only in relative but also in absolute terms. The winter crop sector, which accommodates the expansion of the wheat sector, is winter vegetables. As table 1 shows, production of winter vegetables declines by 46.45%. This happens despite the fact that the cost of wet land for winter vegetables declines by 31.52% (due to the high initial land rents for winter vegetables and the low water intensity of this crop). Apart from the expansion in wheat production, the large decline in winter vegetable production is also a result of the fact that the summer and winter vegetable sectors both produce the same commodity – vegetables. Summer and winter vegetables are assumed to be imperfect substitutes (cf. section 3.2), but the large increase in

[21] The reason why total rice production declines less than direct sales of rice to households and rice exports is that while 64% of rice production is sold directly to the households, 34% of rice production is sold as inputs into other sectors. 42% of these rice inputs go to the food processing industry. As intermediate inputs enters the production structure through a Leontief nest and as the food processing industry is virtually unaffected by the land shock, rice inputs into the food processing industry are also unchanged.

the production of summer vegetables still facilitates a substantial contraction in the winter vegetable sector. Total vegetable production thus only increases by 36.99%. A reinforcing factor for the contraction of the winter vegetable sector is the fact that 64% of the vegetable production is sold directly to the households. As household demand is characterized by a Cobb-Douglas function, the increase in household consumption of vegetables by 51.66%, due to the large expansion in production of summer vegetables, is accompanied by a drop in the household price of vegetables of 33.57% (cf. column 1 and 2 in table 3). Exports of vegetables increase by 66.31%. As a combination of the fact that production costs for vegetables have gone down and that Egypt faces a less elastic demand curve for vegetable exports (cf. section 3.2), the export price of vegetables in local currency drops by 15.14% (cf. column 6 in table 3).

There are only minor adjustments in land allocation and production for the other agricultural sectors. As total land area is increased by 10%, this implies that the importance of these sectors decline in relative terms and in some cases also in absolute terms. One of the interesting cases is the highly water intensive sugar cane sector. Following the enlargement of the agricultural area and the onset of water scarcity, the cost of wet land for sugar cane production increases by 44.96%. However, the amount of land allocated to sugar cane only decreases by 4.67%, and production of sugar cane is virtually unchanged, as the sector’s use of labor and capital increases by 5.76% and 6.32% respectively. All in all, the unit costs of producing sugar cane increases by 19.28%, which raises the question why sugar cane production can remain unchanged in the face of such increases in costs? The explanation for this observation is the fact that sugar cane is neither imported nor exported, and 86% of sugar cane production ends up in the food processing industry. However, sugar cane only accounts for 3% of intermediate inputs into the food processing industry, so an increase in the price of sugar cane of 19.28% does not have a significant impact on the food processing sector. Production of processed food is virtually unaffected in the present simulation, and the production of the water intensive crop sugar cane is thus kept up by demands from the domestic food processing industry.

The only non-agricultural sector, which is significantly affected by the expansion of agricultural land, is the highly trade-exposed oil industry. Total production of oil thus decreases by 8.14%. 53% of domestic oil production is exported, and the decline in oil production is a result of oil exports declining by 14.99%. The decline in oil exports is a result of the fact that local sales and exports of domestically produced oil are assumed to be perfectly substitutable and oil export demand is assumed to be highly elastic. The oil industry is highly capital-intensive, with capital costs accounting for 79% of total sector costs. Even a minor increase in the price of capital of 0.76% (combined with an increase in labor costs of 2.54%) thus results in unit costs of oil production – and hence also export prices - increasing by 0.87% in local currency and 0.33% in foreign currency.[22]

In terms of export revenue and import expenditures, the only commodities for which export revenue or import expenditures change significantly in absolute terms is oil (exports) and wheat (imports). As it turns out, the decline in oil export revenue matches the decline in wheat import expenditures fairly closely. This is in accordance with the long run closure, which requires the nominal trade balance as a fraction of nominal GDP to be unchanged, as the rest of the world is assumed to be unwilling to fund an increasing trade deficit.

Turning to the remaining macro results in table 4, we see that total employment (aggregated across sectors using wage bill weights) is fixed in accordance with the long run closure, and the pull of labor into agriculture consequently results in a decline in non-agricultural employment of 0.54%. As for the capital markets, the long run closure entails that the gross rate of return for capital in each sector is assumed to be exogenous, which results in identical changes in the rental rate of capital (cf. table 2).[23] While the agricultural capital stock increases by 4.00%, the non-agricultural capital stock decreases by 0.82%, which results in a decrease of the total capital stock of 0.65%. The decrease in the non-agricultural capital stock is attributable to the contracting, capital-intensive oil industry, which accounts for 10.7% of total capital costs in the economy.

[22] The price of exports in foreign currency is calculated by subtracting the change in the nominal exchange rate from the change in the export price in local currency.

[23] In ORANI-G model, the gross rate of return on capital is defined as the rental price of capital divided by the price of new capital. In the long run closure, the gross rate of return on capital in all sectors is set exogenously. The rental price of capital is consequently determined by the price of new capital in the long run. As the SAM only contained one investment commodity, this commodity was distributed proportionally across all sectors (by assuming that each industry's share of aggregate investment is proportional to the industry's share of total capital rent). The investment profile in all sectors is thus identical. This is not a realistic assumption, but data was not available for differentiating investment profiles across sectors. The fact that each sector has identical investment profiles results in the price of new capital being identical across sectors, which in turn results in changes in rental prices of capital being identical across sectors in the long run. As the sector "other industry" accounts for 52.3% of the investment good, and as 47% of the total supply of other industry goods are imported, the price of new capital and hence also the long run rental price of capital is sensitive to changes in the exchange rate.

The cropping sectors only account for 10% of the value of total sectoral output. The cropping sectors thus only amount to a minor share of the total economy, and as table 4 shows, the increase of summer and winter dry land by 10% only results in an increase in real GDP of 0.44%. Real household and real government consumption increase by 0.74. The nominal exchange rate depreciates by 0.54% and export volumes and import volumes decline by 3.15% and 2.22% respectively. Despite the significant impact on the agricultural sector itself, the expansion of summer and winter land by 10% thus only has minor impacts on the economy-wide level.

*Results for the water-abundant land-expansion scenario.*
In order to determine the impact of the water constraint on agricultural production and international trade, a second scenario is run featuring a 10% increase in the amount of summer and winter dry land. However, this time the water constraint is relaxed so as not to become binding despite the expansion of the land area. In all other respects the scenario is identical to the previous water constrained scenario.

The production, trade, and macro economic results for the non-water constrained scenario are presented in tables 5 to 8. Similarly to the presentation of the results in the water-constrained scenario, table 5 shows the changes percentage changes in output and input quantities in the different sectors, while table 6 shows the percentage changes in the corresponding input and output prices. Table 7 presents the percentage changes in quantities and prices for household demands, imports and exports, while table 8 presents the macro economic results for the scenario.

As table 8 shows, the expansion of summer and winter dry land by 10% results in consumption or loss of irrigation water increasing by 11.6%. The increase in agricultural employment of 4.79% is larger than in the water-constrained scenario and so is the expansion in the agricultural capital stock of 5.95%.

The fact that the agricultural sector does not become water constrained has significant implications for land rents. In the previous scenario, the onset of water scarcity following the land expansion resulted in general summer and winter dry land rents declining by 68% and 50% respectively. In the current water abundant scenario, the expansion of dry land only results in general summer and winter dry land rents declining by 10.53% and 2.44%

respectively, while perennial dry land rents decline by 6.61%. As the water constraint does not become binding, the tax on water diversions remain zero. The cost of wet land is consequently identical to the price of dry land, and the cost of wet land thus declines for all crop sectors (except the two "other crop" categories) (cf. table 6). This in turn has significant implications for the allocation of land between crop sectors.

As shown in table 5, expanding the amount of dry land in a water-abundant setting once again primarily affects the winter crop sectors wheat and winter vegetables and the summer crop sectors rice and summer vegetables. As was the case in the previous scenario, the decline in the price of wet land and unit costs of production for wheat results in a drop in wheat imports by 34.44% and an increase in domestic production of wheat by 27.83%. Both the drop in wheat imports and the expansion in domestic wheat production is smaller in this water-abundant scenario than in the previous water-constrained scenario. This may in large part be explained by the changes in the nominal exchange rate. The water-constrained scenario was thus characterized by a devaluation, which would make wheat import more expensive, whereas the present water-abundant scenario produces a minor appreciation of the nominal exchange rate (cf. tables 4 and 8).

The decline in the cost of wet land for rice production results in unit cost of rice production declining by 4.76%, which in turn translates into a decline of 4.76% in the export price of rice in local currency and a decline of 4.71% in the export of rice in foreign currency. As rice for domestic markets and export markets are perfect substitutes and export demands for rice are highly elastic, rice exports subsequently increase ten-fold by 1016%(!) However, as rice exports only amounted to 2% of rice production prior to the expansion of agricultural land, the massive increase in rice exports is "only" accompanied by a 24.34% increase in rice production.

TABLE 5: CHANGES IN PRODUCTION AND INPUT QUANTITIES IN WATER ABUNDANT SCENARIO (PERCENTAGE CHANGE)

| | Sector activity level | Effective labor input | Capital stock | Dry land | Water diverted | Wet land |
|---|---|---|---|---|---|---|
| Wheat | 27.83 | 26.76 | 27.37 | 28.43 | 28.43 | 28.43 |
| Legumes | 0.58 | -0.07 | 0.41 | 1.25 | 1.25 | 1.25 |
| LongBerseem | 0.83 | -0.35 | 0.13 | 0.96 | 0.96 | 0.96 |
| ShortBerseem | 2.70 | 1.51 | 1.99 | 2.93 | 2.93 | 2.93 |
| WinVeg | -15.07 | -15.84 | -15.43 | -14.73 | -14.73 | -14.73 |
| OthWinCrp | 0.15 | 0.13 | 0.61 | 0.00 | 0.00 | 0.00 |
| Cotton | 0.74 | -1.01 | -0.53 | 2.93 | 2.93 | 2.93 |
| Rice | 24.34 | 21.58 | 22.16 | 26.42 | 26.42 | 26.42 |
| MaizeSorg | 3.20 | 0.74 | 1.23 | 4.75 | 4.75 | 4.75 |
| SumVeg | 13.24 | 9.76 | 10.29 | 14.13 | 14.13 | 14.13 |
| OthSumCrp | 0.12 | 0.07 | 0.55 | 0.00 | 0.00 | 0.00 |
| Fruit | 1.75 | 0.52 | 1.01 | 3.19 | 3.19 | 3.19 |
| SugarCane | 0.16 | -1.22 | -0.75 | 1.40 | 1.40 | 1.40 |
| AnimalAgr | 1.13 | 0.74 | 1.23 | - | - | - |
| | | | | | | |
| FoodProcess | 0.18 | -0.56 | 0.40 | - | - | - |
| Oil | -10.77 | -10.90 | -10.76 | - | - | - |
| CottonGin | 0.73 | 0.34 | 1.30 | - | - | - |
| Textiles | 0.00 | -0.54 | 0.42 | - | - | - |
| OthIndustry | -0.40 | -1.15 | -0.20 | - | - | - |
| | | | | | | |
| Electricity | -0.17 | -0.64 | 0.00 | - | - | - |
| Construction | -0.34 | -0.99 | -0.04 | - | - | - |
| GovServ | 0.39 | 0.39 | - | - | - | - |
| Transport | -0.31 | -1.07 | -0.12 | - | - | - |
| OthServ | -0.49 | -1.15 | -0.20 | - | - | - |

TABLE 6: CHANGES IN OUTPUT AND INPUT PRICES IN WATER ABUNDANT SCENARIO (PERCENTAGE CHANGE)

| | Average input / output price | Price of labor composite | Rental price of capital | Dry land rents | Tax on water diverted (absolute change) | Cost of wet land |
|---|---|---|---|---|---|---|
| Wheat | -0.77 | 1.91 | 0.29 | -2.44 | 0.00 | -2.44 |
| Legumes | -0.20 | 1.91 | 0.29 | -2.44 | 0.00 | -2.44 |
| LongBerseem | -1.92 | 1.91 | 0.29 | -2.44 | 0.00 | -2.44 |
| ShortBerseem | -1.94 | 1.91 | 0.29 | -2.73 | 0.00 | -2.73 |
| WinVeg | -1.63 | 1.91 | 0.29 | -2.44 | 0.00 | -2.44 |
| OthWinCrp | 1.59 | 1.91 | 0.29 | 2.35 | 0.00 | 2.35 |
| Cotton | -3.29 | 1.91 | 0.29 | -10.53 | 0.00 | -10.53 |
| Rice | -4.76 | 1.91 | 0.29 | -10.53 | 0.00 | -10.53 |
| MaizeSorg | -5.13 | 1.91 | 0.29 | -10.53 | 0.00 | -10.53 |
| SumVeg | -7.13 | 1.91 | 0.29 | -10.53 | 0.00 | -10.53 |
| OthSumCrp | 1.46 | 1.91 | 0.29 | 2.13 | 0.00 | 2.13 |
| Fruit | -1.92 | 1.91 | 0.29 | -6.61 | 0.00 | -6.61 |
| SugarCane | -2.16 | 1.91 | 0.29 | -6.61 | 0.00 | -6.61 |
| AnimalAgr | -0.64 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| FoodProcess | 0.02 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| Oil | 0.39 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| CottonGin | -2.35 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| Textiles | 0.15 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| OthIndustry | 0.41 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| | | | | | | |
| Electricity | 0.56 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| Construction | 0.48 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| GovServ | 1.46 | 1.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| Transport | 0.51 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |
| OthServ | 0.64 | 1.91 | 0.29 | 0.00 | 0.00 | 0.00 |

TABLE 7: CHANGES IN QUANTITIES AND PRICES OF HOUSEHOLD DEMANDS, IMPORTS AND EXPORTS FOR WATER ABUNDANT SCENARIO (PERCENTAGE CHANGE)

| | Household use of domestic / imported composite | Household price of domestic / imported composite | Total supplies of imported goods | Duty-paid, basic price of imported goods (local currency) | Export basic demands | Purchaser's price of export goods (local currency) |
|---|---|---|---|---|---|---|
| Wheat | 0.88 | -0.49 | -34.44 | -0.05 | - | 0.00 |
| Legumes | 0.55 | -0.16 | 0.49 | -0.05 | 0.64 | -0.07 |
| Berseem | 0.00 | 0.00 | 0.00 | -0.05 | - | 0.00 |
| OthWinCrp | 0.00 | 0.00 | 0.00 | -0.05 | - | 0.00 |
| Cotton | 0.00 | 0.00 | 0.00 | -0.05 | - | 0.00 |
| Rice | 5.41 | -4.76 | 0.00 | -0.05 | 1016.61 | -4.76 |
| MaizeSorg | 5.82 | -5.13 | 0.18 | -0.05 | - | 0.00 |
| OthSumCrp | 0.00 | 0.00 | 0.00 | -0.05 | - | 0.00 |
| Vegetables | 6.39 | -5.64 | 0.00 | -0.05 | 7.30 | -2.37 |
| Fruit | 2.36 | -1.92 | 1.12 | -0.05 | 3.25 | -0.12 |
| SugarCane | 0.00 | 0.00 | 0.00 | -0.05 | - | 0.00 |
| AnimalAgr | 1.01 | -0.62 | 0.63 | -0.05 | - | 0.00 |
| | | | | | | |
| FoodProcess | 0.38 | 0.02 | 0.18 | -0.05 | 0.03 | -0.05 |
| Oil | 0.18 | 0.22 | 0.23 | -0.05 | -19.82 | 0.39 |
| CottonGin | 0.00 | 0.00 | 0.00 | -0.05 | 5.31 | -0.16 |
| Textiles | 0.22 | 0.17 | 0.13 | -0.05 | -0.39 | -0.05 |
| OthIndustry | 0.18 | 0.22 | -0.16 | -0.05 | -1.27 | -0.03 |
| | | | | | | |
| Electricity | -0.17 | 0.56 | 0.00 | -0.05 | - | 0.00 |
| Construction | -0.09 | 0.48 | 0.00 | -0.05 | - | 0.00 |
| GovServ | 0.00 | 0.00 | 0.00 | -0.05 | - | 0.00 |
| Transport | -0.15 | 0.54 | 0.01 | -0.05 | -0.48 | 0.43 |
| OthServ | -0.21 | 0.60 | -0.25 | -0.05 | -0.62 | 0.57 |

TABLE 8: MACRO ECONOMIC RESULTS FOR WATER ABUNDANT SCENARIO (PERCENTAGE CHANGE)

| | | | |
|---|---|---|---|
| Agricultural winter land | 10 | Nominal GDP | 0.35 |
| Agricultural summer land | 10 | Real GDP | 0.07 |
| Consumption or loss of irrigation water | 11.6 | GDP price index (expenditure side) | 0.28 |
| | | | |
| Agricultural employment | 4.79 | Aggregate real household consumption | 0.39 |
| Non-agricultural employment | -0.69 | Aggregate consumer price index | 0 |
| Total employment (wage bill weights) | 0 | Aggregate real government demands | 0.39 |
| | | | |
| Agricultural capital stock | 5.95 | Nominal trade balance as share of nominal GDP (absolute change) | 0 |
| Non-agricultural capital stock | -1.23 | Nominal exchange rate | -0.05 |
| Total capital stock | -0.98 | Terms of trade (export price index - import price index) | 0.41 |
| | | Real devaluation (import price index - GDP price index) | -0.34 |
| | | Export volume index | -2.86 |
| | | Import volume index | -1.94 |

The rice area expands by 26.42%, which amounts to about half of the expansion in the summer dry land area. The remaining part of the new summer dry land is primarily used for summer vegetables and maize-sorghum. Production of summer vegetables thus expands by 13.24%, while production of maize-sorghum expands by 3.20%. The increase in production of summer vegetables leads to a decline in the production of winter vegetables of 15.07%. As the summer vegetable sector is initially more than twice as large as the winter vegetable sector, total vegetable production still increases by 4.44%.

The only non-agricultural sector, which is significantly impacted by the land expansion, is once again the oil industry. In the present water-abundant scenario, oil production decreases by 10.77%, which is 2.6 percentage points more than in the water-constrained scenario. Again the contraction in the oil industry is driven by a drop in oil exports, this time in the order of 19.82%. The larger decline in oil exports is a result of the massive increase in rice exports. While the nominal exchange rate depreciated by 0.54% compared to the consumer price index (i.e. the numeraire) in the previous water constrained scenario, the nominal exchange rate in the present water abundant scenario appreciates by 0.05% compared to the consumer price index.

Turning to the macro economic results, we see that an expansion of summer and winter dry land by 10% in a water-abundant setting only results in an increase in real GDP of 0.07%, while the same increase in summer and winter dry land in a water-constrained setting resulted in an increase in real GDP of 0.44%. Extra water resources consequently do not appear to be beneficial to the Egyptian economy, which seems puzzling. However, a part of this result derives from the development in the rice sector.

As outlined earlier, rice produced for the domestic markets is assumed to be a perfect substitute for rice produced for local markets, and export demands for rice are also highly elastic. This resulted in large swings in rice exports, as these were basically eliminated in the water-constrained land-expansion scenario, while they increased ten-fold in the water-abundant land-expansion scenario. The appreciation of the exchange rate in the latter scenario is driven by this massive increase in rice exports. The appreciation of the nominal exchange rate in the water-abundant scenario corresponds to a real appreciation of 0.34% compared to a real depreciation of 0.15% in the water-scarce scenario (cf. table 4 and table 8). Tests of the model in which rice for domestic markets and rice for export markets are turned into imperfect substitutes using the same CET value as that for other crop commodities show that the appreciation is harmful to the Egyptian economy in the sense that real GDP in the water-abundant scenario increases more when the rice export response is tempered and the exchange rate depreciates leading to a real depreciation. However, even with rice exports being imperfect substitutes for rice for local markets, real GDP in the water-constrained scenario still increases more than real GPD in the water-abundant scenario (0.42% vs. 0.30%).[24]

One factor, which may explain at least part of this remaining gap between real GDP in the two scenarios, is the differences in land rents across sectors. As outlined in section 3.3, land rents in the two vegetable sectors are significantly higher than land rents in most other sectors. In the water-constrained scenario, land use in the summer vegetable sector expands by 88%, while land use for winter vegetables declines by 44%. However, as the summer vegetable sector was initially twice as large as the winter vegetable sector, and as summer vegetable land rents are almost 50% higher than winter vegetable land rents, these changes in the cropping pattern imply that significant amounts of "cheap" land used for production of other crops is converted into "expensive" land for vegetable cultivation in the course of the simulation. This conversion of cheap land for normal crops into more valuable land for vegetable crops comes free of charge, as land is assumed to be perfectly mobile between sectors. In the water-abundant scenario, vegetable production does not expand nearly as much as in the water-constrained scenario – land for summer vegetable production thus only increase by 14.13%, while land for winter vegetable production decreases by 14.73%. Given these differences in the cropping patterns in the two scenarios, Egypt thus gets more of the valuable vegetable land in the water-constrained scenario than in the water-abundant scenario.

The notion that this conversion of normal crop land into more valuable vegetable crop land may explain why real GDP is higher in the water-constrained scenario than in the water-abundant scenario seems to be supported by the results for change in the aggregate amount of wet land. Wet land is aggregated across sectors using basic wet land prices, which are equal to dry land rents, as the basic price of water is zero (cf. section 2.1). In the water-constrained scenario, the results show that the aggregate amount of wet land increases by 13.14%, while it only increases by 8.37% in the water-abundant scenario. Comparing the increases in the

[24] In these scenarios where rice exports are imperfect substitutes for rice for domestic markets, the changes in the aggregate capital stock are approximately the same (-0.67% in the water-constrained scenario vs. -0.63% in the water-abundant scenario), which suggests that the lower GDP in the latter scenario is not explained by a lower aggregate capital stock.

aggregate amount of wet land in the two scenarios with the fact that the aggregate physical amount of dry land increases by 10% in each scenario suggests that the high vegetable land rents make is appear as though the economy is gaining more land in the water-constrained scenario than in the water-abundant scenario, which in turn would explain why real GDP is higher in the former scenario.[25]

## 6. DISCUSSION AND CONCLUSION.

The present analysis has investigated the linkages between Egyptian crop production, the ensuing national water constraint and international trade.

The two scenarios illustrated the impact of the water constraint on Egyptian international trade in a situation where summer and winter dry land was expanded by 10%. Where most of the Egyptian crop sectors were assumed to be relatively sheltered from the developments in the international agricultural markets through low degrees of substitutability either between imports and domestically produced commodities or between commodities destined for export and commodities destined local markets, this was not the case for the wheat and rice sectors. Imports of wheat were thus assumed to be perfectly substitutable for domestically produced wheat, while rice destined for exports were assumed to be perfectly substitutable with rice destined for local markets and export demands were assumed to be highly elastic. Given the relative magnitudes of these sectors – wheat accounts for 35% of winter land use and rice accounts for 22% of summer land use – as well as the degree of trade exposure for wheat and rice commodities, the developments in the wheat and rice sector tended to dominate the results in the two scenarios.

As wheat is not a particularly water-intensive crop, the onset of water scarcity only appeared to have minor impacts on this sector. It should be noted, though, that the difference in the resulting exchange rate between the two scenarios may have masked some of the impacts of the water constraint. Unlike wheat, rice is a highly water-intensive crop, and accounting for the water constraint consequently had very pronounced effects for exports of this trade-exposed commodity. In the water-constrained scenario, rice exports were thus eliminated,

[25] Apart from aggregate labor, aggregate capital, and aggregate wet land, the decomposition of GPD from the income side also includes taxes and technical changes. The technical change term is zero in both scenarios, as the simulations feature no technical changes. As for the contribution from taxes, the results show that this amounts to -0.022 percentage points in the water-constrained scenario and -0.019 percentage points in the water-abundant scenario, despite the significant increase in water taxes in the former scenario.

while rice exports in the water-abundant scenario increased ten-fold. Although rice exports only amounted to 0.1% of total exports in the initial database, the massive increase in exports of this commodity in the water-abundant scenario still brought about an appreciation of the nominal exchange rate, which had a negative impact on the economy and real GDP, although it did not explain all of the difference between real GDP in the two scenarios. The remaining difference between GDP in the two scenarios appears to be driven by the massive shift of land into the summer vegetable sector in the water-constrained scenario, as this implies a costless conversion of normal land into high value land.

The fact that the expansion of agricultural land apparently has relatively small effects on GDP in the land-constrained Egyptian economy raises some questions as to what degree the present simulations illustrate the future conditions of the Egyptian economy. The important thing to note here is that the present simulations merely increase the amount of dry land in the economy without considering changes in population and labor force, the capital stock, and general productivity. In order to fully capture the future realities of the Egyptian economy and the implications of expanding the land area in this economy, it would be necessary to construct a baseline of the Egyptian economy for the time period over which the land expansions will take place.

Further investigation of the land rent issues would also be an area for future work. While the differences in land rents may reflect real-world phenomena, the results from the two scenarios showed that it would be relevant to study the implications of either having more homogenous land rents or limiting substitution in and out of sectors with high land rents, both in terms of the resulting cropping patterns and in terms of the implications for GDP.

Parameter assumptions are clearly also very important for model results as the discussion of the trade results have shown. A set of model parameters, which it would be desirable to update, is the household demand parameters, as household demands are not likely to conform to a Cobb-Douglas function. Combining such parameters with additional model extensions to close the income-expenditure circuits for the households and the government, the model could subsequently also be used for analysis of the distributional aspects of the water constraint.

All in all, the analysis has demonstrated some of the key implications for Egyptian agricultural trade of accounting for the ensuing water constraint as well as how this can be done using CGE models and SAMs, which do not initially account for agricultural water usage. As the degree of water scarcity in Egypt becomes more pronounced in the coming years, accounting for agricultural water usage in the national economic models will only become more important.

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## APPENDIX A: HOUSEHOLD, INDUSTRY AND COMMODITY AGGREGATIONS

### SECTORAL AGGREGATIONS

| Aggregated industries | SAM industries |
|---|---|
| Wheat | Wheat |
| Legumes | Legumes |
| LongBerseem | Long berseem |
| ShortBerseem | Short berseem |
| WinVeg | Winter vegetables |
| OthWinCrp | Other winter crops |
| Cotton | Cotton |
| Rice | Rice |
| MaizeSorg | Maize-sorghum |
| SumVeg | Summer vegetables |
| OthSumCrp | Other summer crops |
| Fruit | Fruit |
| SugarCane | Sugar cane |
| AnimalAgr | Animal agriculture |
| | |
| FoodProcess | Subsidized bread, non-subsidized bread, subsidized flour, non-subsidized flour, other food processsing |
| Oil | Oil |
| CottonGin | Cotton ginning |
| Textiles | Textiles |
| OthIndustry | Other industry |
| | |
| Electricity | Electricity |
| Construction | Construction |
| GovServ | Government services |
| Transport | Transportation |
| OthServ | Other services |

### COMMODITY AGGREGATIONS

| Aggregated commodities | SAM commodities |
|---|---|
| Wheat | Wheat, wheat byproducts |
| Legumes | Legumes, legumes byproducts |
| Berseem | Berseem |
| OthWinCrp | Other winter crops, other winter crops byproducts |
| Cotton | Cotton, cotton byproducts |
| Rice | Rice, rice byproducts |
| MaizeSorg | Maize-sorghum, maize-sorghum byproducts, yellow maize |
| OthSumCrp | Other summer crops, other summer crops byproducts |
| Vegetables | Vegetables |
| Fruit | Fruit |
| SugarCane | Sugar cane |
| AnimalAgr | Animal agriculture, animal labor, manure |
| FoodProcess | Subsidized bread, non-subsidized bread, subsidized flour, non-subsidized flour, other food processsing |
| Oil | Oil |
| CottonGin | Cotton ginning |
| Textiles | Textiles |
| OthIndustry | Other industry |
| Electricity | Electricity |
| Construction | Construction |
| GovServ | Government services |
| Transport | Transportation |
| OthServ | Other services |

## APPENDIX B: CROPPING PATTERN FOR 1997 (MILLION FEDDAN)

| | Summer land | Winter land |
|---|---|---|
| Wheat | | 2.52 |
| Legumes | | 0.42 |
| LongBerseem | | 1.59 |
| ShortBerseem | | 0.70 |
| WinVeg | | 0.47 |
| OthWinCrp | | 0.27 |
| Cotton | 0.86 | |
| Rice | 1.55 | |
| MaizeSorg | 2.31 | |
| SumVeg | 1.01 | |
| OthSumCrp | 0.23 | |
| Fruit | 0.96 | 0.96 |
| SugarCane | 0.29 | 0.29 |
| Total | 7.21 | 7.23 |

Source: Own calculations based on a modified version of IFPRI's 1997 SAM, FAOSTAT core production data (http://faostat.fao.org/site/340/DesktopDefault.aspx?PageID=340) , and data from Mohamed 2001.

## APPENDIX C: NATIONAL CROP EVAPOTRANSPIRATION COEFFICIENTS (000 CUBIC METERS PER FEDDAN)

| | Summer crop ET | Winter crop ET | Annual ET |
|---|---|---|---|
| Wheat | | 2.12 | 2.12 |
| Legumes | | 1.44 | 1.44 |
| LongBerseem | | 2.97 | 2.97 |
| ShortBerseem | | 1.02 | 1.02 |
| WinVeg | | 1.67 | 1.67 |
| OthWinCrp | | 1.87 | 1.87 |
| | | | |
| Cotton | 2.97 | | 2.97 |
| Rice | 4.46 | | 4.46 |
| MaizeSorg | 2.55 | | 2.55 |
| SumVeg | 2.18 | | 2.18 |
| OthSumCrp | 2.93 | | 2.93 |
| | | | |
| Fruit | 3.08 | 1.66 | 4.74 |
| SugarCane | 5.24 | 2.82 | 8.06 |

Source: Own calculations based on data from Mohamed 2001 p A39-A40.