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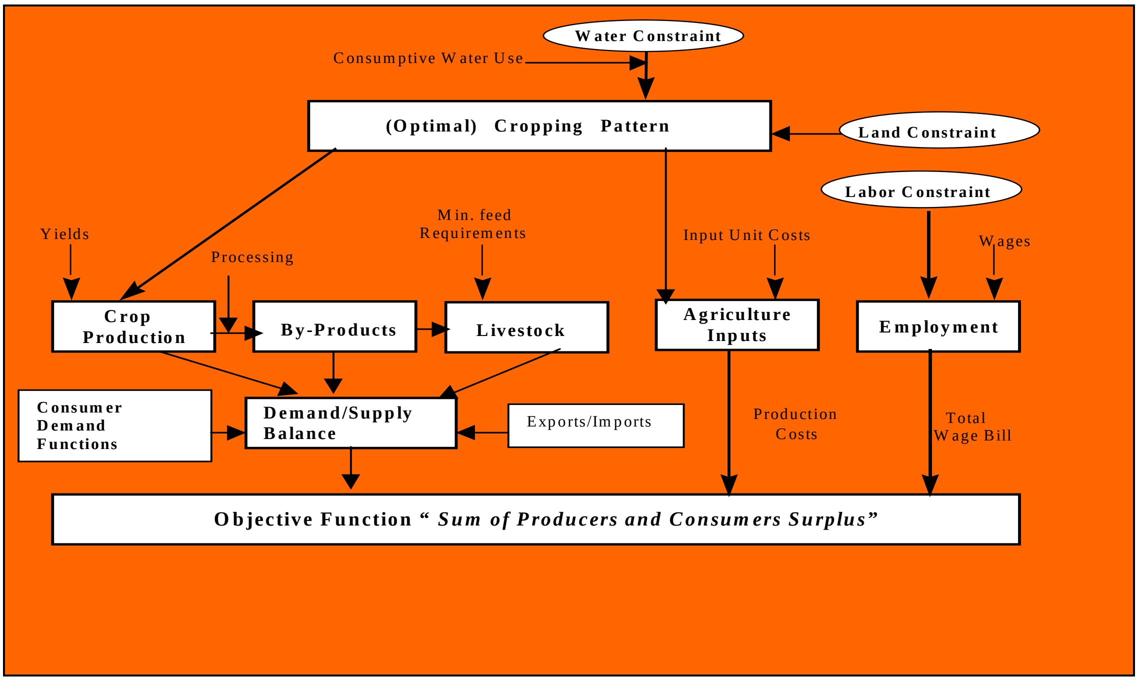

REVIEW OF THE AGRICULTURAL SECTOR MODEL OF EGYPT (ASME97): 1999 VERSION

Report No. 27

December 1999

Water Policy Program

International Resources Group **Winrock International** **Nile Consultants**

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REVIEW OF THE AGRICULTURAL SECTOR MODEL OF EGYPT (ASME97): 1999 VERSION

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Executive Summary

The Agricultural Sector Model for Egypt (ASME) has a long history. Early planning efforts led to the first "Egypt Model" in the GAMS format in the early 1980's. Revisions of that model have been relatively frequent, including those by the Ministry of Water Resources and Irrigation (MWRI) Planning Sector. The last revision was made in 1997 by Dr. Binder through the auspices of RDI.

The current effort involved reviewing the model for consistency, providing a reasonably detailed description of the model structure and data, and evaluating, in so far as possible, the efficacy of the model for policy analysis. A working group, consisting of personnel from MWRI, MALR, EPIQ, NWRP, and RDI, undertook the tasks. Initial model results were used to begin the review process, and problems were identified as the work proceeded.

In the process of the review, all data in the model were updated to base year 1995. A second data set reflecting 1997 data were also developed. A set of automatic checks was developed which identified inconsistencies in the model structure and data. Several aspects of the model were identified as problematic, including the import/export activities, marketing cost determination, portions of the livestock activities, and the structure of the objective function (in particular, the determination of the commodity demand curves). While temporary solutions were found to these problems, in the longer term structural solutions should be found.

An example of the use of the model was developed, in which the demand curves (marginal values) for water were generated. The results appeared to be consistent with other estimates of the value of water. Moreover, these demand curves suggested limited sensitivity to water reallocations or shortages over ranges consistent with short run planning horizons, but strong sensitivity to large changes in water availability to existing agriculture.

Like all very complex programming models, the ASME97 version must be used with discretion. Results should be taken as indicative, rather than definitive. It is recommended that the focus of the use of the model for policy analysis be general (directional) rather than specific. However, it is also recognized that the ASME97 model represents a useful tool for policy analysis and evaluation of potential impacts of both policy and other changes in the agricultural economy of Egypt. It is recommended that the ASME Working Group, or a subcommittee of that group, continue their activity in both the short run improvement and modification of the model and in the long run development of policy analysis.

1. Introduction

1.1 Overview

The Agricultural Policy Reform Program (APRP) is a four-year United States Agency for International Development (USAID) grant program involving several ministries. The Ministry of Agriculture and Land Reclamation (MALR) is the primary Egyptian governmental agency charged with support of agricultural production. The Ministry of Water Resources and Irrigation (MWRI) has the prime responsibility for management of Egypt's water resources. MALR, MWRI and USAID, under the umbrella of the APRP, jointly designed an agricultural and water policy package, which consists of integrated policy and institutional reforms. USAID supports the Ministries' efforts through annual cash transfers based on performance in achieving identified and agreed-upon policy reform benchmarks and technical assistance.

Technical assistance for the water policy analysis activity is provided through a task order (Contract PCE-I-00-96-00002-00, Task Order 807) under the umbrella of the Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ) between USAID and a consortium headed by the International Resources Group (IRG) and Winrock International. Local technical assistance and administrative support is provided through a subcontract with Nile Consultants.

1.2 Purpose of the Report

Given the complexity of Egypt's irrigation system, efforts to develop planning tools with which to manage Egypt's allocation of the Nile Basin water resources have a long history.
The Agricultural Sector Model of Egypt (ASME) is one of those planning tools for which MWRI and MALR have requested APRP assistance in evaluating and upgrading activities. The same tool is being used by Dutch-funded National Water Resources Plan (NWRP) project in the Planning Sector of MWRI.

This report presents a review of the ASME model as it was revised in 1999 by the ASME Working Group (composed of members from the MWRI, NWRP, MALR, EPIQ and RDI representatives), a discussion of data upgrading which has taken place, and a general discussion of the limits of the model for planning and policy evaluation purposes.

1.3 Background

Egypt is dependent upon the Nile River for 98 percent of its water, and receives a fixed allocation from the High Aswan Dam of 55.5 billion cubic meters (bcm). Fresh water availability in Egypt is estimated to be about 950 cubic meters (cum) per capita, a level which is below the “water scarcity” threshold of 1,000 cum per capita, as reported by the FAO and other international agencies interested in water and its management. Moreover, the population is growing at a relatively rapid rate, claiming both municipal and industrial water and adding to the pollution of downstream flows.

Egypt’s agricultural production, a dominant economic sector, is almost entirely based on irrigation. The overall efficiency of water use in Egypt’s portion of the Nile Basin has been estimated to be nearly 75 percent, with outflows and evaporative losses of about 13.5 bcm. Further, the Government of Egypt (GOE) has targeted horizontal expansion of irrigation as a priority economic and social development activity. An additional 1.3 million feddans of irrigated cropland has been developed in the period from 1974 to 1997, and further expansion into the West Desert (Toshka) and the Sinai Peninsula of up to 1 million feddans is foreseen for the next decade. Clearly, water use efficiency and water management are of critical importance to the GOE.

The original ASME model was developed in the early 1980’s under the UNDP funded Water Master Plan[1] It was written in GAMS™ language and can be found in its early GAMS form in the GAMS library (GAMSLIB model EGYPT). The model was further developed by IFPRI in collaboration with the Planning Sector of MWRI, in which a detailed water sub-model was added. The model was further modified in 1997 by Dr. Filmore Binder through a contract with APRP. The latter modification included the addition of a livestock sector and the potential for developing new lands.

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[1] Kutcher, G.P., 1990. The Agro-Economic Model, Water Master Plan Technical Report 16.

1.4 Organization of the Report

This report is organized in four parts and two appendices. Chapter 1 is an introduction to the model and the report. Chapter 2 presents an introduction to the 1999 ASME model structure (ASME97). Chapter 3 presents a detailed discussion of specific attributes of the model structure. Chapter 4 discusses the update to 1997 data in the ASME97 model. Chapter 5 includes a discussion of the interpretation of ASME97 results. Chapter 6 presents a summary and conclusions. The appendices present (1) a theoretical statement of the model, specific definitions of variables and equations within the model and a (2) list of data checks.

2. The ASME Model

The following is a general description of the non-linear programming Agricultural Sector Model of Egypt (ASME) and its use for policy evaluation. The first section deals with the model structure and data; the second section discusses the data input very briefly, and the final section suggests alternatives for policy analysis as well as cautions about model interpretations.

The model is written in GAMS™ 2.25 language and uses the MINOS 5.4 solver[2]. The 1999 version of ASME is the result of close cooperation between APRP/EPIQ, MALR (Economic Affair's Sector), Cairo University and NWRP/MWRI (Planning Sector). The model has been revised and updated from the model's 1995 format, reported by Bender (1997), both in terms of data (now on a 1997 basis) and in terms of model structure.

This description assumes that the reader is familiar with linear and non-linear programming. Appendix A includes a brief discussion of some of the specific characteristics of the GAMS model that should provide the reader with sufficient information to understand many of the specific statements of the model itself. The reader should note that a GAMS structure includes:

- Sets, which identify the indices or specific identifiers in the model. For example the set "R" identifies the regions in the model, and includes U-EGYPT (upper Egypt), M-EGYPT (middle Egypt), E-DELTA (eastern delta), M-DELTA (middle delta), W-DELTA (western delta), SCNLAND (new land-sandy soil-canal irrigated), CCNLAND (new land-clay calcareous soil-canal irrigated), SGNLAND (new land-sandy soil-groundwater irrigated), NEWVAL (new valley land), SINAI (new lands in the Sinai), and SEA (a pseudo region for outflows of water); other examples are the set XC (the planted crops) and C (crop commodities for consumption);
- Variables, the values of which are endogenously determined in the optimal solution and which are defined by names and indices. For example, QCNSC(C) which is the total consumption of crop commodities C;
- Parameters, which are the exogenous data included as coefficients in the equations and which may occur as separate numbers, or in tables. For example, LNDREQ(R,XC,PT,TM), is the land requirement by planted crop, region, water regime and time, where PT and TM refer to the timing of water applications and the calendar month; and
- Equations, which establish the constraints on the variables, given the parameters. For example, DSBAL(C), which is the national supply and demand balance equation for each crop C.

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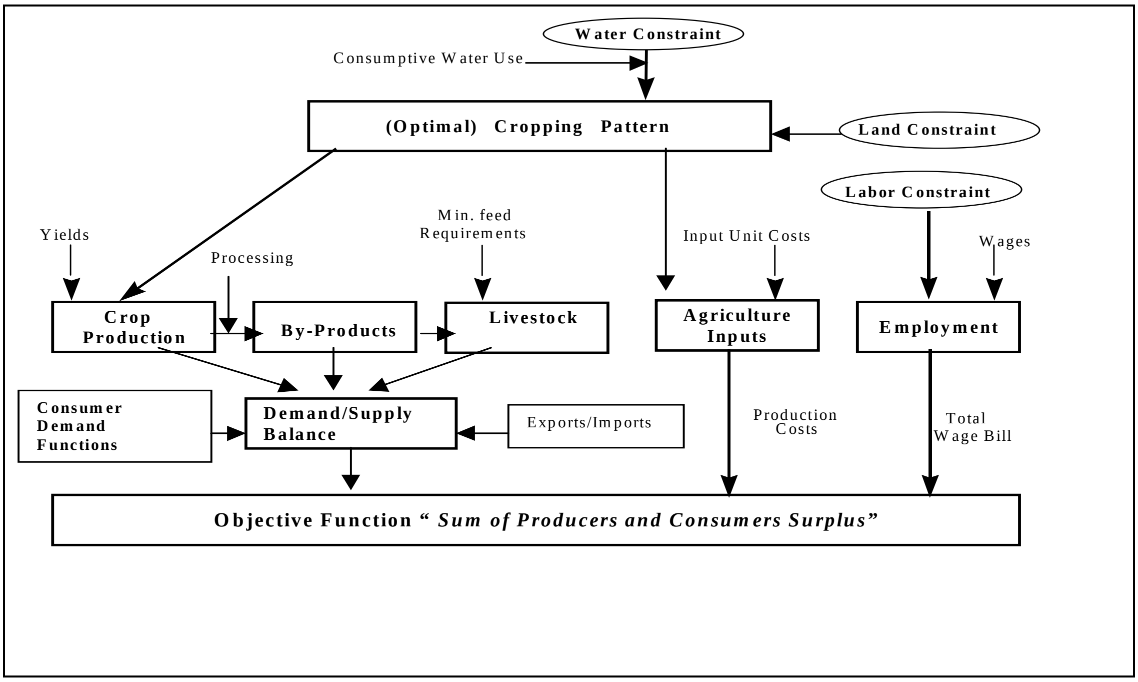
[2] Brook, A. et al (1992): GAMS a User's Guide, The Scientific Press.

Note that the ASME97 model is composed of several modules, including BASE97.GMS (which is the overall model command), BMODEL.INC, DATASET.INC, WATER.INC, YIELD.INC, POLICY.INC, CHECKS.INC, REPORTS INC, as well as other modules (*.INC) which serve to provide sensitivity tests and reporting of specific solution values. A post-processing TABLES.GMS is used to prepare summary tables showing actual 1997 and projected model results.

2.1 General Description of the ASME Model

The ASME model is a static partial equilibrium model in which social welfare in the form of consumers' plus producers' profits (surplus) from agriculturally-based consumption commodities, both crops and livestock, is maximized subject to resource, technical production, balancing, and policy constraints. The following discussion will give a general description of the model in sections along with the identification of specific parameters or tables of parameters including (1) resources; (2) technical relationships; (3) balancing constraints; (4) policy constraints; and (5) the objective function. Appendix A contains verbal descriptions of variables, sets (indices), and equations. The tables which are referenced are found in the DATASET.INC module, except where indicated. A schematic of the model is found in Figure 1 (taken from an unpublished paper by A. Shawky).

Figure 1. Schematization of the Agricultural Sector Model



2.2 Resources

2.2.1 Land

The resource limits in the model consist of land, labor and water. Egypt is divided into eight main regions: 5 old land regions consisting of Upper and Middle Egypt, and East, Middle and West Delta, three “old new lands” regions (SCNLAND), the groundwater irrigated areas (SGNLAND) and Nubaria (CCNLAND), and two new land regions, SINAI and NEWVAL. Sinai and New Valley with their potential for land reclamation have been included but are not active in the present data set. A final “SEA” region serves as a residual “deposit” activity for water and is not a productive region (see BMODEL.INC). Land in each category has an upper bound [found in the table QLNDSUP(R)]. Old new lands generally follow input requirements for Middle Egypt, although some data (water requirements, yields, and fodder byproducts) are unique.

2.2.2 Labor

Labor in the model consists of family and hired (temporary) labor. First, the number of families is given for each region. Available family labor (in man-days) is the number farm families in the specific region multiplied by a factor indicating average number (1.5) of full-time equivalent workers per family [found in table FARMERS(R) and parameter QLABSUP(R)]. Temporary labor can be hired at a specified reservation wage (average male wages) with no restrictions. That is, the supply of temporary labor is assumed infinitely elastic at the going regional wage rate [found in table WAVG(R)]. Family labor is assumed to have a reservation wage of 85% of the going wage. Thus, the model should use family labor up to its maximum availability, and then use hired labor as long as the objective function is increased.

2.2.3 Water

These data are found in the WATER.INC module. Water is limited by the releases from the High Aswan Dam (55.5 billion cubic meters [bcm] found in parameter MAXREL) plus groundwater pumping [table MAXGW(R)]. Water is diverted for crop use based on water needs (see below). Return flows go to the drains (except for Middle and Upper Egypt where water returns to the Nile itself) and are based on application rates, field efficiency (parameter FEFF, see below), and distribution and conveyance efficiencies [parameter IEFF(R)] by regions. A specified percentage of drain water may be reused. Municipal and industrial uses are set as parameters and return flows are a fixed percentage of diversion [tables MUNDEM(R), INDDEM(R), MUNRET(R) and INDRET(R), respectively]. These return flows also go to the drains. Fresh and drainage water flows from upstream regions to downstream regions and then to the sea or sinks are modeled using what appears to be standard water balance equations. That is, these equations are not explicitly temporally dynamic.

2.3 Technical Relationships

There are several kinds of technical relationships: resource and other input requirements for crops and for livestock, yield levels for crops livestock, and processing and byproduct yields. The resource requirements are for land, labor and water.

2.3.1 Cropping relationships

Cropping options

Cropping choices are defined in the model. Some cropping choices are limited (that is, a particular crop in a particular region may not be considered). Some of these limitations are policy-based, rather than physically-based. For instance, growing rice is not permitted in Upper Egypt, even though rice can be grown there. The same is true for sugarcane in the Delta. The choices of crops by region included or permitted by the model is given by the set CRMAP(R,XC) in the BMODEL.INC module.

Land

Land requirements are in terms of feddans (per feddan of crop) on a monthly calendar by region, and vary with the normal growing season of the crop selected (table LNDREQ). Seasons include summer, winter, and nili (early fall). Frequently, the first month and last month's land requirement is only partial for a given crop which indicates a mid-month planting or harvesting activity. Normal annual rotations are preserved by the inability of the model to overlap these growing seasons. However, nothing in the model prevents a single rotation from dominating all production in any region, so that typical multi-year rotations are not assured. Crops may also be grown earlier than normal, at a normal time, or later than normal, with accompanying changes in yields (see below). Note that the cropping intensity can rise above 2 (double cropping plus nili cropping).

Labor

Labor requirements are formulated much like the land requirements. Each crop has a monthly labor requirement per feddan in terms of man-days per month by season and by region [table LABREQ(R,XC,PT,TM)]. Note that one of the functions of the relationships in the CHECKS.INC module is to assure that crops have both land and labor requirements (see below).

Water

Seasonal (rather than monthly) water requirements are given in application rates per feddan by crop and region [table WATER0(R,XC,PT,TM)]. Adjustment factors for water applications for alternative planting dates are specified by the TM set (Early, Late and Normal) and water use intensity or water deficit can also be varied. There are several levels of water deficit (Table WDEF in YIELD.INC), ranging from 5% to 50% in increments of 5%. Note that yields are adjusted for these alternatives (see below). Field efficiencies are also specified by region [table FEFF(R)]. Rice cultivation requires the application of 2,000 cum/feddan (RICEPER) in addition to its water requirement listed in table WATER0, in order to be consistent with current rice cropping practices. (land preparation as well as higher application rates during the growing season). Note that there are two types of paddy rice in the model (PADDY1 and PADDY2). PADDY2 appears to be short-duration rice varieties. However, yields and water requirements for PADDY2 appear to be different from actual practice for the short-duration varieties and need to be modified according to the most recent data.

Other inputs

Other inputs (quantity per feddan) consist of nitrogenous, phosphate, and potassium fertilizers, manure, seeds [table QOINPUT(R,XC,QFR), where QFR specifies the inputs, and pumping, tractor time, spraying, and threshing [QMECH(R,SC,MHP) where MHP refers to the mechanized inputs] per feddan for each crop and region. These values are fixed, but could be modified by changing the table values. Rent, animal traction, pesticides, and miscellaneous [INPUT0(XC,R,*) where * is the specified input] for each crop and region are given as cost per feddan. All “other” inputs are assumed to have an infinitely elastic supply at the input prices or costs.

2.3.2 Resource and other requirements for livestock

Although the livestock parameters (requirements) are generally nationally, rather than regionally, specified, the structure of the livestock sections in the model are more complex than the cropping structure, consistent with multi-season, multi-year livestock production. Large livestock include buffalo, cattle, and sheep/goats. The relationships among breeding stock (female and male), culling and mortality rates for breeding stock (tables CULLR and MORTR), and weaning rates (the net rate of production of young animals - WEANR), are modeled as a long run equilibrium (that is, the proportions of each cannot be varied endogenously). Population dynamics are captured in the calculation of replacement rates for breeding stock. Each general type of animal may have several categories of marketable animals (veal and three levels of fattened animals for buffalo and cattle, for example) as well as livestock commodities (beef meat and milk, poultry meat and eggs, etc., indicated in the set CA).

Draft animals are included in the livestock activities, but in a much less complex way. The number of draft and working animals (camels, horses and donkeys) per region in the old lands is fixed, and no draft animals are included for old new lands or for new lands.

Labor

Each type of livestock, including draft animals, has a labor requirement in terms of man-hours per season (table LLABOR). In addition, there is a labor requirement for milking of buffalo, cattle and exotic breeds (table MLLABOR), and for various kinds of livestock products. These requirements are converted to man days per month in a series of equations and parameters. First, there is a requirement per unit of livestock for men, women and children. These requirements are then converted to man-day equivalents for livestock husbandry and milking (equation LLABOR and LLABORM, respectively). Note that the conversion rate differs between women (WLAB) and children (CLAB). Thus, for each unit of livestock, the seasonal labor requirement includes all three categories of labor, which will be supplied from the farm families (FARMERS as discussed above) or from hired labor. Then the man-days per season are converted to monthly requirements (divided by 6). Finally, the man-day per month requirement is adjusted according to the marketable livestock (for example, buffalo veal of fattening buffalo) in a set of equations that also deduct milking requirements (LABREQA).

Feeds

The link between the animal husbandry sub-sector and the cropping sector is through the feed requirements. The ASME model distinguishes between fodder crops which are cultivated to feed animals (like berseem), fresh or dry crop by-products (like sugarcane tops and wheat straw), and processed by-products (like rice bran, molasses and seedcake). Each unit of livestock, including draft animals, has an annual nutrient requirement (table DFREQ) which is also converted to a seasonal requirement. These have to be met by the nutrient content of the fodder, crop and processed by-products. There is a minimum on the use of crop by-product and green fodders in the diet. The feed requirements are also provided for poultry (tables PCBYREQ and PCREQ). For the poultry sector (with products EGGS and PMEAT), feed requirements are expressed in SOYMEAL and MAIZE, both of which can be imported. There is no limit to the production of EGGS and PMEAT imposed by cropping.[3]

Other inputs

The other inputs for livestock consist of veterinary and breeding services for livestock and pullet and chick purchases (table CSTINPA). Note that these costs are adjusted for ages and types of livestock in a separate set of equations. For the most part, the chick and pullet purchases are imports treated as though the supply is exogenous.

2.3.3 Yield relationships for crops

Agricultural crop commodity yields are based on “typical” technology, and are average yields by crops by region [tons of commodity per planted crop per feddan in table YIELD0(XC,C,R)]. Where crops are used as inputs to processed consumption commodities, processed product and byproduct yields are given per ton of direct yield (tables YLDPR and CBYIELD1, respectively). For livestock feed, fed crops and byproducts are further identified by nutrient content (tables NUTSHRC and NUTSHRCBY, respectively). Processing byproducts, such as soybean meal and cotton seed cake are also included in livestock feed as nutrients (table YLDCPB). As indicated above, yields are adjusted depending on planting time and water application rates (YIELD1 and YLDC equations), but specific alternative technologies (such as gated pipe or sprinkler) are not specifically included, nor are variable levels of fertilizer, pesticides, or other inputs.

2.3.4 Livestock yields

Meat and milk are the primary commodities from livestock animals and meat and eggs, of poultry. The yields vary by the type and age of livestock (veal, fed cattle, breeder cattle, etc.) which are mapped into the various types of livestock animals. The average carcass weight for each type of animal is found in table CARCASS, and a set of equations (YLDA) generates both the specific meat and the milk production. YLDA equations also indicate poultry meat and egg yields.

2.4 Balancing Constraints

The balancing constraints consist of three types: first, regional production of commodities must be consistent with cropping and livestock activities; second, consumption and production must be balanced nationally; and, finally, resource availabilities must constrain resource use. The first two sets of equations are denoted by DSBALXXX, and the latter group is designated by XXXCON. The specifications of these equations are found in the BMODEL.INC module.

2.4.1 Production constraints

These equations insure that production cannot exceed the “optimal” level of physical units (such as feddans of rice) times the yields for those units. Regional supply balances constrain

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[3] The implication is that the model becomes unbounded once EGGS and/or PMEAT exports can be generated from imported MAIZE and/or SOYMEAL import at a positive profit. The solution to this problem is to either limit the imports of poultry feed or the export of poultry products.

production of any crop to the area of production of that crop in the region multiplied by the yield in the region. In addition, similar constraints for crop processing and feeding are included, as is livestock production (for example, livestock for fattening cannot exceed livestock production rates, and livestock consumption of nutrients cannot exceed production of those nutrients).

2.4.2 National consumption constraints

These constraints limit the national consumption of crop commodities (direct household consumption plus direct livestock consumption) to be less than or equal to crop production plus net imports (or less than net exports). For livestock consumption commodities, total consumption must be less than or equal production plus net imports as well. Note that the ASME structure allows a given crop to be selected as either produced for direct consumption (for example, corn) or to be used for either byproducts or processed commodities (for example, corn fodder).

2.4.3 Resource constraints

These constraints limit the use of resources to regional and national availabilities. The specific resources are land, labor, and water. Family plus hired labor must be equal to the regional labor requirements for the "optimal" crop and livestock production. Regional family labor availability is limited [LABFAMCON(R,TM)]. Land is limited to the available land [LANDCON(R,TM)]. Old new land is also limited, as is reclaimable land in the Sinai and New Valley (LNDRECL). A water constraint (WATERCON) is listed in BMODEL.INC, but that constraint is not operative. Actual water constraints are found in the WATER.INC module, and are regional [WBAL(R) and DBAL(R) for regional fresh water and drainage water balances] and national (NASBAL).

2.5 Policy Constraints

One module of the model deals with policy constraints (POLICY.INC). However, other policy constraints may be found in other modules, as well, and some policy constraints may be implicit. The policy constraints often are limits on specific crops (either maxima or minima) which are consistent with expected practice. For example, rice production is limited to the delta regions [YLDC(R,XC,...) for rice in Upper and Middle Egypt is set equal to 0] and sugar cane cannot be grown in the Delta [YLDC(R,XC,...) for sugarcane in the three delta regions is set equal to 0]. Implicit constraints exist in cropping mapping. For example, the activity for sugarcane in the East Delta does not exist in the production activity set. The constraints in this module are primarily politically imposed constraints, rather than physical limits.

Many of the “policy” constraints are used to prevent “nonsense” solutions in the model. For example, the import and export structures are such that unbounded solutions or unrealistic solutions are possible. For example, unlimited transshipment (unbounded solution) is possible in cases for which the import price is less than the export price of a commodity. Aggregation of products in the import/export activities is generally the cause of such a problem, wherein the imported good is either different from (such as seed potatoes classed as potatoes in the model) or less processed than the export good. Another example is the export of eggs and poultry meat given above. As a result, exports and imports are explicitly limited to existing (base-year) quantities [QIMP(C) and QEXP(C) equations in the POLICY.INC module]. Unfortunately, the export sector is an important one from a policy perspective (tariffs, trade barriers, etc.). The transshipment problem can be eliminated by setting import prices to less than export prices (as should be the case for any specific commodity), but the specific data inputs should be examined carefully.

Other constraints may be attempts to reflect “realistic” conditions, which are not found in the optimal solution (usually due to data issues, as discussed above). For some data sets, the minimally constrained solution indicates no rice production in the Middle Delta and no sugarcane production in Upper Egypt. Policy constraints have been placed in the model for these cases by: (1) forcing rice into production in the Middle Delta region (EDELRICE), or (2) forcing sufficient sugarcane to be grown in Upper Egypt to satisfy the processing capacity of existing sugar processing plants.

The treatment of new lands is also subject to policy constraints. For example, under most conditions, the new lands do not enter into an optimal solution, or do so with only limited production. This result is due to the limited economic returns on these new lands, based on the cropping patterns currently in the model. It is possible, however, to simulate extensive development by changing the available water from the HAD to be consistent with withdrawal of water from the existing deliveries.

There are many other parameters and equations in the model that could be interpreted as “policy” since they represent exogenously imposed restrictions or conditions. In general, solutions are obtained for the least constrained case, subject to the model being able to reach a solution. This provides some confidence testing of the model.

2.6 Objective Function

As indicated above, the objective function of the model is the net consumers’ plus producers’ surplus to agricultural commodities consumed by households, including crop and crop-based commodities and livestock commodities. These goods are primarily food. Processed consumption goods derived from agricultural production (such as cotton cloth or chemicals from sugarcane processing) are not included. The objective function consists of demand functions and supply (in the form of costs). Equilibrium (maximal) prices [MKT-PRICE(C)], quantities (from the optimal solution), and shadow values (REPSHAD and WATERSHAD) are calculated (WATREP.INC).

2.6.1 Demand functions

The demand functions in the model are for agricultural consumer commodities are determined endogenously. The commodities for which demand functions exist are listed in the parameter tables DEMDAT(C) and LDEMDAT(CA) in the module DATASET.INC. These data tables include the base-year prices and quantities (domestic, import and export), as well as estimates of the own-price market demand elasticity for each commodity. From these data, the parameters for a linear (inverse) demand function for each commodity are calculated (slope = base year price divided by base year consumption divided by elasticity; intercept = base year price – slope times base year consumption). Note that cross-price and income elasticities are not included in the calculations. The demand functions are then integrated (in definite form) to arrive at the quadratic functions by which consumers' surplus is calculated. Note that the demand functions for cotton and flax must be derived (input) demands, rather than final household consumption demands. The inclusion of the derived demand functions as a part of the consumer/producer surplus mix is not exactly straight forward and requires careful interpretation.

2.6.2 Rural self sufficiency

The module RURSELF.INC was added with the consent of the ASME Working Group in order to force the model to produce a number of key commodities in each region (provided the commodity can be grown there) in proportion to the rural population. This is accomplished by using a per-person consumption minimum of the selected commodities (rice, wheat, corn, fava beans, onions, potatoes, and lentils) for the rural population in each region. The underlying assumption is that farmers will first supply their own basic needs before producing for the market. Note, however, that home consumption is included as a part of the consumption in the demand equation system for a given commodity (that is, the amount of home consumption is included in the quantity consumed in the demand function). Since both supply and demand are affected by home consumption in the same quantity, the equilibrium prices (and quantities) in the model are consistent with aggregate consumers' surplus maximization.

2.6.3 Cost and supply functions

Most costs are calculated by multiplying the inputs used for production, by their prices or costs. These equations are found in the BMODEL.INC module with the prefix CSTXXX. For crops, in the cases of labor, fertilizer (Nitrogen, Phosphorous, and manure), seeds, mechanical treatment (water pumping, tractor, spraying, and threshing), prices per unit of input are specified (WAVG or WRF for labor cost, table POINPUT and PMECH)) and multiplied by the level of that input (as indicated in the LABCOST equation). In other cases, the costs per unit of production are specified (CSTINP or CSTOINP, for example). Costs of processing of agricultural crops to produce both consumable commodities (such as vegetable oils and sugar) or byproducts (such as seedcake) are found in table CSTPR. For livestock, veterinary services, breeding services, and the purchases of pullets and chicks are treated as costs per unit of livestock or poultry (table CSTINPA).

One specific set of costs should be mentioned because it may require revision: the marketing costs for agricultural products [CSTMRK(C) and CSTMRKA(CA)]. These costs are fixed costs based on percentages of the base prices (20% of the base price of crops and a more complex proportion of farm and gross margins for livestock). Neither of these calculations reflects the level of gross farm revenue by crop at equilibrium prices and quantities, because the dynamic relationship between endogenous prices (determined by the demand equations and equilibrium quantities) and marketing costs causes difficulties in reaching solutions. Thus, marketing costs will have no relationship with the equilibrium prices and revenues in the model solutions.

3. Data

Two sets of data are available for the model: the 1995 data (which were provided by the previous model update as reported in Report No. 25 of the RDI Unit of APRP (Bender, 1997). The second data set is taken from 1997 data from the Ministry of Agriculture and Land Reclamation (MALR). Some of these data are not yet published. The water data were developed by the Planning Sector of the Ministry of Water Resources and Irrigation and are currently under review and revision.

The accuracy of the data (parameters) in the model is both important to the model solution and subject to significant distortion and/or misinterpretation. Discussion of some of the specific data problems encountered can be found below. In general, the data are - at best - averages across space and time. The model does not account for variability, which may influence real world decisions far more than the average conditions. Moreover, The Monitoring, Verification and Evaluation (MVE) Unit of the APRP reported that their analysis of data from the Ministry of Agriculture and Land Reclamation - from which much of the model's data is derived – indicated that there is considerable doubt about the dependability those data. To the extent that the data inaccuracies are similar in direction and magnitude for all activities, the model results may not be significantly affected. However, if the data are skewed or differentially distorted, model results may be suspect. Some significant problems were found in both the data sets. The 1997 data set was corrected by the ASME Working Group.

3.1 Crop and Livestock Production Data

Crop livestock and production data have been closely reviewed and updated (table YIEDL0 and equations YLDA). However, several crops included in the model may be "experimental" or just being introduced into Egyptian agriculture. Yields for those crops may have been based on experimental plots, for which the "best" production techniques are used. Yields are often much higher than in actual practice. This is as true for regional yields as for national yields. An example is the yield of sugar beets in Upper Egypt. This experimental yield data lead to the total replacement of sugarcane by sugar beets in Upper Egypt in the solution. The data were modified to reflect field conditions in so far as possible in the 1997 data, but the model sensitivity to production and cost data was clear.

3.2 Commodity Demand

Commodity demand data consists of base-year consumption commodity prices, base year national commodity consumption, and demand elasticities (DEMDAT and LDEMDAT, as indicated above). For the 1995 data set, the market own-price demand elasticities used were identical to those found in the 1985 version of the model found in the GAMS Library (EGYPT.GMS model), with the exception of cotton and livestock elasticities (livestock was not included in the older version). The reference publication(s) for those elasticities was not available to the Working Group, so that the estimation technique(s) could not be determined. However, the elasticities appeared to be more or less consistent with expectations; most were relatively inelastic, ranging from elasticities of -0.4 to -0.85.

The 1997 data used elasticities from the IFPRI household survey. These elasticities were estimated using the "commodity characteristics" approach. Two observations are significant. First, the own price elasticities for almost all of the commodities are very close to unitary (-1.0), although most are slightly inelastic. This may be due to the assumptions required for the characteristics analysis. Secondly, the IFPRI estimations included cross-price and income elasticities. The elasticities in the model (in particular for the optimal solutions) consider only own-price effects. How consistent the solutions will be with the market conditions is not clear. Sensitivity analysis on the 1995 data set indicated that the model solutions were not overly sensitive to the input consumer demand data, within a reasonable variance (10 per cent, for example).

Again, the demand functions for cotton and flax can not be household demand for final consumption commodities, and must reflect a derived demand from processors or manufacturers. As such, the "consumers'" surplus measure reflects returns to the users of these products, rather than a final consumption surplus. The source of the input data for these demand functions is unknown.

3.3 Data Consistency

In order to improve the confidence in ASME97, more than 60 data consistency checks have been programmed by MWRI/NWRP to verify the completeness and consistency of the data set, and to filter out data entries that are outside expected value ranges. These checks are included in the CHECKSXX.INC files and are applied for every run. A detailed description of the programming for the data checks can be found in Appendix B.

The modules check for consistencies within sub-sets and between input tables to determine if data are entered for all set elements. For example, if a crop has a land requirement, but no labor requirement, the checks module will identify that problem. If applicable, the modules also assure that the entered data are within a range of technical or practical limits. In case an inconsistency is encountered, the module aborts the execution and publishes the inconsistencies encountered at the end of the BASE97.LST file. The model aborts the run at the first inconsistency detected, so full error detection requires a sequence of runs until no inconsistencies are encountered. While the checks modules do provide some data control, the quality of the data remains the responsibility of the user.

These checks can also be interpreted as explicit statements of the assumptions made by the modelers. In addition, they make it safer to update the model. For example, if new crops are added, the checks remind the modeler of all the data that have to be provided for that crop. A full list of checks is included in Appendix B.

4. Model Solutions and Interpretation

Solutions to the model (printed in BASE97.LST) give those production quantities that maximize the total consumers' surplus net of production, processing and other costs given the parameters and constraint sets. Farm profits are implicit in the objective function value. In addition, marginal (dual) values are given for both constraints and variables in the model. The WATREP.INC module calculates the water flows and use by region, equilibrium market prices and elasticities, gross farm income (crop and livestock quantities multiplied by endogenous market equilibrium prices) and net farm income (gross farm income less costs) as well as shadow values for land, labor, wand water. Note that, as for any non-linear programming model, the solution algorithm (MINOS) indicates only a locally optimal solution. As an example of the potential uses of the model, an examination of the marginal value of water was made by altering the maximum releases from the HAD.

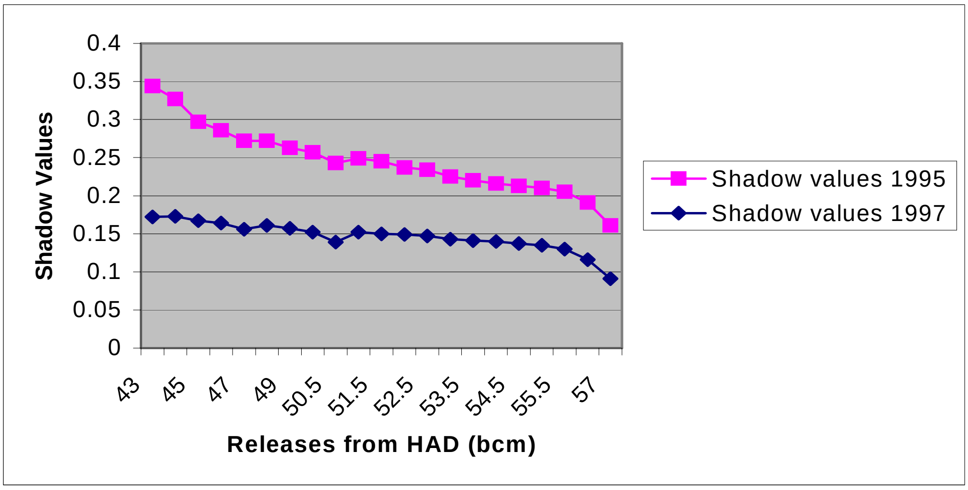
4.1 Water Demand

As both an example of the usefulness of the model, and a test of the model's consistency, a set of optimal solutions were obtained for differing levels of water availability from the HAD for both the 1995 and 1997 data sets. The MAXREL constraint was increased from 55.5 bcm to 57.0 bcm, and decreased from 55.5 bcm to 43 bcm. These values bracket the general consensus relative to increasing the water supply (the Jongli Canal, for example, is expected to increase water supplies by around 2 bcm) and reducing the supply of water to the "old lands" by diversion to new developments (approximately 9 bcm at full build-out). The solutions gave the shadow value of water from the HAD releases (the change in the objective function with a unit change in the release constraint), which can be interpreted as the marginal, or incremental, value of water (Table 1). Note that this value includes both consumers' and producers' surplus measures, so that the farmers' marginal ability to pay is only a part of the shadow value. In general, producers' surplus (profits to farmers) is about 20 percent to 30 percent of the total surplus measure (the objective function value). The marginal value of water to farmers would be roughly that percentage of the marginal values reported below. In addition, the effect of including the rural self sufficiency constraints was examined for selected levels of releases for the 1997 data set, and is reported in Table 1. Figure 2 is a graphical representation of the shadow values for the two data sets.

Table 1. Shadow Values of Water

HAD Releases (bcm)	Water Shadow Value 1995 Data (LE/m^3)	Water Shadow Value 1997 Data (LE/m^3)	Water Shadow Value w/Self Sufficiency (LE/m^3)
43	0.172	0.172	
44	0.173	0.154	
45	0.167	0.13	
46	0.164	0.122	
47	0.156	0.116	
48	0.161	0.111	
49	0.157	0.106	
50	0.152	0.105	
50.5	0.139	0.104	
51	0.152	0.097	
51.5	0.15	0.095	0.112
52	0.149	0.088	
52.5	0.147	0.087	
53	0.143	0.082	
53.5	0.141	0.079	0.100
54	0.14	0.076	
54.5	0.137	0.076	
55	0.135	0.075	
55.5	0.13	0.075	0.081
56	0.116	0.075	0.080
57	0.091	0.07	

Figure 2. Water Shadow Values



The results indicated in the table seem reasonable. Assuming 30% of the shadow value is producers' surplus yields marginal values of water ranging from about 2 to 4 piasters per cubic meter. The average value of water has been previously estimated from farm budget data as between 5 and 10 piasters per cubic meter of water., and the marginal value should be less than the average. The 1997 data appear to suggest a lower marginal value for water than the 1995 data, however.   In both cases, decreasing the availability of water increases its marginal value (and decreases the total objective function value). However, it is only with substantial decreases (8 to 10 bcm) that the value of water rises sharply. This suggests that limited development of new lands can probably be accomplished with minimal loss of value to old land production, but large-scale development will result in a significant impact on agricultural production on old lands and on consumers as well.

The self-sufficiency constraints increase the shadow value of water, as would be expected, since water is being diverted to produce subsistence crops, and is not available for higher valued crops. The objective functions for the constrained solution are on the order of 1 to 2 percent lower than the unconstrained values. Thus, increments in water availability will increase the objective function more than if an optimal production were achieved initially and, conversely, limiting water is more costly to society at the margin in a condition of subsistence agriculture. This result suggests that encouraging commercial agriculture, as opposed to subsistence agriculture, will likely increase the net value to society.

Three main aspects of the model should be kept in mind when interpreting these or other solutions: (1) linear constraint construction; (2) data sensitivity; and (3) deterministic parameters.

4.2 Linearity

Although the ASME model is structured as a non-linear optimization, the only non-linearities are found in the quadratic objective function. The constraint set is entirely linear. As a result, "corner solutions" can occur with respect to a given activity with only slight differences in that activity's influence on the objective function compared to a competing activity. Thus, highly specific results (the number of buffalo grown for veal in the East Delta, for example) may differ substantially from the "real world" conditions. The more aggregated the results, the more likely they are to conform to those real world conditions, since aggregate national demand curves “drive” the model’s solutions, rather than local production (excepting for the self-sufficiency constraints).

For example, total sugarcane area in production in the optimal solution for the 1995 data set (301,000 feddans) was consistent with the area reported by the MALR (300,800 feddans). On the other hand, the production of sugarcane at the regional level showed wide differences from the actual production (no sugarcane grown in Upper Egypt, for example). Some solutions (with alternative productivities) based on the 1995 data showed similar kinds of solutions for rice (no rice grown in the East Delta, for example). Moreover, solutions varied widely for many of the minor crops, and some of the major crops. For example, both maize and wheat in the solution (2.7 and 4.8 million feddans, respectively) were slightly less than double the actual production, while long and short berseem (.4 and .3 million feddans) were about 25% of actual production. There was likely direct competition between wheat and berseem, and the value of berseem (for fodder) may be underestimated in the model. While the 1997 data have “corrected” some of these anomalies (maize and wheat appear to be consistent with actual production) others do occur (such as quite low cropping intensities in the Delta compared to the new old lands).

4.3 Data Sensitivity

Sensitivity analysis indicated that for both the 1995 and 1997 data, small differences in yield or cost of production data generated significant changes in solution values, particularly with respect to regional production levels. Several cases reflecting the sensitivity of model solutions to data input have been cited above, and do not need to be repeated. Sensitivity of model solutions to changes in the demand functions does not appear to be high, however. What is clear is that the user must evaluate the sensitivity of the model to whatever data he/she is considering.

4.4 Deterministic Parameters

The model solutions must be interpreted with care when compared to “real world” activities. Significant assumptions are made in the interest of model size or efficacy. In particular, the model assumes a profit-maximizing producer faced with deterministic prices and costs. These assumptions may not reflect the actual decisions of farmers. As an example, the average profitability of cotton in a specific region may be higher than that of rice, yet the uncertainty with respect to cotton production (relatively wide swings in market prices and sensitivity to climate or pests) may be much greater than rice. Thus, in the "real world" farmers would select rice as a risk-reducing (but still quite profitable) crop, whereas cotton would be selected as the optimal crop by the model. The inclusion of risk in the ASME would require a large expansion of the model.

The temptation of the modeler to try to achieve results which "mirror" the real world conditions through "forcing" constraints is great, but it should be avoided. Rather, the solutions to the model should be regarded as indicative, and the model best used as an indicator of direction of change, rather than an indicator of optimal absolute values.

5. Conclusions and Recommendations

It may appear to the casual reader that the model is flawed because some of its results are not consistent with expectations or with real world conditions. It should be remembered that all models are abstractions, and can not, in general, reflect the complexities of the real world. Thus, using any model requires as much "art" as it does science. The more complex the model, the more care must be exercised in interpretation of results, simply because the interactions among variables, parameters and constraints becomes less and less transparent. The ASME97 model is no exception.

Many of the anomalies cited above are due in one form or another to the input data. That is not to say that the data are "bad," but rather that the structure of the model is such that solutions can be quite sensitive to small variations in data. Users of the model must be aware of the relative sensitivity of the model and the limits which that fact imposes on its use. Testing the sensitivity of model solutions to changes in the data of interest is strongly recommended.

There are three areas in which structural problems appear important. The first is in the import/export activities in the model, the second is the marketing cost, and the third is in the commodity demands. With respect to the international market activities, since the model may be used to assess various policies related to import and export interventions, it is recommended that the base level imports, exports and prices be assessed carefully. Any case in which non-similar goods are "lumped" should be eliminated. For example, base year potato imports are generally seed potatoes, and are not a part of the consumption. These imports should be treated as either inputs to potato production or dropped from the model. The importation of Basmati rice is another example. While Basmati rice is a consumable, it should not be "lumped" with the Japonicus varieties produced (and exported) by Egyptian agriculture. The use of imported short staple cotton relative to the locally-produced long staple cotton should be carefully examined as well. In general, any case in which commodities can be imported at a lower price than the export price should be noted and realistic solutions to a transshipment problem be found. Similarly, in cases such as the livestock sector (poultry meat, eggs, and meat, for example)., where production is unconstrained by land or labor availability, the import/export activities must be adjusted to assure realistic activity levels.

Marketing cost calculations should be restructured to be more closely related with market conditions. One approach could be to calculate a per-unit cost, based on the current existing data. While this approach fails to reflect the endogenous market prices, it does allow the solution to reflect marketing costs as important to production decisions at the margin.

The demand functions have two different aspects. The first is the underlying assumption in economic theory that competitive producers will maximize profit at the (long run) point which coincides with the maximization of the sum of consumers' and producers' surplus. While true for a perfectly competitive market in a deterministic world, farmers' production choices may be very different in the real world, and be no less optimal. Thus, interpretations of model solutions should be relative rather than absolute. The second issue with regard to the demand curves in the model is the mix of consumer and the intermediate commodities cotton and flax, discussed above.

It is highly recommended that when the model is used for policy analysis, the sensitivity of the most relevant parameters and constraints be examined carefully, to be sure that results do not fluctuate widely over incremental changes in data. Moreover, while the model solutions may suggest directions of changes from specific policy interventions, they should not be interpreted as providing the socially optimal crop rotations for any specific region. The philosophy of the model is that farmers will choose those crops that give them the best return. Changing market conditions and policy environments can influence that choice significantly. Thus, the model's solutions would be suggestive of the impacts of various policies on farmer choice, rather than a prescription for farmer choice.

Finally, it is strongly recommended that the cooperation currently existing between the model users in the MWRI and the MALR be extended and formalized. The current working group has clearly improved communications, understanding and evaluation of the model and its data, as well as developing structural modifications that improve the model's applicability in policy analysis. The exchange of information and conceptualization among members of the working group has been very fruitful. Only as all users become more familiar with the model, its data and its structure, will it become recognized as a useful planning tool for both Ministries.

Appendix A: GAMS Model Statements

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1. GAMS Model Statement

The following detailed description will be divided into three sections: the variables, the objective function, and the constraint equations.
The general format for any linear programming model is:

> Max F(X)
> Subject to $G_i(X) <, =, > B_i$ i = 1, m
>
> Where X is a vector of variables (often termed "activities") whose level will be optimal and F may be an aggregate of several functions (f_j).

The following description will examine the variables, objective function, and constraints of the ASME model in more detail.

The variables in the ASME model are activities or products related to the production of agricultural commodities. These variables can be divided into subcategories:

- *Agriculture Production:* commodities produced, commodities consumed including imports and exports, commodities used as intermediate inputs (particularly for livestock production), livestock units produced (as opposed to measures of consumption commodities), and costs of production and marketing.
- *Labor:* family and hired labor
- *Land:* Old land and new land by regions
- *Water:* water flow, diversions to agriculture, drainage flow, drainage use, groundwater pumping, and releases from the High Aswan Dam.

Each of these variables has (or may have) specific spatial (region - R), seasonal, time (planting dates and months – S, TM, PT), or activity (specific crop, byproduct, livestock, or commodity; level [e.g., water - WI], category [e.g., sex]) characteristics or indices (as in $x_{i,j,k,}$ a member of X). These characteristics are identified in a GAMS model as "sets." Sets can be "mapped" to each other, which creates a combination "set" of characteristics. For example, raw crops (XC – such as "PADDY" rice) can be mapped into consumer commodities (C or CN – such as "RICE"). This is done so that coefficients in equations (called parameters) can be entered in at most a table of values, but include several characteristics (XC.C in a yield table by region). In addition, some sets are subsets of other sets (for example, "CIP" – crops input to processing – is a subset of "C" – crops produced. The names of the sets and subsets are included on the following page.

1.1 Sets

C	crop commodities
CA	animal commodities
CBY	crop and processed byproducts fed to animals
NT	nutrients for animals
PT	planting dates
R	regions
S	seasons (for animal nutrient requirements)
TM	monthly time periods
WI	intensities of water application
XA	animals (livestock and poultry)
XC	planted crops (plant names)

1.2 Subsets

CBYC(cby)	crop byproducts fed to animals
CBYP(cby)	processing byproducts fed to animals
CBYPP(cby)	processing byproducts given as poultry feeds
CFED1(c)	crop commodities fed to animals
CFED2(c)	crop commodities fed to animals only
CFG(c)	green fodder feed crops
CHA(c)	crop commodities consumed by both humans and animal
CIP(C)	commodity inputs to processing
CN(c)	commodities consumed nationally
CNPP(c)	both final and intermediate commodities
COP(c)	commodity outputs from processing
CPFED(c)	crop commodities used as poultry feeds
MCBYR(cby,r)	mapping bt fodder byproducts and regions
MCR(xc,pt,wi,r)	mapping crop activities-input levels-regions
MSC(s,c)	mapping bt seasons and feed crops
MSCBY(s,cby)	mapping bt seasons and crop by-products
MSCBYP(s,cby)	mapping bt seasons and processing byproducts
NTDRY(nt)	dry matter nutrients
NTO(nt)	nutrients other than dry matter
RSW(r)	regions with surface water as irrigation source
XAINP	other inputs to animal sector
XAL(xa)	livestock units (excl. poultry and sheep-goat)
XAP(xa)	poultry production animals
XCCOT(xc)	cotton crops
XCRICE(xc)	rice crops
MXABF(xa,xal)	mapping breeding and fattening units

2. Variables

Within the GAMS model, these characteristics can be specifically mapped. For example, wheat might be produced in Upper Egypt with less than its water requirement and planted earlier than normal. The change in productivity for wheat may depend on both the region and crop. The variable would then be represented by XCROP (WHEAT.UPPER EGYPT,WATER,TIME), where WHEAT.UPPER EGYPT represents a "mapping." The variable identifiers (indices) are listed below:

2.1 Agricultural Production

QCNSA(CA)	consumption of animal comm CA (000t)
QCNSC(C)	consumption of crop commodity C (000t)
QCNSCBY	anim cons of crop byprod CBY in R & S (000t)
QCNSCBYP(CBY,S,R)	anim cons of proc byprod CBY in R & S (000t)
QCNSCBYPP(CBY,S,R)	poultry cons of proc byprod CBY in R & S (000t)
QEXPA(CA)	exports of animal comm CA (000t)
QEXPCBY(CBY)	exports of proc byprod CBY (000t)
QEXPC(C)	exports of crop comm C (000t)
QEXPFED(C)	exports of feed crop comm C (000t)
QFEDC(C,S,R)	anim cons of crop comm C in R & S (000t)
QFEDCP(C,S,R)	poultry cons of crop comm C in R & S (000t)
QIMPA(CA)	imports of animal comm CA (000t)
QIMPC(C)	imports of crop comm C (000t)
QIMPCBY(CBY)	imports of proc byprod CBY (000t)
QIMPFED(C)	imports of feed crop comm C (000t)
QPRDA(CA,R)	prod of animal comm CA in region R (000t)
QPRDC(C,R)	prod of crop commodity C in region R (000t)
QPRDCBY(CBY,R)	prod of crop byprod CBY in region R (000t)
QPRDCBYP(CBY)	prod of proc byprod CBY (000t)
QPRDCIP(C,R)	prod of proc input C in region R (000t)
QPRDCOP(C,R)	prod of proc output C in region R (000t)
XLIVE(XA,R)	level of animal XA in region R (000 units)
LABCOST	total labor cost (000LE)
LRECCOST	total land reclamation cost (000LE)
OINPCOST	total other input cost (000LE)
PMCOST	total processing and marketing cost (000LE)

2.2 Labor

QLABF(R,TM)	family labor use in region R for month TM (000md)
QLABT(R,TM)	temp labor hiring in R for month tm (000md)

3. Constraint Equations

These are the constraints in the model:

3.1 Crop Equilibrium Equations

DSBALC(c)	dem-sup bal for crop commodity C (000t)
DSBALCR1(c,r)	dem-sup bal for crop comm C in region R (000t)
DSBALCR2(c,r)	dem-sup bal for crop comm CNPP in R (000t)
PRDPROC(cop,r)	defn of prod of proc comm COP in region R (000t)

3.2 Animal Equilibrium Equations

DSBALA(ca)	dem-sup bal for animal commodity CA (000t)
DSBALAR(ca,r)	dem-sup bal for animal commodity CA in reg R (000t)
BFRATIO(xa,r)	ratio of breeders to fatteners for XA in R

3.3 Feeds and Byproducts Equations

PRDCROPBY(cby,r)	defn of prod of crop byproduct CBY in reg R (000t)

3.4 Feeds and Byproduct Equilibrium Equations

DSBALFCROP(c,r)	dem-sup bal for feed crop in region R (000t)
DSBALCBY(cby,r)	dem-sup bal for crop byproduct CBY in reg R (000t)
DSBALPBY(cby)	dem-sup bal for proc byproduct CBY (000t)
DSBALNTO(nto,s,r)	dem-sup bal for anim nutrient NTO by S & R (000t)
DSBALNTDRY(ntdry,s,r)	dem-sup bal for anim nut ntdry by S & R (000t)
HAYRATIO(s,r)	min hay and gcrop share in tot feed by season S & R
DSBALPFED1(cby,s,r)	d-s bal for proc poultry feed CBY by S & R (000t)
DSBALPFED2(c,s,r)	d-s bal for poultry crop feed C by S & R (000t)

3.5 Resource Constraints

WATERCON	annual national water constraint (000m3) NOT ACTIVE
LANDCON(r,tm)	land constraint for region R in time TM (000fed)
LANDRECCON(r)	land reclamation constraint for region R (000fed)
LABBAL(r,tm)	labor bal for region R in time TM (000md)
LABFAMCON(r,tm)	fam lab constr for reg R in time TM (000md)

3.6 Cost Equations

CSTDEFLAB	defn of total labor cost (000LE)
CSTDEFOINP	defn of total other input cost (000LE)
CSTDEFPM	defn of total processing and marketing cost (000LE)
CSTDEFLREC	defn of total land reclamation cost (000LE)

3.7 Objective Function

OBJFN	objective function (000LE)

3.8 Definitions and Summations

XCDEFNAT(xc)	defn of national area of crop act XC (000fed)
COTDEFREG(r)	defn of cotton area in region R (000fed)
RICEDEFNAT	defn of national rice area (000fed) ;
WBAL(R)	regional water balances
GENDR(R)	regional drainage generation
DBAL(R)	regional drainage flow balance
GENDRDIS(R,R1)	area distribution of generated drainage going to the Nile
WATBAL(R)	water balances for regions
NASBAL	allowed annual release from Lake Nasser
MAXDU(R)	maximum drainage re-use
RICEWATBAL(R)	balance extra rice water

The following are based on Drainage Research Institute limits:

MAXGWP(R)	maximum groundwater pumping
EDELRICE	force rice area in M-DELTA

Appendix B: Data Consistency Checks

Data consistency checks for BMODEL.INC. These checks ensure that set elements are fully distributed over subsets[4]:

- Crop by-products plus processing by-products equal total by-products
- Green crop by-products and dry crop by-products equal total crop by-products
- Perennial crops plus annual crops equal total crops
- Summer and Nili crops plus winter crops equal annual crops
- Winter months plus summer months equal total months
- Non-poultry animals plus poultry equal total animals
- Dry matter nutrients and other nutrients equal total nutrients
- land requirement >=0 and <=1 are specified for all XC
- land requirements are the same for all PT
- labor is available for all months a crop is in the field
- labor req. are the same for all PT in U-EGYPT
- labor req. are the same for all PT in M-EGYPT
- labor req. are the same for all PT in E-DELTA
- labor requirement is >=0 and <35 hours per fed per month
- land is available for all months labor is used for a crop
- a male wage >0 and <20 LE per day has been specified for all R and TM
- a number of farmers is specified for all R
- family labor is specified for all R
- water requirement >0 and <11000 m3 per fed is specified for all XC and R
- field efficiency >0 and <1 is specified for all R
- quantity of seed is specified for all crops
- some manure or fertilizer is specified for all crops
- specified seed, manure and fertilizers have a price
- pumping hours >0 and <70 are specified for all crops
- a yield >0 and <50 t per fed is specified for all C, XC and R
- no yield is specified for combinations of XC and R not in CRMAP
- all crops with a yield are in the model through MCR unless disabled in POLICY.INC (or one of its variants)
- a processing yield is specified for all CIP
- processing yields are >0 and <=1 for all CIP
- a processing cost is specified for all CIP
- a base-price is specified for all CN
- an import price is entered for all crop commodities
- crop commodities are net imported or net exported
- export prices are less than import prices for all crop commodities
- a domestic consumption is specified for all CN
- an elasticity >-4 and <0 is specified for all CN
- a weaning rate >0 and <1 is specified for all LBR

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[4] The GAMS compiler checks that the elements of the subsets are indeed elements of the main set.

- a culling rate >0 and <1 is specified for all LBR and H
- a mortality rate >0 and <1 is specified for all LBR and H
- the cows per bull are specified for all LBR and H???
- an average breeding age >15 and <40 months is specified for all LBR
- husbandry labor requirement >0 and <450 hours is specified for all XA
- milking labor requirement is specified for all XA
- man equivalent of woman labor >0.5 and <=1 is specified
- man equivalent of child labor >0.2 and <=0.8 is specified
- hours per manday >6 and <12 are specified
- a carcass weight <400 kg is specified for all LBR and H
- a base-price is specified for all CA
- a domestic consumption is specified for all CA
- an elasticity >-3 and <0 is specified for all CA
- export prices are less than import prices for all animal commodities
- all animal commodities are net imported or net exported
- a wholesale margin >0 and <1 is specified for all CA
- a retail margin >0 and <1 is specified for all CA
- a gross margin >0 and <1 is specified for all CA
- a farm margin >0 and <1 is specified for all CA
- annual nutrient requirements >0 and <7 is specified for all CA
- draft animal nutrient requirement is specified for all DP
- additional draft energy is specified for all DP
- a by-product yield <5 t per fed is specified for all XC, CBY and R
- an initial number of draft animals is specified for DP
- a processing yield is specified for all CBYP
- processing yields are >0 and <=1 for all CBY
- a nutrient content is specified for all CBY
- a nutrient content is specified for all CFED2 and CHA
- an import price is specified for all CBY
- export prices are less than import prices for all CBY
- a base area is specified for all XC

Data consistency checks for WATER.INC. These checks ensure that:

- drainage fractions for each RL add to 1
- groundwater abstraction levels are specified for all OL
- a conveyance/distribution efficiency >0 and < 1 is specified for all RL
- a municipal demand is specified for all RL
- an industrial demand is specified for all OL
- municipal return factors >0 and < 1 are specified for all RL
- industrial return factors >0 and < 1 are specified for all RL

Data consistency checks for YIELD.INC. These checks ensure that:

- water deficits are specified for all WI
- Ky factors are specified for all XC