Technical Manual no. 9

Adapting the Global Food and Water Models for Analysis of SAT Futures and Development Opportunities

International Crops Research Institute for the Semi-Arid Tropics
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Adapting the Global Food and Water Models for Analysis of SAT Futures and Development Opportunities

Technical Notes & Exercises

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Contents

Preface

Agriculture and livelihoods in the semi-arid tropics (SAT) are undergoing far-reaching changes in response to the changing socioeconomic and biophysical environment. There are increasing concerns about pervasive poverty, water scarcity, environmental degradation, and human vulnerability in many fragile regions of the rainfed SAT. At the same time, growth opportunities in more favored zones are being exhausted due to non-sustainable intensification and scarcity of land and water resources for further expansion. Hence, there is urgent need for accelerating development in the drylands through diversification of production, locally adapted innovations (e.g., integrated surface-groundwater management and new varieties), improved market access, and better policies. This will, however, require a better understanding of the impacts of emerging factors like water scarcity and globalization of markets on development pathways and future prospects for SAT agriculture and livelihoods.

Currently, the capacity to assess such effects, future opportunities, and challenges for rainfed SAT agriculture is constrained by lack of a suitable analytical tool that can be used for identifying future trends and development pathways, and for evaluating the effect of market, policy, and technological changes for specific crops and livestock products important in the SAT. Many of the SAT crops are often aggregated in existing models under broad commodity groups like coarse grains (e.g., millets and sorghum), pulses (e.g., chickpea and pigeonpea) and oil crops (e.g., groundnut and safflower). As a result, previous outlook studies for specific SAT crops suffered from aggregation problems, limiting their relevance for assessing crop-specific future prospects and growth opportunities. Broad geographical aggregates for SAT and rainfed tropical countries also limit the policy relevance of many of the analytical results.

However, the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by IFPRI is a leading agricultural sector model widely used for assessing the global food situation and the effect of changes in policy, technology, and R&D investments. It has recently been extended to account for the effects of water scarcity on global food production, demand, and trade. The newly developed global food and water model (IMPACT-WATER) offers further opportunities for strategic analysis of SAT agriculture where drought and water scarcity are critical problems for future economic growth and sustainability of livelihoods. Hence the interest to develop a useful analytical tool by explicitly introducing SAT crops (sorghum, millets, chickpea, pigeonpea, and groundnut, etc.) and agricultural products into IFPRI's global food and water model. The number of countries in the model will also be increased to evaluate country-specific effects. Development of the analytical tool and knowledge of future options for SAT and rainfed agriculture is expected to enhance the capacity to make strategic choices through careful analysis of emerging and future opportunities, including the effects of water constraints and options to mitigate impacts in rainfed and drought-prone areas. This work will be implemented in close collaboration with the IFPRI team working on the extended version of the IMPACT model.

Therefore, a short training workshop was organized at ICRISAT, Patancheru, on 24-31 January 2003. Siet Meijer, senior research analyst with IFPRI, who has been working on the IMPACT model, led the training program. The presentation on the IMPACT model and its variants was supported by relevant exercises. The purpose of the training was to (i) help develop skills on the basic structure of the analytical tool, (ii) understand the potentials and opportunities for adaptation of the model to SAT agriculture, and (iii) help understand the data requirements for introducing the major SAT crops into the model. This technical manual brings together the technical notes and exercises used in the training workshop. We hope it can serve as a useful source of information about the IMPACT model and its variants and how it can be implemented in a given context.

1. International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) - The Food Model

1.1 Model description - *Mark W Rosegrant, Siet Meijer and Sarah A Cline*

The lack of a long-term vision and consensus about the actions that are necessary to feed the world in the future, reduce poverty, and protect the natural resource base spurred IFPRI to develop a global food projection model in the beginning of the nineties: the International Model for Policy Analysis of Agricultural Commodities and Trade, or IMPACT In 1993, these same long-term global concerns launched the 2020 Vision for Food, Agriculture and the Environment Initiative. This Initiative created the opportunity for further development of the IMPACT model, and in 1995 the first results from the model were published as a 2020 Vision discussion paper: *Global Food Projections to 2020: Implications for Investment* (Rosegrant et al. 1995). This publication documented how population, investment, and trade scenarios affect food security and nutrition status, especially in developing countries.

Since then, the IMPACT model has been used for a variety of research analyses. For example, the paper *Alternative Futures for World Cereal and Meat Consumption* (Rosegrant et al. 1999) examines whether high-meat diets in developed countries limit improvement in food security in developing countries. The article *Global Projections for Root and Tuber Crops to the Year 2020* (Scott et al. 2000) gives a detailed analysis of roots and tuber crops. These commodities are of high importance to the poor, but are often overlooked by the developed world. *Livestock to 2020: The Next Food Revolution* (Delgado et al. 1999) assesses the influence of the livestock revolution, which was triggered by increasing demand for livestock through rising incomes in developing countries during the last decade. This report is also a helpful tool for policy decision-makers and other relevant parties, considering current and expected future developments of livestock demand in many developing regions.

Regional studies have also been done, such as *Asian Economic Crisis and the Long-Term Global Food Situation* (Rosegrant and Ringler 2000) and *Transforming the Rural Asian Economy: the Unfinished Revolution* (Rosegrant and Hazell 2000). These studies were a response to the Asian financial crisis of 1997, and analyzed the impact of this crisis on future developments of the food situation in that region.

The most recent results from the IMPACT model were published in the book *Global Food Projections to 2020* (Rosegrant et al. 2001). These projections were presented at the IFPRI-organized conference entitled: *Sustainable Food Security for All by 2020* that was held in Bonn on September 4-6, 2001. These latest projections are reported in far more detail than in previous publications. Not only does the baseline scenario give the best assessment for all IMPACT commodities given the future food situation, but the effects of changes in policy, technology, and lifestyles are also examined through two sets of alternative scenarios. One set explores changes at the global level; the other set is regional, focusing on alternative developments specific to Asia and Sub-Saharan Africa.

As can be verified by the substantial number of publications, IMPACT is recognized as a leading agricultural sector model for assessing the global food situation, and has been applied to a wide variety of contexts for medium- and long-term policy analysis of global food markets. In addition to work undertaken under IFPRI's medium-term research plan, the model has been used in specific projects for international organizations, including the World Bank, the Asian Development Bank, the FAO, and national governments.

The next section will discuss the model, including a technical description that shows the equations and the sources of the data used in the model. A general overview of the countries/regions and commodities is given in Table 1.1, while the detailed definitions of the countries and regions are shown in Table 1.2 and Table 1.3, and those for commodities in Table 1.4. Finally, a schematic overview of the model can be found in Figure 1.1.

The model

Basic IMPACT methodology

IFPRI's IMPACT model offers a methodology for analyzing baseline and alternative scenarios for global food demand, supply, trade, income and population. IMPACT covers 36 countries and regions (which account for virtually all of world food production and consumption), and 16 commodities, including all cereals, soybean, roots and tubers, meats, milk, eggs, oils and oilcakes and meals. IMPACT is a representation of a competitive world agricultural market for crops and livestock. It is specified as a set of country or regional submodels, within each of which supply, demand and prices for agricultural commodities are determined. The country and regional agricultural submodels are linked through trade, a specification that highlights the interdependence of countries and commodities in the global agricultural markets. The model uses a system of supply and demand elasticities incorporated into a series of linear and nonlinear equations to approximate the underlying production and demand functions. World agricultural commodity prices are determined annually at levels that clear international markets.

Demand is a function of prices, income and population growth. Growth in crop production in each country is determined by crop prices and the rate of productivity growth. Future productivity growth is estimated by its component sources, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector agricultural research and development, agricultural extension and education, markets, infrastructure and irrigation.

A wide range of factors with potentially significant impacts on future developments in the world food situation can be modeled based on IMPACT. They include population and income growth, the rate of growth in crop and livestock yield and production, feed ratios for livestock, agricultural research, irrigation and other investment, price policies for commodities, and elasticities of supply and demand. For any specification of these underlying factors, IMPACT generates projections for crop area, yield, production, demand for food, feed and other uses, prices, and trade; and livestock numbers, yield, production, demand, prices, and trade. A base year of 1997 (a three-year average of 1996-98) is used because this was the most recent data available from the FAOSTAT database at the time of the 2001 update of the projections. Projections are made to the year 2020.

Since the model results were first published in 1995, some changes and updates have been made. The number of country and regional groupings has varied between 35 and 37, and the number of commodities between 16 and 18. Recently, the model has been expanded to include 32 commodities, including tropical and semitropical fruits, temperate fruits, vegetables, sugar and sweeteners, eight fish commodities, and fishmeal (Table 1.4).

IMPACT technical methodology

Crop production

Domestic crop production is determined by the area and yield response functions. Harvested area is specified as a response to the crop's own price, the prices of other competing crops, and the projected rate of exogenous (nonprice) growth trend in harvested area (Equation 1). The projected exogenous trend in harvested area captures changes in area due to factors other than direct crop price effects, such as expansion due to population pressure, contraction due to soil degradation, or conversion of land to nonagricultural uses. Yield is a function of the commodity price, the prices of labor and capital, and a projected nonprice exogenous trend factor reflecting technology improvements (Equation 2). Annual production of commodity *i* in country n is then estimated as the product of its area and yield (Equation 3).

Area response:
$$AC_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times (1 + gA_{tni}) \quad (1)$$

Yield response:
$$YC_{tni} = \beta_{tni} \times (PS_{tni})^{\gamma_{iin}} \times \prod_{k} (PF_{tnk})^{\gamma_{ikn}} \times (1 + gCY_{tni}) \quad (2)$$

Production:
$$QS_{tni} = AC_{tni} \times YC_{tni} \quad (3)$$

where

AC = crop area
YC = crop yield
QS = quantity produced
PS = effective producer price
PF = price of factor or input k (for example labor and capital)
Π = product operator
i, j = commodity indices specific for crops
k = inputs such as labor and capital
n = country index
t = time index
gA — growth rate of crop area
gCY = growth rate of crop yield
e = area price elasticity
γ = yield price elasticity
α = crop area intercept
ß = crop yield intercept

The nonprice yield trend projections are central to projecting yield. The sources of growth considered in these projected trend factors include:

1. Public research (by international and national agricultural research centers)
   - Management research
   - Conventional plant breeding
   - Wide-crossing/hybridization breeding
   - Biotechnology (transgenic) breeding
2. Private sector agriculture-related research and development
3. Agricultural extension and farmers' schooling
4. Markets
5. Infrastructure
6. Irrigation

The growth contribution of modern inputs such as fertilizers is accounted for in price effects in the yield response function and as a complementary input with irrigation and with the modern varieties generated by research. To generate the projected time path of yield growth, the methodology makes use of before-the-fact and after-the-fact studies of agricultural research priority setting, studies of the sources of agricultural productivity growth, an examination of the role of industrialization in growth, and expert opinion (Evenson and Rosegrant 1995).

Livestock production

Livestock production is modeled similarly to crop production, except that livestock yield reflects only the effects of expected developments in technology (Equation 5). Total livestock population is a function of the livestock's own price and the price of competing commodities, the prices of intermediate (feed) inputs, and a trend variable reflecting growth in the number of livestock slaughtered (Equation 4). Total production is calculated by multiplying the number of slaughtered animals by the yield per head (Equation 6).

Number slaughtered:

$$AL_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times \prod_{b \neq i} (PI_{tnb})^{\gamma_{ibn}} \times (1 + gSL_{tni}) \quad (4)$$

. Yield:

$$YL_{tni} = (1 + gLY_{tni}) \times YL_{t-1,ni} \quad (5)$$

Production:

$$QS_{tni} = AL_{tni} \times YL_{tni} \quad (6)$$

where

AL	=	number of slaughtered livestock
YL	=	livestock product yield per head
PI	=	price of intermediate (feed) inputs
i, *j*	=	commodity indices specific for livestock
b	=	commodity index specific for feed crops
gSL	=	growth rate of number of slaughtered livestock
gLY	=	growth rate of livestock yield
α	=	intercept of number of slaughtered livestock
£	=	price elasticity of number of slaughtered livestock
γ	=	feed price elasticity

The remaining variables are defined as for crop production.

Demand functions

Domestic demand for a commodity is the sum of its demand as food, feed, and for other uses (Equation 12). Food demand is a function of the price of the commodity and the prices of other competing commodities, per capita income, and total population (Equation 7). Per capita income and population increase annually according to country-specific population and income growth rates as shown in Equations 8 and 9. Feed demand is a derived demand determined by the changes in livestock production, feed ratios, and own- and cross-price effects of feed crops (Equation 10). The equation also incorporates a technology parameter that indicates improvements in feeding efficiencies. The demand for other uses is estimated as a proportion of food and feed demand (Equation 11). Note that total demand for livestock consists only of food demand.

Demand for food:

$$QF_{tni} = \alpha_{tni} \times (PD_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PD_{tnj})^{\varepsilon_{ijn}} \times (INC_{tn})^{\eta_{in}} \times POP_{tn} \quad (7)$$

where

$$INC_{tn} = INC_{t-1,ni} \times (1 + gI_{tn}) \text{ and} \quad (8)$$

$$POP_{tn} = POP_{t-1,ni} \times (1 + gP_{tn}) \qquad [9]$$

Demand for feed:

$$QL_{tnb} = \beta_{tnb} \times \sum_{l} (QS_{tnl} \times FR_{tnbl}) \times (PI_{tnb})^{\gamma_{bbn}} \times \prod_{o \neq b} (PI_{tnb})^{\gamma_{bon}} \times (1 + FE_{tnb}) \qquad (10)$$

Demand for other uses:

$$QE_{tni} = QE_{t-1,ni} \times \frac{(QF_{tni} + QL_{tni})}{(QF_{t-1,ni} + QL_{t-1,ni})} \qquad (11)$$

Total demand:

$$QD_{tni} = QF_{tni} + QL_{tni} + QE_{tni} \qquad (12)$$

where

- QD = total demand
- QF = demand for food
- *QL* = derived demand for feed
- *QE* = demand for other uses
- *PD* = the effective consumer price
- *INC* = per capita income
- FOP = total population
- *FR* = feed ratio
- *FE* = feed efficiency improvement
- *PI* = the effective intermediate (feed) price
- *i,j* = commodity indices specific for all commodities
- *l* = commodity index specific for livestock
- *b,o* = commodity indices specific for feed crops
- *gI* = income growth rate
- *gP* = population growth rate
- *£* = price elasticity of food demand
- γ = price elasticity of feed demand
- η = income elasticity of food demand
- α = food demand intercept
- *ß* = feed demand intercept

The rest of the variables are as defined earlier.

(Note: for i belonging to livestock, QL and QE are equal to zero)

The supply and demand data was sourced from the FAOSTAT database (www.fao.org), UN (1998) was used for the population data, and elasticities and growth rates were obtained from literature reviews and expert estimates.

Prices

Prices are endogenous in the model. Domestic prices are a function of world prices, adjusted by the effect of price policies, expressed in terms of the producer subsidy equivalent (PSE), and consumer subsidy equivalent (CSE)[1], and the marketing margin (MI). PSEs and CSEs measure the implicit level

Source: Ingco and Ng 1998; Fan and Tuan 1998; Finger et al. 1996; McDougall et al. 1998; UNCTAD (various years); Valdes 1996; Valdes and Schaeffer 1995a; Valdes and Schaeffer 1995b; Valdes and Schaeffer 1995c; Valdes and Schaeffer 1995d.

of taxation or subsidy borne by producers or consumers relative to world prices and account for the wedge between domestic and world prices. MI reflects other factors such as transport and marketing costs. In the model, PSEs, CSEs and MIs are expressed as percentages of the world price. In order to calculate producer prices, the world price is reduced by the MI value and increased by the PSE value (Equation 13). Consumer price is obtained by adding the MI value to the world price and reducing it by the CSE value (Equation 14). The MI of the intermediate prices is smaller because wholesale instead of retail prices are used, but intermediate prices (reflecting feed prices) are otherwise calculated the same way as consumer prices (Equation 15).

Producer prices: $$PS_{tni} = [PW_i (1-MI_{tni})] (1+PSE_{tni}) \quad (13)$$

Consumer prices: $$PD_{tni} = [PW_i (1 + MI_{tni})] (1-CSE_{tni}) \quad (14)$$

Intermediate (feed) prices: $$pI_{tni} = [PW_i (1 + 0.5MI_{tni})] (1-CSE_{tni}) \quad (15)$$

where

PW = the world price of the commodity
MI = the marketing margin
PSE = the producer subsidy equivalent
CSE = the consumer subsidy equivalent
i,j = commodity indices specific for all commodities

The rest of the variables are as defined earlier.

Most prices are obtained from the World Bank's *Global Commodity Markets; A Comprehensive Review and Price Forecast* (World Bank 2000)[2]. The ones that were not available in this report were collected from the Food and Agriculture Organization (FAO 2000a, 2000b) and the USDA's National Agricultural Statistics Service (NASS) (USDA 2000a, 2000b).

International linkage: trade

The country and regional submodels are linked to each other through trade. Commodity trade by country is the difference between domestic production and demand (Equation 16). Countries with positive trade are net exporters, while those with negative trade values are net importers. This specification does not permit a separate identification of countries that are both importers and exporters of a particular commodity. In the 1997 base year, changes in stocks are computed at the 1996-1998 average levels. Therefore, production and demand values are not equal in the base year. Stock changes in the base year are phased out during the first three years of the projections period to achieve long run equilibrium, that is, a supply-demand balance is achieved with no annual changes in stocks.

Net trade: $$QT_{tni} = QS_{tni} - QD_{tni} \quad (16)$$

where

QT = volume of trade
QS = domestic supply of the commodity
QD = domestic demand of the commodity
i = commodity index specific for all commodities

The rest of the variables are as defined earlier.

2 Although we use a three-year average around 1997 for all other variables in the baseline, it was decided to use a 1998 three-year average for most prices, in order to capture the recent downturn in commodity prices.

Algorithm for solving the equilibrium condition

The model is written in the General Algebraic Modeling System (GAMS) programming language. The solution of the system of equations is achieved by using the Gauss-Seidel method algorithm. This procedure minimizes the sum of net trade at the international level and seeks a world market price for a commodity that satisfies Equation 17, the market-clearing condition.

$$\sum_{n} QT_{tni} = 0 \qquad (17)$$

The world price (*PW)* of a commodity is the equilibrating mechanism such that when an exogenous shock is introduced in the model, *PW* will adjust and each adjustment is passed back to the effective producer (*PS*) and consumer (*PD*) prices via the price transmission equations (Equations 13 through 15). Changes in domestic prices subsequently affect commodity supply and demand, necessitating their iterative read-justments until world supply and demand balance, and world net trade is again equal to zero.

Determination of malnutrition

In order to explore food security effects, IMPACT projects the percentage and number of malnourished preschool children (0 to 5 years old) in developing countries. A malnourished child is a child whose weight-for-age is more than two standard deviations below the weight-for-age standard set by the U.S. National Center for Health Statistics/World Health Organization. This standard is adopted by many United Nations agencies in assessing the nutritional status of persons in developing countries. The projected numbers of malnourished children are derived from an estimate (for detailed information see Smith and Haddad 2000) of the functional relationship between the percentage of malnourished children and several factors: average per capita caloric consumption, non-food determinants of child malnutrition such as the quality of maternal and child care (proxied for by the percentage of females undertaking secondary schooling as well as by females' status relative to men as captured by the ratio of female to male life expectancy at birth), and health and sanitation (proxied for by the percentage of the population with access to treated surface water or untreated but uncontaminated water from another source).

The analysis employed a fixed-effects model on pooled, cross-section time-series data from 63 developing countries covering the 1970s, 1980s and 1990s from a variety of sources for both dependent and independent variables. The majority of the data on prevalence of child malnutrition came from the *World Health Organization's Global Database on Child Growth and Malnutrition* (WHO 1997), with other sources including the *United Nations Administrative Committee on Coordination - Subcommittee on Nutrition* (ACC/SCN 1992 and 1996) and *World Development Indicators* (World Bank 1997). Sources for explanatory factor data include the FAO FAOSTAT database (FAO 1998) for calorie availability, the UNESCO UNESCOSTAT database (UNESCO 1998) for female secondary enrollment data, and *World Development Indicators* (World Bank 1998) for female to male life expectancy ratios. For greater detail on sources, data coverage, specific observations used, and model estimation procedures and tests, see Smith and Haddad (2000).

The estimated functional relationship used to project the percentage of malnourished children in the model is as follows:

$$MAL = -25.24 * \ln(KCAL) - 71.76\ LFEXPRAT_t - 0.22\ SCH_t - 0.08\ WATER, \qquad (18)$$

where

MAL = percentage of malnourished children
KCAL = per capita kilocalorie availability
LFEXPRAT = ratio of female to male life expectancy at birth

SCH = total female enrollment in secondary education (any age group) as a percentage of the female age-group corresponding to national regulations for secondary education
$WATER$ = percentage of population with access to safe water

Coefficients for non-food explanatory variables come from an equation estimated by Smith and Haddad (2000) that fit the pooled data series well. The semi-log functional relationship with child malnutrition for the food component ($KCAL$) approximates a "three-spline" approach (estimated coefficients differ depending on whether calorie consumption falls above or below specific thresholds) found in Smith and Haddad (2000) because it fits the data well and provides a smooth relationship more appropriate for use with a projection model. Projected per capita calorie consumption ($KCAL$) comprises two components. The first component is the amount of calories derived from commodities included in the model. These are obtained via conversion of projected per capita food consumption of those commodities, and use as a benchmark country-level 1997 per capita food consumption (actually an average of FAO estimates for 1996-98) expressed in kilocalories per commodity. The second component consists of calories from commodities outside the model, although as sugar, fruits and vegetables were recently added, only a few calories are not accounted for any more. The kilocalorie contribution is projected using the base year kilocalorie contribution and the specified income elasticity of demand for calories from the remaining commodities. Projected life expectancy ratios, female enrollment rates, and percentage of population with access to safe water are based on recent trends at country level, taking into consideration projected investment levels as well as diminishing returns as prevalence rates improve.

The percentage of malnourished children derived is then applied to the projected population of children 0 to 5 years of age to compute the number of malnourished children:

$$NMAL_t = MAL_t \times POP5_t$$

where
$NMAL$ = number of malnourished children, and
POPS = number of children 0 to 5 years old in the population.

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Table 1.1 IMPACT countries/regions and commodities (old).

Countries/regions	Commodities
1. United States of America	1. Beef
2. European Union 15	2. Pork
3. Japan	3. Sheep and goats
4. Australia	4. Poultry
5. Other Developed Countries	5. Eggs
6. Eastern Europe	6. Milk
7. Central Asia	7. Wheat
8. Other Former Soviet Union Countries	8. Rice
9. Mexico	9. Maize
10. Brazil	10. Other coarse grains
11. Argentina	11. Potatoes
12. Colombia	12. Sweet potato and yam
13. Other Latin American Countries	13. Cassava and other roots and tubers
14. Nigeria	14. Soybean
15. Northern Sub-Saharan Africa	15. Meals
16. Central and Western Sub-Saharan Africa	16. Oils
17. Southern Sub-Saharan Africa	
18. Eastern Sub-Saharan Africa	
19. Egypt	
20. Turkey	
21. Other West Asian and North African Countries	
22. India	
23. Pakistan	
24. Bangladesh	
25. Other South Asian Countries	
26. Indonesia	
27. Thailand	
28. Malaysia	
29. Philippines	
30. Vietnam	
31. Myanmar	
32. Other Southeast Asian Countries	
33. China	
34. South Korea	
35. Other East Asian Countries	
36. Rest of the World	

Note: The extended list of the IMPACT commodities and their definition is given in Table 1.4.

Table 1.2 Definitions of IMPACT countries and regions: Developed countries and regions.

Western World

1. United States
2. European Union (EU 15): Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
3. Japan
4. Australia
5. Other developed countries: Canada, Iceland, Israel, Malta, New Zealand, Norway, South Africa and Switzerland
6. Eastern Europe: Albania, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia, Slovenia and Yugoslavia

Former Soviet Union (FSU)

7. Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan
8. Other Former Soviet Union: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova, Russian Federation and Ukraine

Table 1.3 Definitions of IMPACT countries and regions: Developing countries and regions.

Central and Latin American Countries

1. Mexico
2. Brazil
3. Argentina
4. Colombia
5. Other Latin American countries: Antigua and Barbuda, Bahamas, Barbados, Belize, Bolivia, Chile, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, E1 Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent, Suriname, Trinidad and Tobago, Uruguay and Venezuela

Sub-Saharan African Countries

6. Nigeria
7. Northern Sub-Saharan Africa: Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Somalia and Sudan
8. Central and Western Sub-Saharan Africa: Benin, Cameroon, Central African Republic, Comoros Island, Congo Democratic Republic, Congo Republic, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Sao Tome and Principe, Senegal, Sierra Leone and Togo
9. Southern Sub-Saharan Africa: Angola, Botswana, Lesotho, Madagascar and Malawi, Mauritius, Mozambique, Namibia, Reunion, Swaziland, Zambia and Zimbabwe
10. Eastern Sub-Saharan Africa: Burundi, Kenya, Rwanda, Tanzania and Uganda

Continued

Table 1.3 *Continued*

West Asian and North African (WANA) Countries

11. Egypt
12. Turkey
13. Other WANA countries: Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, United Arab Emirates and Yemen

South Asian Countries

14. India
15. Pakistan
16. Bangladesh
17. Other South Asian countries: Afghanistan, Maldives, Nepal and Sri Lanka

Southeast Asian Countries

18. Indonesia
19. Thailand
20. Malaysia
21. Philippines
22. Vietnam
23. Myanmar
24. Other Southeast Asian countries: Brunei, Cambodia and Laos

East Asian Countries

25. China: includes Taiwan and Hong Kong
26. Republic of Korea
27. Other East Asian countries: Democratic People's Republic of Korea, Macao and Mongolia

Rest of the World

28. Cape Verde, Fiji, French Polynesia, Kiribati, New Guinea, Papua New Guinea, Seychelles and Vanuatu

Table 1.4 Definitions of IMPACT commodities (extended).

Livestock

Meat

1. Beef: Beef and veal (meat of bovine animals, fresh, chilled or frozen, with bone in) and buffalo meat (fresh, chilled or frozen, with bone in or boneless).
2. Pork: Pig meat (meat, with the bone in, of domestic or wild pigs, whether fresh, chilled or frozen).
3. Poultry: Chicken meat (Fresh, chilled or frozen. May include all types of poultry meat like duck, goose and turkey if national statistics do not report separate data).
4. Sheep and goat: Meat of sheep and lamb (whether fresh, chilled or frozen, with bone in or boneless) and meat of goats and kids (whether fresh, chilled or frozen, with bone in or boneless).

Other livestock products

5. Eggs: (weight in shell).
6. Milk: Cow, sheep, goat, buffalo and camel milk (Production data refer to raw milk with all its constituents. Trade data normally cover milk from any animal, and refer to milk that is not concentrated, pasteurized, sterilized or otherwise preserved, homogenized or peptonized.).

Crops

Grains

7. Maize: Used largely for animal feed and commercial starch production.
8. Other coarse grains: Barley (Varieties include with husk and without. Used as a livestock feed, for malt and for preparing foods.), millet (used locally, both as a food and as a livestock feed), oats (used primarily in breakfast foods. Makes excellent fodder for horses), rye (Mainly used in making bread, whisky and beer. When fed to livestock, it is generally mixed with other grains.), and sorghum (a cereal that has use as both food and feed).
9. Rice: Rice-milled equivalent (white rice milled from locally grown paddy. Includes semi-milled, whole-milled and parboiled rice).
10. Wheat: Used mainly for human food.

Roots and tubers

11. Cassava et al.: Cassava and other tubers, roots or rhizomes. Cassava is the staple food in many tropical countries.
12. Potatoes: Mainly used for human food.
13. Sweet potatoes and yams: Sweet potatoes (Used mainly for human food. Trade data cover fresh and dried tubers, whether or not sliced, or in the form of pellets) and yams (starchy staple foodstuff, normally eaten as a vegetable, boiled, baked or fried).

Vegetables and fruits

14. Vegetables: Artichokes; asparagus; beans, green; broad beans, green; cabbages (Chinese, mustard cabbage, pak-choi, white, red, Savoy cabbage, Brussels sprouts, collards, kale and kohlrabi); carrots; cassava leaves; cauliflower and broccoli; chillies, peppers (green); cucumbers, gherkins; eggplants; garlic; green corn (maize); leeks and other alliaceous; lettuce (witloof chicory, endive, escarole

Continued

chicory); melons, cantaloupes; mushrooms; okra; onions, dry; onions, shallots (green); peas, green; pumpkins, squash, gourds; spinach; string beans; tomatoes, fresh; watermelons.

15. Tropical and sub-tropical fruits: Avocados, citrus fruit nes (including among others: bergamot, citron, chinotto, kumquat), dates, figs, grapefruit and pomelo, kiwi fruit, lemons and limes (lemon, sour lime, sweet lime), oranges common (sweet orange, bitter orange, persimmons, tangerines, mandarins, Clementines, satsumas).
16. Temperate fruits: Apples; apricots; berries, nes (including among others: blackberry; loganberry; white, red mulberry; myrtle berry; huckleberry; dangleberry); blueberries (European blueberry; wild bilberry; whortleberry; American blueberry); cherries; cranberries; currants; gooseberries; grapes; peaches and nectarines; pears; plums; quinces; raspberries; sour cherries; stone fruit; strawberries.

Sugar and sweeteners

17. Sugar cane: In some producing countries, marginal quantities are consumed, either directly as food or in the preparation of jams, and a non-refined, crystallized material is derived from the juices of sugar cane stalk that consists either wholly or essentially of sucrose.
18. Sugar beets: In some producing countries, marginal quantities are consumed, either directly as food or in the preparation of jams, and a non-refined, crystallized material is derived from the juices extracted from the root of the sugar beet that consists either wholly or essentially of sucrose.
19. Sweeteners: FAO includes products used for sweetening that are derived from sugar crops, cereals, fruits or milk, or that are produced by insects. This category includes a wide variety of monosaccharides (glucose and fructose) and disaccharides (sucrose and saccharose). They exist either in a crystallized state as sugar, or in thick liquid form as syrups.

Fish products

20. High-value finfish aquaculture: Cod, hake, haddock; flounder, halibut, sole; redfish, bass, conger; salmon, trout, smelt; sturgeon, paddlefish; tuna, bonito, billfish.
21. High-value finfish capture: Cod, hake, haddock; flounder, halibut, sole; redfish, bass, conger; salmon, trout, smelt; shark, ray, chimaera; sturgeon, paddlefish; tuna, bonito, billfish.
22. High-value other aquaculture: Abalones, winkles, conches; clams, cockles, arkshells; freshwater mollusks; miscellaneous marine mollusks; mussels; oysters; scallops, pectens; squids, cuttlefishes, octopuses.
23. High-value other capture: Abalones, winkles, conches; clams, cockles, arkshells; freshwater mollusks; miscellaneous marine mollusks; mussels; oysters; scallops, pectens; squids, cuttlefishes, octopuses.
24. High-value crustaceans aquaculture: Freshwater crustaceans; lobsters, spiny- rock lobsters; miscellaneous marine crustaceans; sea- spiders, crabs; shrimps, prawns.
25. High-value crustaceans capture: Freshwater crustaceans; horseshoe crabs and other arachnoids; lobsters, spiny-rock lobsters; miscellaneous marine crustaceans; sea-spiders, crabs; shrimps, prawns; squat-lobsters.
26. Low-value finfish aquaculture: Carps, barbels and other cyprinids; tilapias and other cichlids; miscellaneous freshwater fishes; miscellaneous diadromous fishes; herrings, sardines, anchovies; jacks, mullets, sauries; miscellaneous marine fishes.

Continued

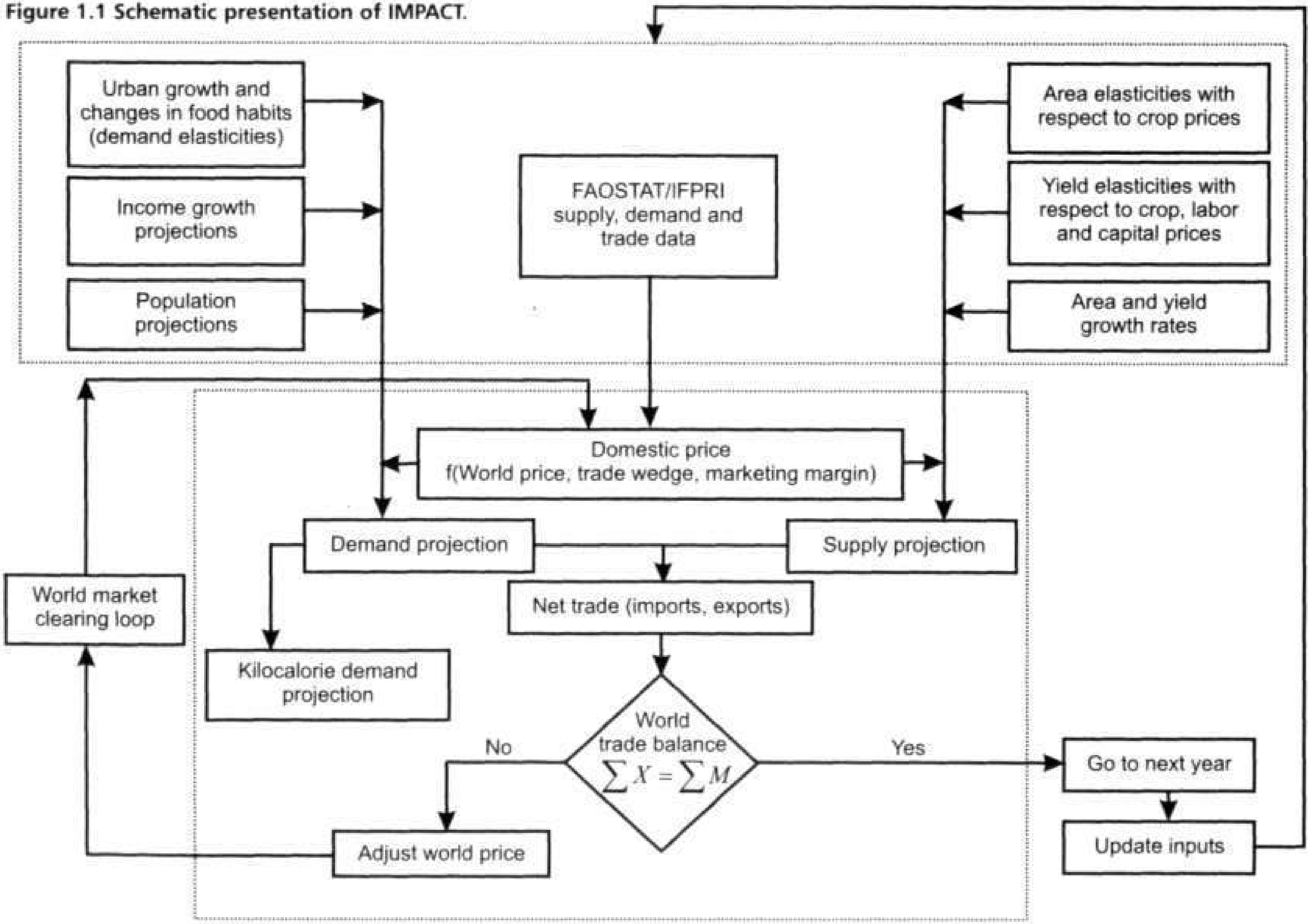
Table 1.4 *Continued*

27. Low value finfish capture: Herrings, sardines, anchovies; jacks, mullets, sauries; mackerels, snoeks, cutlassfishes; river eels; shads; carps, barbels and other cyprinids; tilapias and other cichlids; miscellaneous diadromous fishes; miscellaneous freshwater fishes; miscellaneous marine fishes.
28. Fish meals: including products powdered or in pellets, not fit for human consumption.
29. Fish oils: including products, generally liquid, edible or inedible, extracted from fish liver and body.

Others

30. Meals: Copra cake, cottonseed cake, groundnut cake, other oilseed cakes, palm kernel cake, rape and mustard seed cake, sesame seed cake, soybean cake, sunflower seed cake, fish meal, meat and blood meal (Residue from oil extraction, mainly used for feed).
31. Oils: Vegetable oils and products, animal fats and products (Obtained by pressure or solvent extraction, used mainly for food).
32. Soybeans: The most important oil crop (oil of soybeans under oils), but also widely consumed as a bean and in the form of various derived products because of its high protein content, e.g. soy milk, meat, etc.

Figure 1.1 Schematic presentation of IMPACT.



1.2 Data requirement for the addition of new commodities into the IMPACT model - *siet Meijer*

IFPRI's IMPACT model is described in detail in the paper *International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description* by MW Rosegrant, S Meijer and S Cline (downloadable at http://www.ifpri.org/themes/impact/impact model.pdf).

The data that is required to include new commodities in the IMPACT model is outlined below. It is important to note that the data needs to be downloaded for about 180 countries, but aggregated to the 36 countries and regions as defined in the IMPACT model description in Section 1.1.

The data needed for the IMPACT model is provided in a set of Lotus spreadsheets. The Tables mentioned in this section on the IMPACT model refer to these Lotus files and contain data on the following variables and parameters.

Table 1	Table 2	Table 4	Table 5
Population and income variables	Population growth rates at six different time periods till 2020	Livestock supply elasticities (own and cross price)	Growth rate assumptions for area and yield at six different time periods till 2020
Production variables (Area, yield, production, trade, stock balance, etc)		Area response elasticities for different crops (own and cross price)	
Demand variables		Crop yield elasticities and yield growth rates	
Price variables		Food elasticity (livestock products and crops)	
World prices damping factor		Feed efficiency	
World prices of commodities		Trade liberalization parameters	
		Proportion of irrigation to total area	
		Proportion of area planted to high-yielding variety	

DATA NEEDED FOR TABLE 1.WK4

Supply data

1. Area
2. Production
3. Yield

To obtain Area and Production data, go to the www.fao.org Web site, then to Statistical Databases, and the FAOSTAT agriculture database. In this database go to the Domain 'Agricultural Production" and Data Collections "Crops Primary". There the harvested area and production can be selected for the relevant countries and crops for all years available. All years have to be downloaded because the historical data is needed for future growth rate estimates in Table 5.wk4 . The data can be saved as a CSV (comma separated value) file that can be opened in Excel, where further modification is possible.

Yield is calculated based on the area and production data discussed in the previous section. Yield values given in the database are not used, but are calculated in order to avoid inconsistencies.

Demand and trade data

Demand

4. Total Demand
5. Food Demand
6. Feed Demand
7. Other Demand

Trade

8. Exports
9. Imports
10. Net Trade
11. Stock Change

For this data, go to the FAOSTAT Database, and to the Domain "Commodity Balances" and Data Collections "Crops Primary Equivalent". For most commodities, data on Food Demand, Feed Demand, Exports, Imports and Stock Change are directly available for downloading. As there is no Total Demand group available, it is calculated as the sum of Food, Feed, Seed, Waste, Food Manufacture, and Other Uses while Other Demand is calculated as Total Demand minus Food Demand and Feed Demand. Net Trade is calculated by subtracting Imports from Exports.

Price-related data

12. World Price
13. Producer Price
14. Consumer Price
15. Intermediate Price
16. Marketing Margin
17. Producer Subsidy Equivalent (PSE)
18. Consumer Subsidy Equivalent (CSE)

The World Price can be obtained from several sources, but the World Bank Commodity Outlook and FAO's Food Outlook are good places to start. The PSE and CSE (PSE is positive when a real subsidy is paid to producers, CSE negative when a real tax is paid by consumers) as well as the Marketing Margin have to be gathered by literature search and "expert estimates". As follows, the Producer Price is calculated by subtracting the Marketing Margin from the World Price, and then multiplying this number by 1 + PSE, while the Consumer Price is calculated by adding the Marketing Margin to the World Price and multiplying by 1+CSE. Finally, the Intermediate Price is obtained by adding *half* the value of the Marketing Margin to the World Price and multiplying that value times 1+CSE[3].

To summarize:

$$PS = (WP - Ml) * (1 + PSE)$$

3 Intermediate Price is the price for inputs like feed, which is an intermediate product. The Marketing Margin stands for the costs (expressed in percent of World Price) of hringing the product to the market, which decreases the profit to the producer and increases the price to consumers.

$PC = (WP + MI) * (1 - CSE)$

$PI = ((WP + 0.5*MI)) * (1 - CSE)$

where

PS	=	Producer Price
PW	=	World Price
MI	=	Marketing Margin
PSE	=	Producer Subsidy Equivalent
PD	=	Consumer Price
CSE	=	Consumer Subsidy Equivalent
PI	=	Intermediate Price

DATA NEEDED FOR TABLE 4.WK4

The required data in the next section needs to be collected based on review of available literature and expert estimates.

Supply elasticities data

1. Livestock Supply Elasticities

These elasticities show the relationship between increases in prices of the new commodities and their influence on livestock and fisheries production. Also included is the effect of changes in feed prices on livestock production.

2. Area Response Elasticities

Area elasticities show the effect of price changes of the new commodities on own area and area of the other commodities, as well as the effect of other commodity price changes on the area of the new commodities. Own prices are likely to have larger effects on area cultivated of a certain crop than the prices of other commodities which may be complements or substitutes with the particular commodity.

3. Yield Supply Elasticities

The elasticities needed here are for the three factors influencing the yield of the new commodities, i.e., the crop yield elasticity with respect to the own-crop price, with respect to the wage rate for labor and with respect to the price of capital.

Demand elasticities data

4. Income Demand Elasticities

Income demand elasticities express the change in demand as a result of a change in income.

5. Annual Income Elasticity Adjustment

The income adjustment factor changes (mainly increases) the income demand elasticity over time in order to adjust for changes in expenditures due to higher incomes and urbanization.

6. Food Demand Elasticities

The effect of changes in prices of other commodities and its effect on demand for the new commodities, the effect of changes in prices of the new commodities on the demand for the old commodities and the effect of changes in own prices of the new commodities on its demand have to be expressed with demand elasticities.

7. Feed Demand Elasticities

Feed demand elasticities express the influence of feed price changes on the demand for feed. Data is needed for own and cross-price elasticities.

Feed conversion ratio

8. Feed Conversion Ratio

The feed conversion ratio is the ratio that calculates how much feed from a certain commodity is demanded. For example, wheat has conversion factors with all the livestock commodities that use wheat as feed to raise livestock. The wheat conversion factor for beef multiplied by the production of beef, plus the wheat conversion factor for poultry multiplied by the production of poultry, etc, will have to add up to the feed demand number for wheat that is in the baseline. So, in order to get the conversion ratios, the amount of feed of the new commodity that goes to the production of the specific livestock commodity has to be known/estimated.

9. Changing Factor Feed Conversion Ratio

With this changing factor an increase or decrease in feed efficiency over time can be taken into account (the value is negative when it gets more efficient over time; and positive when it gets less efficient over time).

Malnourished children

10. Kilocalorie Availability per Capita per Day

This data is available on the FAO Web site, listed by commodity.

DATA NEEDED FOR TABLE 5.WK4

Growth rate data

11. Yield Growth Rates
12. Area Growth Rates

Future growth rates of yield and area need to be estimated based on past trends and expert estimates (based on literature reviews if possible). There are six different growth periods for which the yield and area growth rates need to be defined:

Growth period 1: 1997-2000
Growth period 2: 2001-2005
Growth period 3: 2006-2010
Growth period 4: 2011-2015
Growth period 5: 2016-2020
Growth period 6: 2021-2025

IMPACT Model

Overview of the presentation

- Introduction to the basics of the IMPACT Model and schematic overview
- Equations of the IMPACT Model
- IMPACT projection results to 2020 under baseline and alternative scenarios

The IMPACT Model

- IMPACT stands for International Model for Policy Analysis of Agricultural Commodities and Trade

  It is a representation of a global competitive agricultural market for crops and livestock

- It is a global model that divides the world into 36 regions and countries, and Includes 31 agricultural commodities

IMPACT commodities

Livestock: Beef, pork, sheep & goat, poultry, eggs and milk

Cereals: Wheat, rice, maize and other coarse grains

Roots & Tubers: Potatoes, sweet potatoes & yams, cassava & other roots and tubers

Fish: Eight capture and aquaculture fish commodities plus fishmeals and fish oils

Other: Soybeans, meals and oils

Included in the model but results not yet published: Vegetables, sub-tropical fruits, temperate fruits, sugar cane, sugar beets and sweeteners

IMPACT countries and regions

Developed countries: USA, EU15, Japan, Australia, Other Developed, Eastern Europe, Central Asia, Other Former Soviet Union

Latin America: Mexico, Brazil, Argentina, Colombia, Other Latin America

Sub-Saharan Africa (SSA): Nigeria, Northern SSA, Central & Western SSA. Southern SSA, Eastern SSA

West Asia/North Africa (WANA): Egypt, Turkey, Other WANA

South Asia: India, Pakistan, Bangladesh, Other South Asia

Southeast Asia: Indonesia, Thailand, Malaysia, Philippines, Vietnam, Myanmar, Other South East Asia

East Asia: China, South Korea, Other East Asia

Rest of the World

Sub-Saharan African regions

Central & Western SSA: Benin, Cameroon, Central African Republic, Comoros Island, Congo Democratic Republic, Congo Republic, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Sao Tome and Principe, Senegal, Sierra Leone and Togo

Eastern SSA: Burundi, Kenya, Rwanda, Tanzania and Uganda

Nigeria

Northern SSA: Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Somalia and Sudan

Southern SSA: Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Reunion, Swaziland, Zambia and Zimbabwe

Note: South Africa falls under "other developed countries"

IMPACT basics

- Partial equilibrium agricultural sector model
- Specified as a set of country or regional sub-models within each of which supply, demand and prices are determined
- Country-level models are linked to the rest of the world through trade
- World food prices are determined annually at levels that clear international commodity markets

IMPACT equations: Production

Production:

$$QS_{tni} = AC_{tni} \times YC_{tni}$$

QS = quantity produced
t = time index
n = country Index
i,j = commodity indices specific for crops
AC = crop area
YC = crop yield

IMPACT supply functions

- Area Is a function of crop prices and irrigation investment
- Yield is a function of crop prices, input price and other sources of growth:

Public research (by IARC and NARS), management research, conventional plant breeding, wide-crossing/hybridization breeding, biotechnology (transgenic) breeding, private sector agriculturally related research and development, agricultural extension and farmers schooling, markets. Infrastructure and Irrigation

IMPACT equations: Area response

Area response.

$$AC_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times (1 + gA_{tni})$$

AC = crop area
t = time Index
n = country index
i.j = commodity indices specific for crops
α = crop area Intercept
PS = effective producer price
£ = area price elasticity
Π = product operator
gA = growth rate of crop area

IMPACT equations: Yield response

Yield response:

$$YC_{tni} = \beta_{tni} \times (PS_{tni})^{\gamma_{iin}} \times \prod_{k} (PF_{tnk})^{\gamma_{ikn}} \times (1 + gCY_{tni})$$

YC = crop yield
t = time Index
n = country Index
i,j = commodity indices specific for crops
ß = crop yield intercept
PS = effective producer price
y = yield price elasticity
Π = product operator
k = inputs such as labor and capital
PF = price of factor or input *k (e.g. labor/capital)*
gCY = growth rate of crop yield

IMPACT food demand

Food demand is a function of commodity prices, income and population

$$QF_{tni} = \alpha_{tni} \times (PD_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PD_{tnj})^{\varepsilon_{ijn}} \times (INC_{tn})^{\eta_{in}} \times POP_{tn}$$

$$INC_{tn} = INC_{t-1,ni} \times (1 + gI_{tni})$$

$$POP_{tn} = POP_{t-1,ni} \times (1 + gP_{tn})$$

IMPACT feed demand

Feed demand is a function of livestock production, feed prices and feeding efficiency

$$QL_{tnl} = \beta_{tnl} \times \sum_{l} (QS_{tnl} \times FR_{tnli}) \times (PI_{tnl})^{\gamma_{lnn}}$$
$$\times \prod_{i \neq b} (PI_{tnb})^{\gamma_{bnn}} \times (1 + FE_{tnl})$$

IMPACT other demand

Other demand grows in the same proportion as food and feed demand

$$QE_{tni} = QE_{t-1,ni} \times \frac{(QF_{tni} + QL_{tni})}{(QF_{t-1,ni} + QL_{t-1,ni})}$$

IMPACT total demand

Total demand It the sum of food, feed and other demand

$$QD_{tni} = QF_{tni} + QL_{tni} + QE_{tni}$$

IMPACT prices

Prices are endogenous in the model. Domestic prices are a function of world prices, adjusted by the effect of price policies, expressed in terms of the producer subsidy equivalent (PSE), consumer subsidy equivalent (CSE) and marketing margin (MI).

Producer Prices $PS_{tni} = [PW, (1 - MI_{tni})] (1+ PSE_{tni})$

Consumer Prices $PD_{tni} = [PW_1 (1+MI_{tni})] (1-CSE_{tni})$

Feed Prices $PI_{tni} = [PW, (1+0.5\ MI_{tni})] (1 - CSE_{tni})$

IMPACT net trade

The country and regional submodels are linked to each other through trade. Commodity trade by country is the difference between domestic production and demand. Countries with positive trade are net exporters, while those with negative values are net importers.

$$QT_{tni} = QS_{tni} = QD_{tni}$$

IMPACT market clearing condition

The model is written in the GAMS programming language. The solution of the system of equations Is achieved by using the Gauss-Seidel method algorithm. This procedure minimizes the sum of net trade at the international level and seeks a world market price for a commodity that satisfies the market-clearing condition

$$\sum_{n} QT_{tni} = 0$$

IMPACT malnourished children

Estimates of number and percentage of malnourished children were done together with FCND and are based on:

- Percentage of females undertaking secondary schooling
- Ratio of female to male life expectancy at birth
- Percentage of the population with access to safe drinking water
- Calorie availability per capita per day

Number and percentage malnourished children

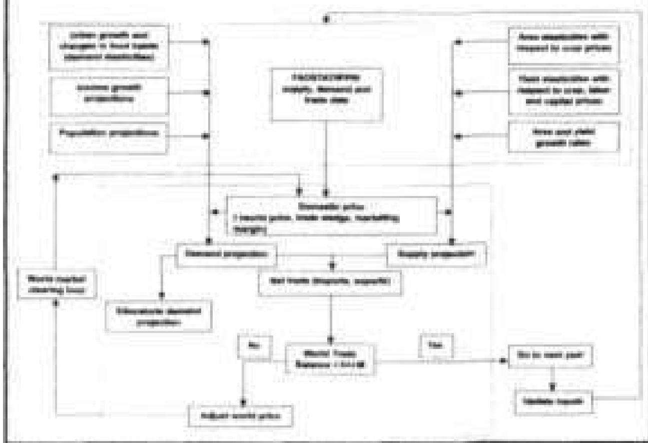
Malnourished children are projected as follows:

$$\% MAL_t = -25.24 * \ln(PCKCAL_t) - 71.76\ LFEXPRAT_t - 0.22\ SCH_t - 0.08\ WATER_t$$

$$NMAL_t = \% MAL_t \times POP5_t$$

%MAL	= Percent of malnourished children
PCKCAL	= Per capita calorie consumption
SCH	= Total female enrollment in secondary education as a % of the female age group
LFEXPRAT	- Ratio of female to male life exp. at birth
WATER	• Percent of people with access to clean water
NMAL	• Number of malnourished children
POPS	* Number of children 0-5 years old

Flow-Chart IMPACT Model



IMPACT outputs

Besides 1997 base year data, results for 2020 and 2025 include (by IMPACT commodity and region):

- Supply
- Demand (food, feed and other demand)
- Net trade
- World prices
- Per capita demand
- Number and percent of malnourished children
- Calorie consumption per capita

IMPACT scenario potential

- Changes in population and income growth
- Rate of growth in crop and livestock yield and production
- Price policies for agricultural commodities
- Supply and demand elasticities
- Feed ratios / technology

IMPACT: Commodity-based analysis

- Livestock
- Roots and tubers
- Fish
- Fruit and vegetable analysis expected to come out this year

IMPACT: Past global scenarios

- Optimistic and pessimistic
- Low population growth
- Low and high yield growth rates
- Higher livestock productivity through lower feed ratios
- Trade liberalization

IMPACT: Past regional scenarios

Asia scenarios

- India and China: agricultural growth slowdown
- Higher Asian feed ratio
- High meat demand in India

Sub-Saharan Africa scenarios

- Optimistic
- Pessimistic

IMPACT investment requirement estimates

Irrigation: Irrigated area (adjusted for cropping intensity) increases * irrigation cost per hectare

Rural Roads: Incremental road length (based on crop area and yield growth) * costs of road increase

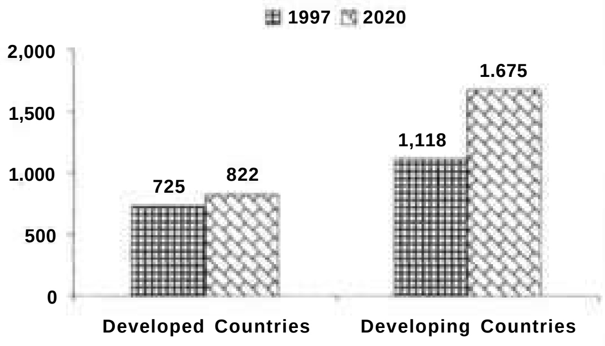
Public Agricultural Research: National and international CGIAR expenditures are summed up

IMPACT investment requirement estimates

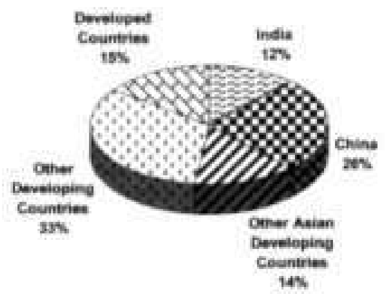
Education: Additional female students needed to get % of female access to secondary school education at baseline levels * education investment costs

Clean Water: Additional number of people needed to get % of people with access to clean water at baseline levels * Investment cost per person

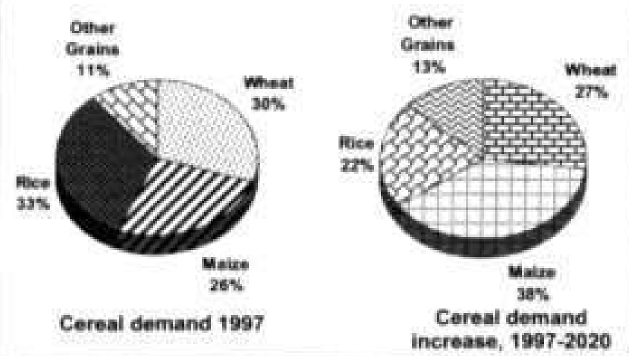
Cereal demand 1997 and 2020 baseline



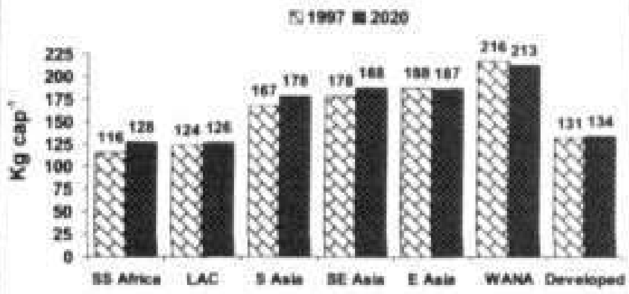
Shares in global cereal demand increase, 1997-2020 baseline



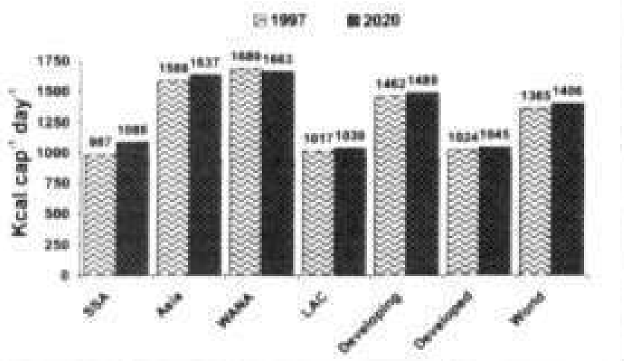
Cereal crop share in developing countries, 1997 and increase 1997-2020 baseline



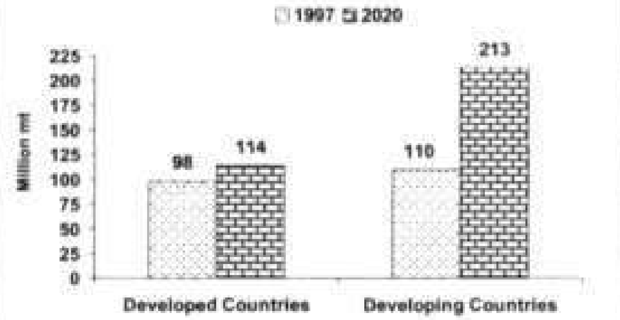
Per capita food demand for cereals, 1997-2020 baseline



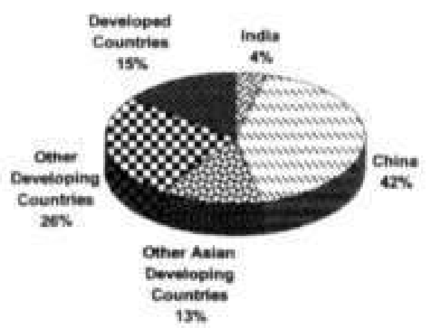
Per capita Kcal consumption of cereals, 1997 and 2020 baseline



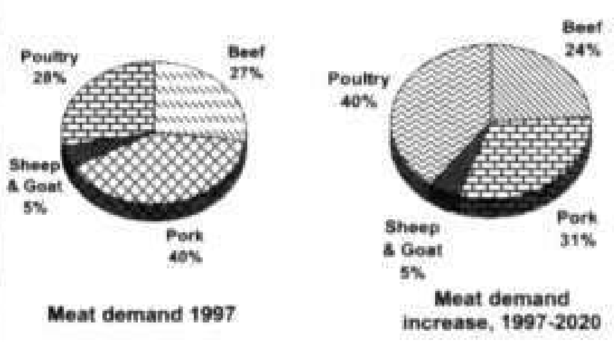
Meat demand, 1997 and 2020 baseline



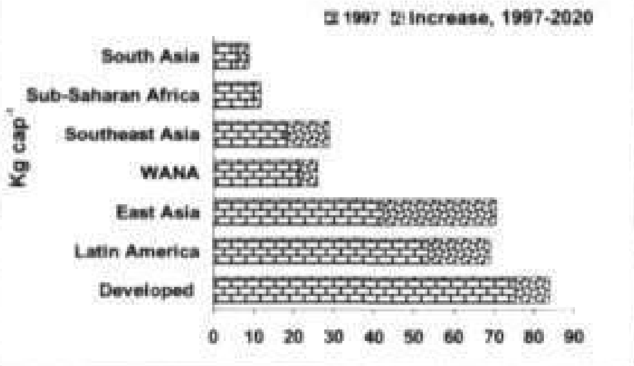
Shares in global meat demand increase, 1997-2020 baseline



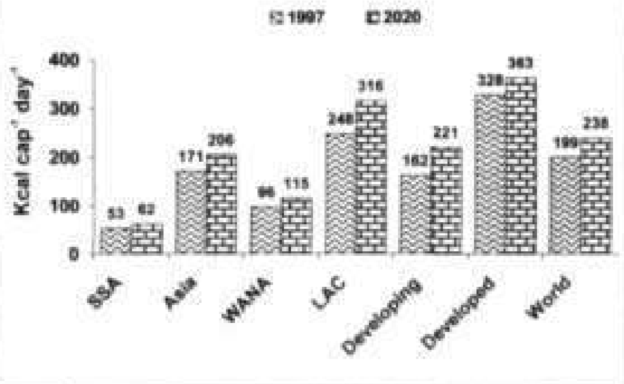
Meat share in developing countries, 1997 and increase 1997-2020 baseline



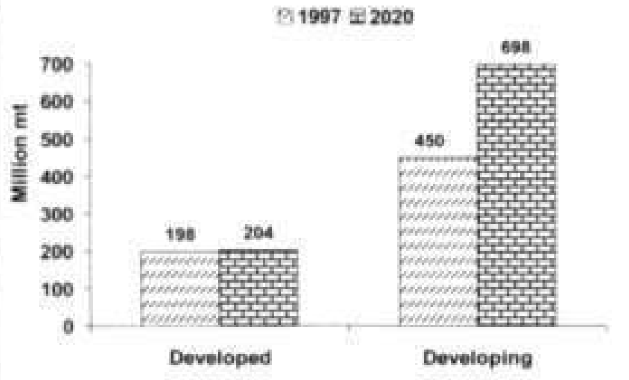
Per capita demand for meat products, 1997-2020 baseline



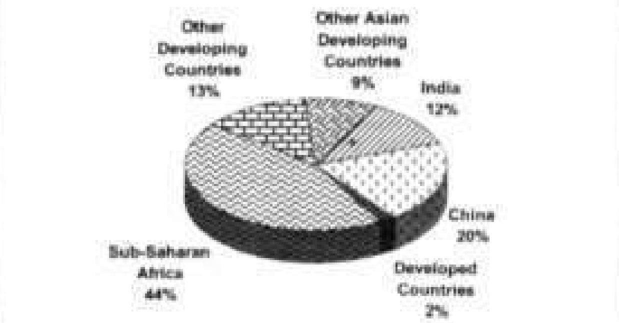
Per capita Kcal consumption of meat products, 1997-2020 baseline



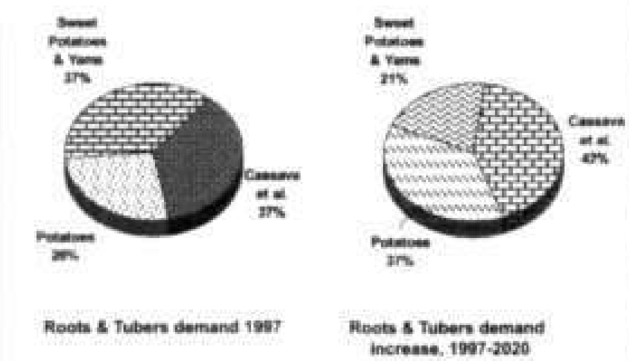
Roots and tubers demand, 1997-2020 baseline



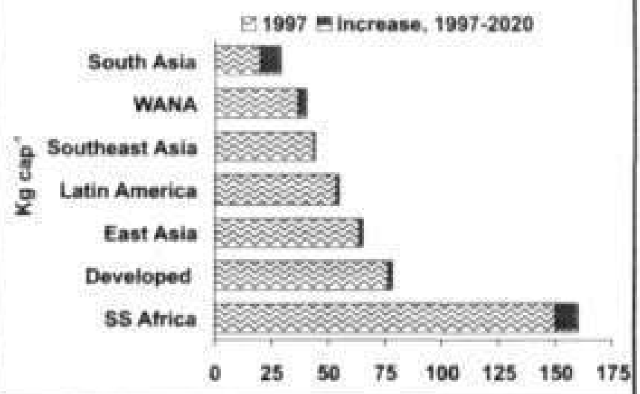
Shares in global roots and tubers demand increase, 1997-2020 baseline



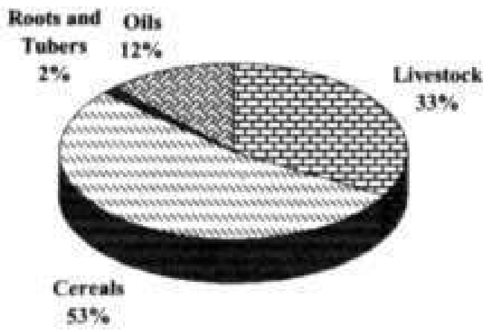
Roots and tubers share in developing countries 1997 and increase 1997-2020 baseline



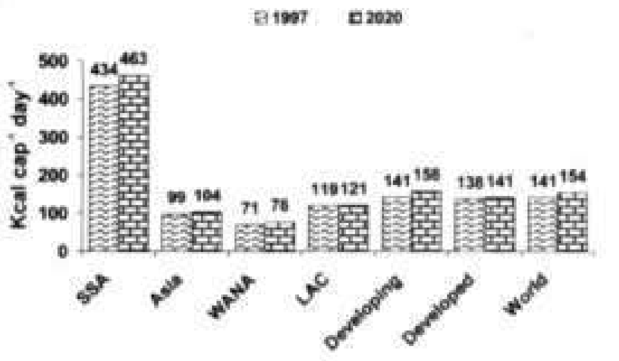
Per capita food demand for roots and tubers, 1997-2020 baseline



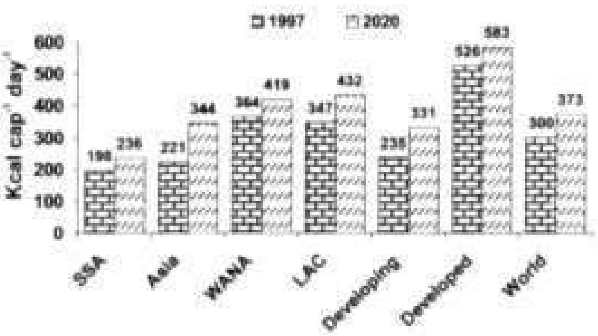
Commodity share in Kcal consumption, 2020 baseline



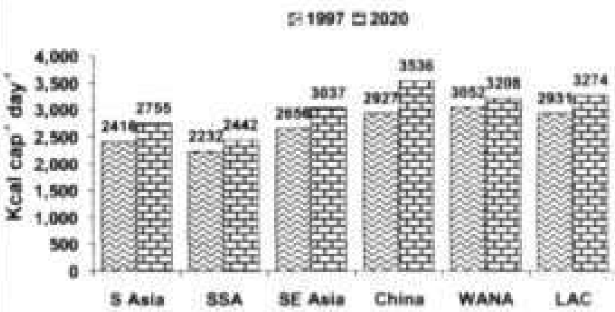
Per capita Kcal consumption of roots and tubers, 1997-2020 baseline



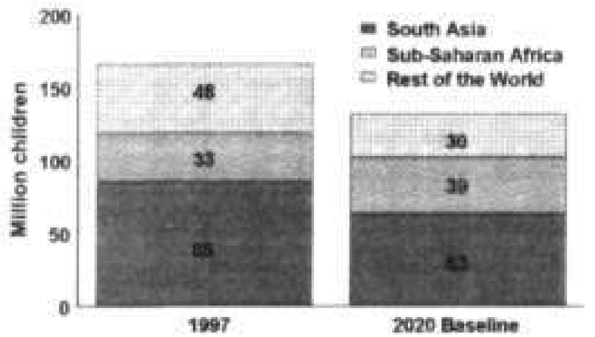
Per capita Kcal consumption of oils, 1997-2020 baseline



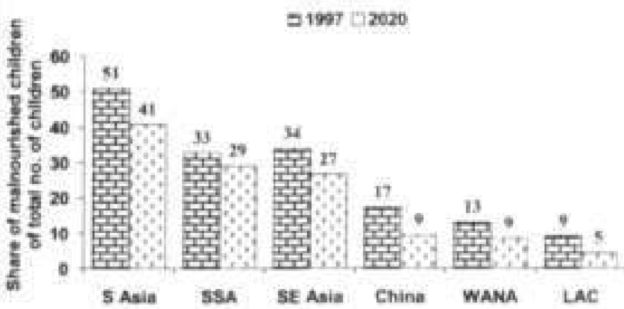
Total daily Kcal availability per capita, 1997-2020 baseline



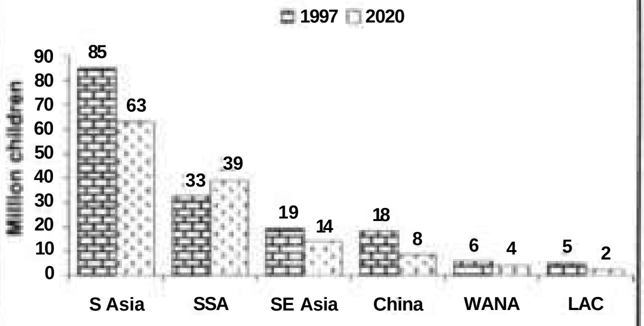
Number of malnourished children, 1997-2020 baseline



Percentage malnourished children by region, 1997-2020 baseline



Number of malnourished children by region, 1997 and 2020 baseline



Sub-Saharan Africa scenario outline

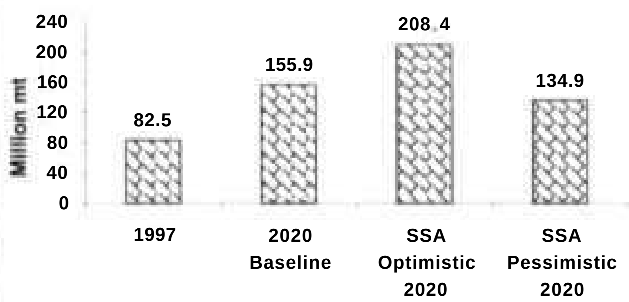
SSA Pessimistic:

- Reduction in crop area and yield growth of 50 percent
- Reduction in livestock, milk and egg numbers growth of 30 percent
- GDP growth cut by SO percent

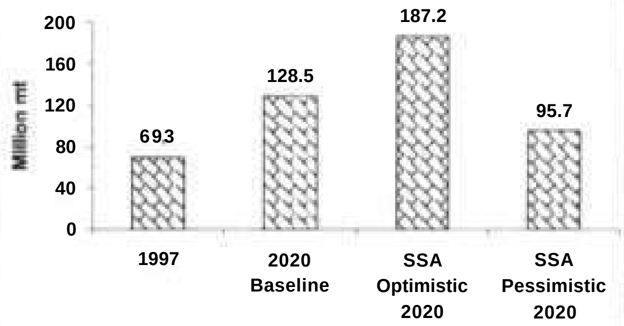
SSA Optimistic:

- Improvements in a variety of social Indicators affecting childhood malnutrition by between 10 and 20 percent
- GDP growth in the various sub-regions reaching B percent
- Cereal crop and livestock yield growth rising to an annualized rate of between 3 and 4 percent

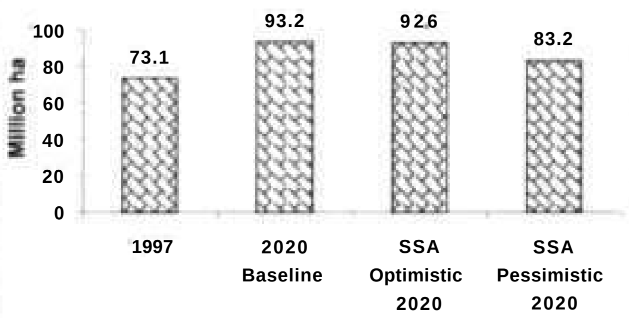
Cereal demand, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



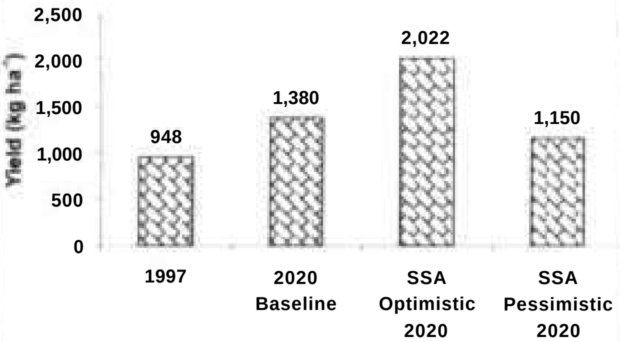
Cereal production, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



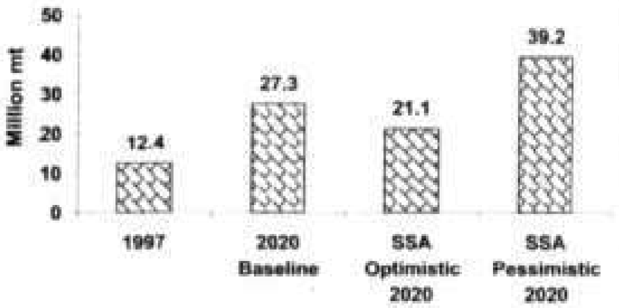
Cereal area, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



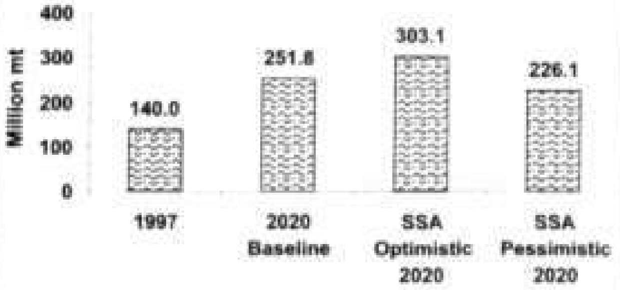
Cereal yield, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



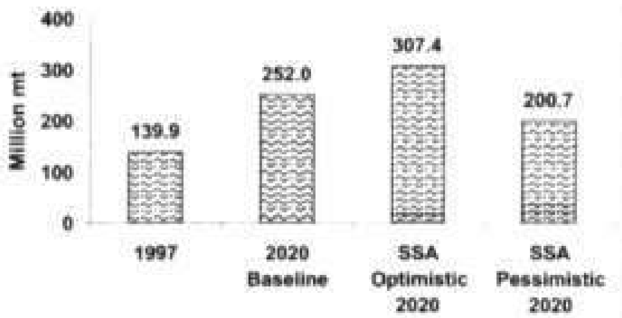
Net cereal imports, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



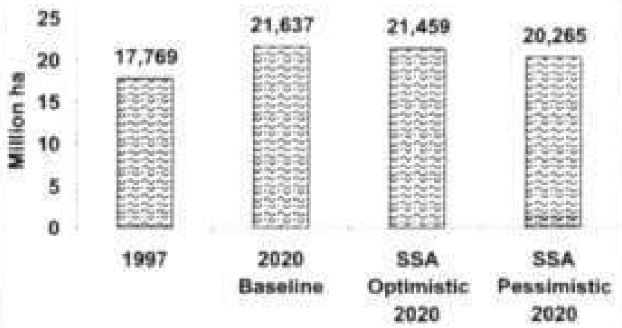
Roots and tuber demand, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



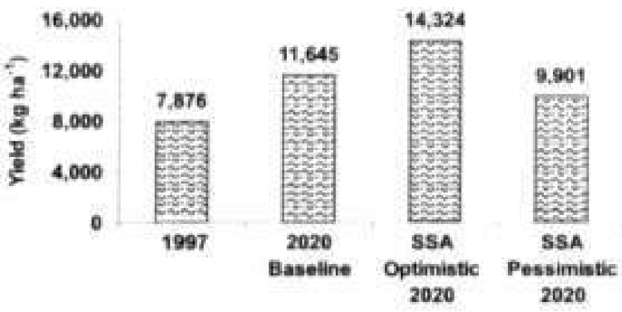
Roots and tuber production, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



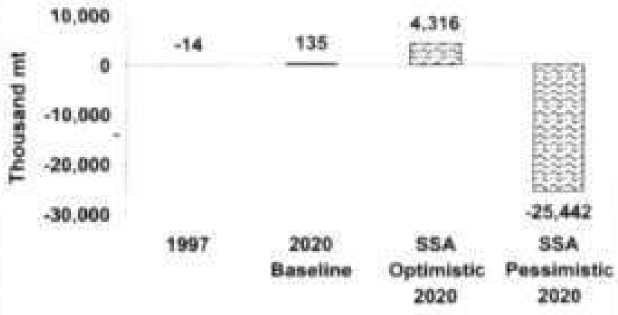
Roots and tuber area, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



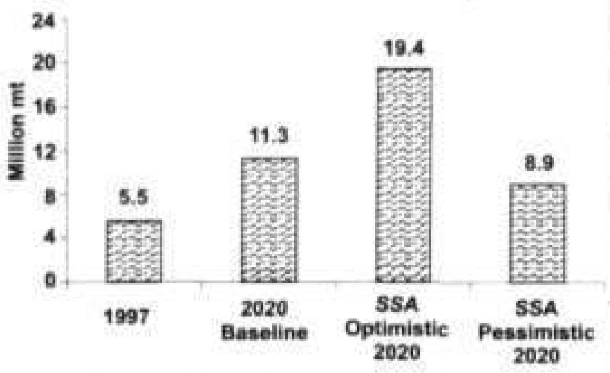
Roots and tuber yield, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



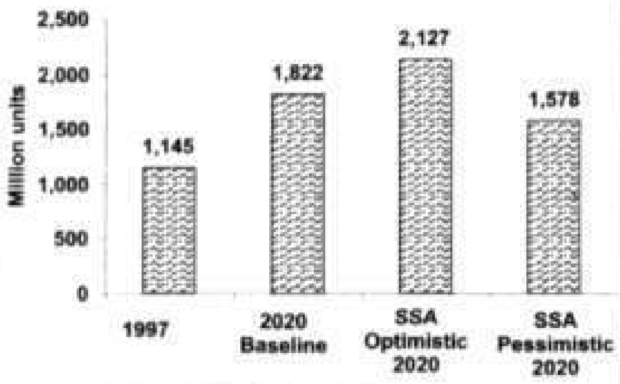
Net roots and tuber trade, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



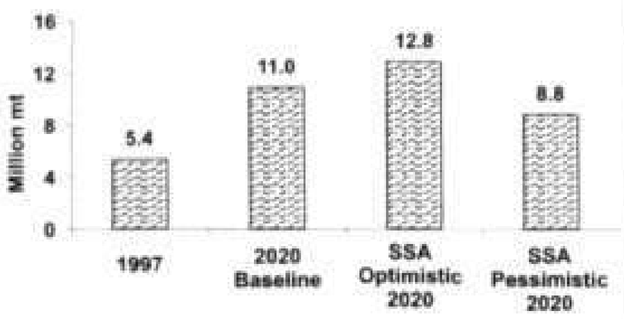
Meat demand, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



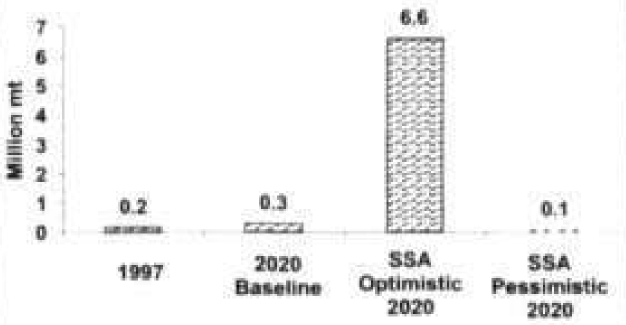
Number of livestock, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



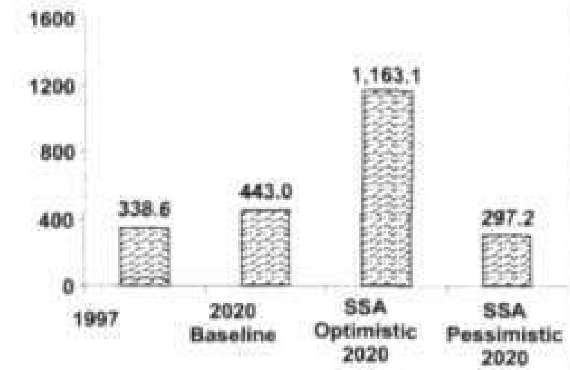
Meat production, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



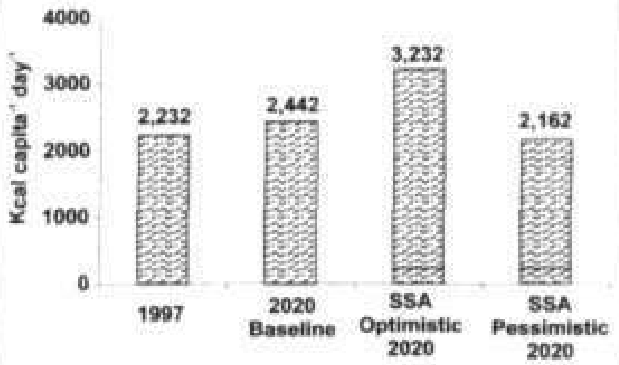
Net meat imports, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



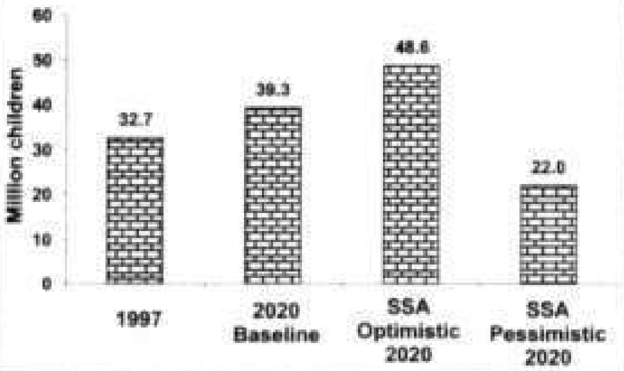
Per capita income, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



Calorie demand, Sub-Saharan Africa, 1997 and projected 2020, alternative scenarios



Number of malnourished children, SSA, 1997 and projected 2020, alternative scenarios



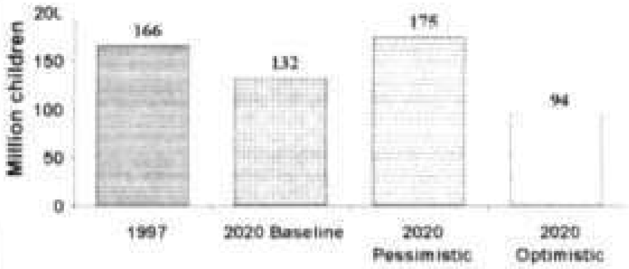
Pessimistic scenario changes compared to the baseline

- Decline in projected income growth In developing countries (25% reduction)
- Decline in crop yield growth (40% reduction in developed countries, 50% in developing countries)
- Decline in area growth in developing countries (15% reduction)
- Zero growth in irrigation
- Reduction in social indicators (10% reduction in schooling and clean water access, 4% reduction in female life expectancy)
- High UN population growth scenario

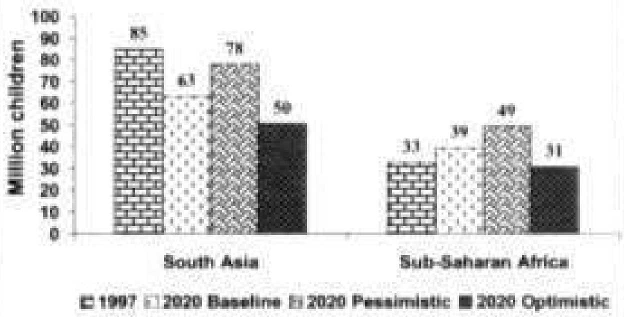
Optimistic scenario changes compared to the baseline

- Increase in projected Income growth In developing countries (25% increase)
- Increase in crop yield growth (10% increase in developed countries, 10-20% In developing countries)
- Increase in area growth in developing countries (10% increase)
- Increase in developing country irrigated area (additional 1% per year)
- Improvement in social indicators (10% increase in schooling and clean water access, 4% Increase in female life expectancy)
- Low UN population growth scenario

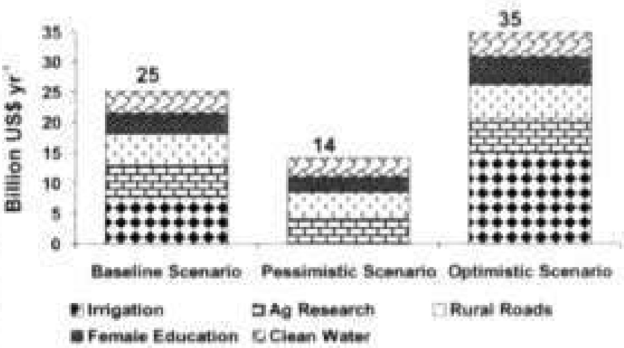
Malnourished children 1997, and 2020 baseline and alternative scenarios



Malnourished children in South Asia and SSA, 1997 and 2020 baseline and alternative scenarios



Annual investments between 1997-2020, baseline and alternative scenarios



Conclusions

- Meat becomes an increasingly Important source of calories
  - Rapid demand growth for livestock products and feeds in developing countries
- Roots and tubers also have strong demand growth
  - Dietary shift to potatoes In Asia
  - Subsistence consumption of cassava and yams in Africa

Conclusions

- Cereals remain primary source of calories
  - Shift in human consumption of maize and other coarse grains to wheat and rice
- Oils are important source of Kcal consumption in developing countries
  - After cereals at 53% and livestock at 33%, oils come in at the third place with a share 12% of total Kcal consumption

Conclusions

- Baseline projections only bring slow decrease in level of malnourished children
- Sub-Saharan Africa numbers even increase
- Need for Pro-Poor Investment Strategy
  - Education of women and girls
  - Clean water, health and nutrition
  - Agricultural research
  - Rural infrastructure
  - Irrigation and water resources

Conclusions

- Baseline scenario is projected to cost US$ 25 billion annually or 3.6% of annual government investments
- Optimistic scenario is projected to cost US$ 35 billion

- This Is a difference of only US$ 10 billion of annual investments
- This will save an estimated 38 million children from malnutrition

2.1 Model description - *Mark W Rosegrant, Ximing Cai and Sarah A Cline*

This section draws from three methodology papers and describes the equations used in the IMPACT model and the Water Simulation Model (WSM)—in particular, the connection between the water demand and supply components and the food production, demand, and trade components is highlighted. The data requirements are also described. For IMPACT, see Rosegrant et al. (2002a); for WSM, see Cai and Rosegrant (2002); and for the combined IMPACT and WSM model, see Rosegrant and Cai (2000).

The model

Basic IMPACT methodology

The IMPACT model offers a methodology for analyzing baseline and alternative scenarios for global food demand, supply, trade, income and population. IMPACT covers 36 countries and regions (which account for virtually all the world's food production and consumption — see Tables 1.1, 1.2 and 1.3), and 16 commodities including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes and meals (Table 1.1). IMPACT is a representation of a competitive world agricultural market for crops and livestock. It is specified as a set of country or regional submodels, within each of which supply, demand, and prices for agricultural commodities are determined. The country and regional agricultural submodels are linked through trade, a specification that highlights the interdependence of countries and commodities in the global agricultural markets.

The model uses a system of supply and demand elasticities incorporated into a series of linear and nonlinear equations to approximate the underlying production and demand functions. World agricultural commodity prices are determined annually at levels that clear international markets. Demand is a function of prices, income and population growth. Growth in crop production in each country is determined by crop prices and the rate of productivity growth. Future productivity growth is estimated by its component sources, including crop management research, conventional plant breeding, wide-crossing and hybridization breeding, and biotechnology and transgenic breeding. Other sources of growth considered include private sector agricultural research and development, agricultural extension and education, markets, infrastructure, and irrigation.

IMPACT technical methodology

Crop production

Domestic crop production is determined by the area and yield response functions. Harvested area is specified as a response to the crop's own price, the prices of other competing crops, the projected rate of exogenous (nonprice) growth trend in harvested area, and water (Equation 1). The projected exogenous trend in harvested area captures changes in area resulting from factors other than direct crop price effects, such as expansion through population pressure and contraction from soil degradation or conversion of land to nonagricultural uses. Yield is a function of the commodity price, the prices of labor and capital, a projected nonprice exogenous trend factor reflecting technology improvements, and water (Equation 2). Annual production of commodity i in country n is then estimated as the product of its area and yield (Equation 3).

Area response:

$$AC_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times (1 + gA_{tni}) - \Delta AC_{tni}(WAT_{tni}) \tag{1}$$

Yield response:

$$YC_{tni} = \beta_{tni} \times (PS_{tni})^{\gamma_{iin}} \times \prod_{k} (PF_{tnk})^{\gamma_{ikn}} \times (1 + gCY_{tni}) - \Delta YC_{tni}(WAT_{tni}) \tag{2}$$

Production:

$$QS_{tni} = AC_{tni} \times YC_{tni} \tag{3}$$

where

AC	=	crop area
YC	=	crop yield
QS	=	quantity produced
PS	=	effective producer price
PF	=	price of factor or input k (for example labor and capital)
Π	=	product operator
i,j	=	commodity indices specific for crops
k	=	inputs such as labor and capital
n	=	country index
t	=	time index
gA	=	growth rate of crop area
gCY	=	growth rate of crop yield
£	=	area price elasticity
γ	=	yield price elasticity
α	=	crop area intercept
ß	=	crop yield intercept
Δ*AC*	=	crop area reduction due to water stress
Δ YC	=	crop yield reduction due to water stress
WAT	=	water variable

Incorporation of water in crop area functions

Reduction of crop harvest area ΔAC is calculated as:

$$\Delta AC^i = 0, \text{ if } \frac{ETA}{ETM} > E^*, \text{ otherwise} \tag{4}$$

$$\Delta AC^i = AC^i \cdot \left[1 - \left(\frac{ETA^i}{ETM^i} / E^{*i} \right) \right] \text{ for irrigated areas} \tag{5}$$

$$\Delta AC^i = AC^i \cdot \left[1 - \left(ky^i \cdot \left(1 - \frac{ETA^i}{ETM^i} / E^{*i} \right) \right)^{\gamma} \right] \text{ for rainfed areas} \tag{6}$$

where

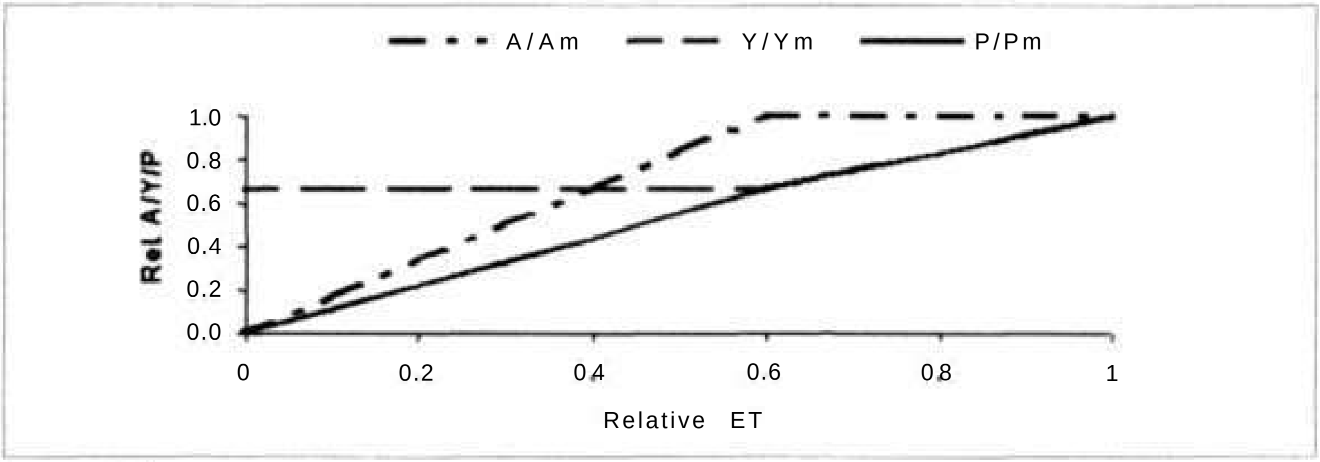
ETA = actual crop evapotranspiration in the crop growth season
ETM = potential crop evapotranspiration in the crop growth season (see description later in Equation 24)
*E** = threshold of relative evapotranspiration, below which farmers reduce crop area
ky = crop response coefficient to water stress

Actual crop evapotranspiration includes irrigation water that can be used for crop evapotranspiration (*NIW)* and effective rainfall (PE),

$ETA^i = NIW^i + PE^i$

where, for rainfed crops, NIW = 0. The determination of NIW for irrigated crops and PE for both rainfed and irrigated crops will be described later. The determination of E* is empirical. For irrigated area, farmers can reduce area and increase water application per unit of the remaining area. Assuming E* = ky - 0.25, Figure 2.1 shows relative irrigated yield, area and production versus relative ET As can be seen, for irrigated area, when ETA/ETM > E*, farmers will maintain the entire crop area, and yield is reduced linearly with ETA/ETM; and when ETA/ETM < E*, farmers will reduce the crop area linearly with ETA/ETM, and maintain constant crop yield corresponding to E*. Equation 5 is derived based on the assumption that the total available water can be totally applied in the remaining irrigated area.

Figure 2.1 Relative irrigated yield, area and production versus relative crop evapotranspiration.



Source: Authors' assessments.

Notes: E* = 0.6; A indicates area; Am, maximum area; Y, yield; Ym, maximum yield; P, production; and Pin, maximum production.

For the same crop, the value of E* is generally much lower for rainfed areas than for irrigated areas. For rainfed area, theoretically, when ETA/ETM < E*, farmers will give up cultivating all the area. However, in the real world this may not hold true. Historical records show that in a region with arid or semi-arid climate, even in a very dry region, the harvested rainfed area did not reduce to zero. However, a general empirical relationship between rainfed harvested area and ETA/ETM is not available from the existing data. We assume the FAO yield-water relationship can be applied to harvested area and water, which is shown in Equation 6, but with a calibration coefficient (γ). This coefficient for a crop is estimated based on evaluation of rainfed harvested area and effective rainfall in recent years.

Equations 5 and 6 capture the effect of extreme water shortages on the crop area decision. The parameter E* will vary with respect to the sensitivity of crops to water stress. When E* equals 1, all adjustments to water shortages are realized through area reduction while crop yield is maintained. For crops that are highly sensitive to water stress, (that is, ky > 1.0), E* in fact approaches a value of 1.0 (for example, 0.9 or more). For these crops, water shortages are handled by leaving a portion of the land fallow while maintaining yields on the remaining area, a strategy that maximizes crop production and returns given the constrained water availability. For relatively drought-tolerant crops, E* has a lower value. For these crops, maximization of production and returns requires spreading the water over as broad an area as possible to maintain production while reducing crop yields. E* can be estimated based on a yearly series of historical data including crop area and yield in different basins/countries, or can be estimated through a field survey. The modeling framework currently only incorporates a relationship between E* and the crop response to water stress (ky). The assumed relationship is E* = ky - 0.25 for irrigated crops and approximately E* = ky*0.6 for rainfed crops.

Incorporation of water in crop yield function

Reduction of crop yield ΔYC is calculated as:

$$\Delta YC = YC^i = ky^j \cdot (1 - ETA^i / ETM^i) \left[\frac{\min\limits_{t \subset growthstages} \left((1 - ETA_m{}^i / ETM_m{}^u) \right)}{(1 - ETA^i / ETM^i)} \right]^{\beta} \quad (7)$$

in which ß is the coefficient to characterize the penalty item, which should be estimated based on local water application in crop growth stages and crop yield. Here crop yield reduction is calculated based on seasonal water availability (that is, seasonal ETA), but crop yields are "penalized" if water availability in some crop growth stages (month) is particularly lower than the seasonal level. All other items have been previously defined.

Livestock production

Livestock production is modeled similarly to crop production except that livestock yield reflects only the effects of expected developments in technology (Equation 9). Total livestock slaughter is a function of the livestock's own price and the price of competing commodities, the prices of intermediate (feed) inputs, and a trend variable reflecting growth in the livestock slaughtered (Equation 8). Total production is calculated by multiplying the slaughtered number of animals by the yield per head (Equation 10).

Number slaughtered:

$$AL_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times \prod_{b \neq i} (PI_{tnb})^{\gamma_{ibn}} \times (1 + gSL_{tni}) \quad (8)$$

Yield:

$$YL_{tni} = (1 + gLY_{tni}) \times YL_{t-1,ni} \quad (9)$$

Production:

$$QS_{tni} = AL_{tni} \times YL_{tni} \quad (10)$$

where

AL	=	number of slaughtered livestock
YL	=	livestock product yield per head
PI	—	price of intermediate (feed) inputs
i, j	—	commodity indices specific for livestock
b	=	commodity index specific for feed crops
gSL	=	growth rate of number of slaughtered livestock
gLY	=	growth rate of livestock yield
α	=	intercept of number of slaughtered livestock
£	=	price elasticity of number of slaughtered livestock
γ	=	feed price elasticity

The remaining variables are defined as for crop production.

Demand functions

Domestic demand for a commodity is the sum of its demand for food, feed, and other uses (Equation 16). Food demand is a function of the price of the commodity and the prices of other competing commodities, per capita income, and total population (Equation 11). Per capita income and population increase annually according to country-specific population and income growth rates as shown in Equations 12 and 13. Feed demand is a derived demand determined by the changes in livestock production, feed ratios, and own- and cross-price effects of feed crops (Equation 14). The equation also incorporates a technology parameter that indicates improvements in feeding efficiencies. The demand for other uses is estimated as a proportion of food and feed demand (Equation 15). Note that total demand for livestock consists only of food demand.

Demand for food:

$$QF_{tni} = \alpha_{tni} \times (PD_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PD_{tnj})^{\varepsilon_{ijn}} \times (INC_{tn})^{\eta_{in}} \times POP_{tn} \tag{11}$$

where

$$INC_{tn} = INC_{t-1,ni} \times (1 + gI_{tn}) \text{ and} \tag{12}$$

$$POP_{tn} = POP_{t-1,ni} \times (1 + gP_{tn}) \tag{13}$$

Demand for feed:

$$QL_{tnb} = \beta_{tnb} \times \sum_{l} (QS_{tnl} \times FR_{tnbl}) \times (PI_{tnb})^{\gamma_{bbn}} \times \prod_{o \neq b} (PI_{tnb})^{\gamma_{bon}} \times (1 + FE_{tnb}) \tag{14}$$

Demand for other uses:

$$QE_{tni} = QE_{t-1,ni} \times \frac{(QF_{tni} + QL_{tni})}{(QF_{t-1,ni} + QL_{t-1,ni})} \tag{15}$$

Total demand:

$$QD_{tni} = QF_{tni} + QL_{tni} + QE_{tni} \tag{16}$$

where

QD	=	total demand
QF	=	demand for food
QL	=	derived demand for feed
QE	=	demand for other uses
PD	=	the effective consumer price
INC	=	per capita income
POP	=	total population
FR	=	feed ratio
FE	=	feed efficiency improvement
PI	=	the effective intermediate (feed) price
i,j	=	commodity indices specific for all commodities
l	=	commodity index specific for livestock
b,o	=	commodity indices specific for feed crops
gI	=	income growth rate
gP	=	population growth rate
£	=	price elasticity of food demand
γ	=	price elasticity of feed demand
η	=	income elasticity of food demand
α	=	food demand intercept
ß	=	feed demand intercept

The rest of the variables are as defined earlier.

(Note: For *i* belonging to livestock, QL and QE are equal to zero)

Prices

Prices are endogenous in the model. Domestic prices are a function of world prices, adjusted by the effect of price policies and expressed in terms of the producer subsidy equivalent (PSE), the consumer subsidy equivalent (CSE), and the marketing margin (MI). PSEs and CSEs measure the implicit level of taxation or subsidy borne by producers or consumers relative to world prices and account for the wedge between domestic and world prices. MI reflects other factors such as transport and marketing costs. In the model, PSEs, CSEs, and MIs are expressed as percentages of the world price. To calculate producer prices, the world price is reduced by the MI value and increased by the PSE value (Equation 17). Consumer prices are obtained by adding the MI value to the world price and reducing it by the CSE value (Equation 18). The MI of the intermediate prices is smaller because wholesale instead of retail prices are used, but intermediate prices (reflecting feed prices) are otherwise calculated the same as consumer prices (Equation 19).

Producer prices:

$$PS_{tni} = [PW_i(1 - MI_{tni})](1 + PSE_{tni}) \quad (17)$$

Consumer prices:

$$PD_{tni} = [PW_i(1 + MI_{tni})](1 - CSE_{tni}) \quad (18)$$

Intermediate (feed) prices:

$$PI_{tni} = [PW_i(1 + 0.5\,MI_{tni})](1 - CSE_{tni}) \quad (19)$$

where

- PW = world price of the commodity
- MI = marketing margin
- PSE = producer subsidy equivalent
- CSE = consumer subsidy equivalent

The rest of the variables are as defined earlier.

International linkage: Trade

The country and regional submodels are linked through trade. Commodity trade by country is the difference between domestic production and demand (Equation 20). Countries with positive trade are net exporters, while those with negative values are net importers. This specification does not permit a separate identification of both importing and exporting countries of a particular commodity. In the 1997 base year, changes in stocks are computed at the 1996-98 average levels. Therefore, production and demand values are not equal in the base year. Stock changes in the base year are phased out during the first three years of the projection period to achieve long run-equilibrium—that is, a supply-demand balance is achieved with no annual changes in stocks.

Net trade: $$QT_{tni} = QS_{tni} - QD_{tni} \quad (20)$$

where

- QT = volume of trade
- QS = domestic supply of the commodity
- QD = domestic demand of the commodity
- i = commodity index specific for all commodities

The rest of the variables are as defined earlier.

Algorithm for solving the equilibrium condition

The model is written in the General Algebraic Modeling System (GAMS) programming language. The solution of the system of equations is achieved by using the Gauss-Seidel method algorithm. This procedure minimizes the sum of net trade at the international level and seeks a world market price for a commodity that satisfies Equation 17, the market-clearing condition.

$$\sum_{n} QT_{tni} = 0 \quad (21)$$

The world price (PW) of a commodity is the equilibrating mechanism such that when an exogenous shock is introduced in the model, PW will adjust and each adjustment is passed back to the effective producer (PS) and consumer (PD) prices via the price transmission equations (Equations 17-19). Changes in domestic prices subsequently affect commodity supply and demand, necessitating their iterative readjustments until world supply and demand balance, and world net trade again equals zero.

Determination of malnutrition

To explore food security effects, IMPACT projects the percentage and number of malnourished pre-school children (0-5 years old) in developing countries. A malnourished child is a child whose weight-for-age is more than two standard deviations below the weight-for-age standard set by the U.S. National Center for Health Statistics/World Health Organization. The estimated functional relationship used to project the percentage of malnourished children in the model is as follows:

$$MAL = -25.24 * \ln(KCAL_t) - 71.76\ LFEXPRAT_t - 0.22\ SCH_t - 0.08\ WATER, \quad (22)$$

where

MAL	=	percentage of malnourished children
KCAL	=	per capita kilocalorie availability
LFEXPRAT	=	ratio of female to male life expectancy at birth
SCH	=	total female enrollment in secondary education (any age group) as a percentage of the female age-group corresponding to national regulations for secondary education
WATER	=	percentage of population with access to safe water

The percentage of malnourished children derived is then applied to the projected population of children 0-5 years of age to compute the number of malnourished children:

$$NMAL_t = MAL_t \times POP5_t, \quad (23)$$

where

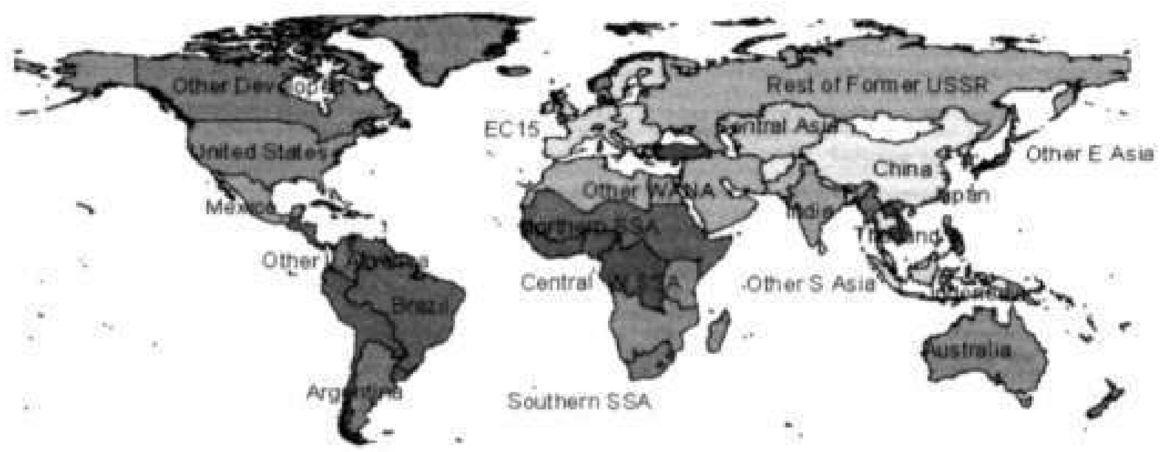
NMAL = number of malnourished children, and
POP5 = number of children 0-5 years old in the population.

Water simulation model

The water simulation model is based on a river basin approach. Figure 2.2 presents maps of the spatial units used in the modeling exercise, including 9 basins in China, 13 basins in India, 14 basins in the United States, and 33 'aggregated basins' in other countries or regions (See Table 1.1). 1995 is treated as the base year, in which all demand and supply items are assessed and calibrated. Projections of water demand and supply are made for the 30 years from 1995 to 2025.

Figure 2.2 IMPACT-WATER spatial elements.

(a) Combined basins



Source: Authors' assessments.

Figure 2.2 IMPACT-WATER spatial elements (*continued*)

(b) Major basins in China

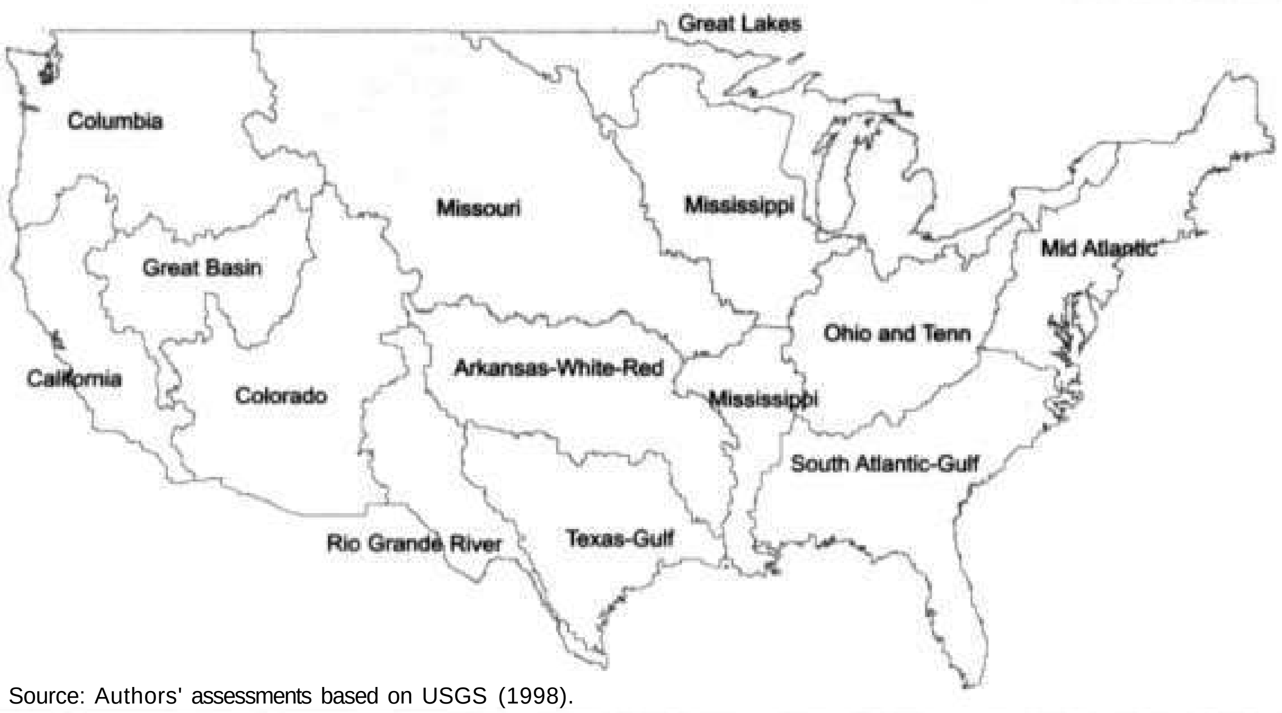
Source: Authors' assessments based on HPDGJ (1989) and Quian (1991).

(c) Major basins in India

Source: Authors' assessments based on Revenga et al. (1998).

Figure 2.2 IMPACT-WATER spatial elements *(continued)*

(d) Major basins in the United States



Source: Authors' assessments based on USGS (1998).

Water demand

Irrigation water demand

Irrigation water demand is assessed as crop water requirement based on hydrologic and agronomic characteristics. Net crop water demand (NCWD) in a basin in a year is calculated based on an empirical crop water requirement function (Doorenbos and Pruitt 1977):

$$NCWD = \sum_{cp}\sum_{ct} kc^{cp,ct} \cdot ET_0^{ct} \cdot A^{cp} = \sum_{cp}\sum_{ct} ETM^{Ct\,.\,cp} .\, A^{CP} \qquad (24)$$

in which *cp* is the index of crops, *ct* is the index of crop growth stages, ET_0 is the reference evapotranspiration [L], *kc* is the crop coefficient and A is the crop area.

Part or all of crop water demand can be satisfied by effective rainfall (PE), which is the rainfall infiltrated into the root zone and available for crop use. Effective rainfall for crop growth can be increased through rainfall harvesting technology. Then net irrigation water demand (*NIRWD),* taking into consideration effective rainfall use and salt leaching requirement, is:

$$NIRWD = \sum_{cp}\sum_{st}\left(kc^{cp,st} \cdot ET_0^{st} - PE^{cp,st} \right) \cdot AI^{CP} \,.\, (1+LR) \qquad (25)$$

in which AI is the irrigated area, and LR is the salt leaching factor, which is characterized by soil salinity and irrigation water salinity.

Total irrigation water demand represented in water depletion (*IRWD)* is calculated as:

$$IRWD = NIRWD / BE \tag{26}$$

where *BE* is defined as basin efficiency.

The concept of basin efficiency has been discussed, and various definitions provided, by Molden et al. (2001). The basin efficiency used in this study measures the ratio of beneficial water depletion (crop evapotranspiration and salt leaching) to the total irrigation water depletion at the river basin scale. Basin efficiency in the base year (1995) is calculated as the ratio of the net irrigation water demand (MRWD, Equation 25) to the total irrigation water depletion estimated from records. It is assumed that basin efficiency in future years will increase at a prescribed rate in a basin, depending on water infrastructure investment and water management improvement in the basin.

The projection of irrigation water demand depends on the changes in irrigated area and cropping patterns, water use efficiency, and rainfall harvest technology. Global climate change can also affect future irrigation water demand through temperature and precipitation change, but is not considered in the current modeling framework.

Livestock water demand

Livestock water demand (*LVWD)* in the base year is estimated based on livestock production (QS_{lv}) and water consumptive use per unit of livestock production w_{lv} (beef, milk, pork, poultry, eggs, sheep and goats, and aquaculture fish production). For all of the livestock products except fish, it is assumed that the projection of livestock water demand in each basin, country or region follows the same growth rate of livestock production. Then livestock water demand is determined as a linear function of livestock production, assuming no change in w_{lv} as

$$LVWD = QS_{lv} \cdot w_{lv} \tag{27}$$

The water demand for fish production is assumed to grow at the weighted average of livestock water demand growth.

Industrial water demand

Projection of industrial water demand (INWD) depends on income (gross domestic production per capita, or GDPC) and water use technology improvement. A linear relationship between industrial water demand intensity (IWDI) per cubic meter of water per $1,000 GDP, GDP per capita and a time variable (T) is estimated by regression based on historical records (Shiklomanov 1999) for industrial water consumption (World Bank. 1998) and adjusted according to our perspectives on future industrial water demand in different regions and countries:

$$IWDI = \alpha + \beta \cdot GDPC + \gamma \cdot T \tag{28}$$

in which α is the intercept; ß is the income coefficient, reflecting how industrial water use intensity changes with GDPC; and γ is the time coefficient, mainly reflecting the change of water use technology with technology change. It is found that $\alpha>0$, $\partial IWDI/\partial GDPC = \beta < 0$, and $\partial IWDI/\partial T = \gamma < 0$ for all basins and countries, which shows that in future years, the industrial water use intensity will reduce with the GDPC and *T* (*T* = 95 for 1995; 100 for 2000; and so on).

Domestic water demand

Domestic water demand (DOWD) includes municipal water demand and rural domestic water demand. Domestic water demand in the base year is estimated based on the same sources and method as those used for industrial water demand assessment. Domestic water demands in future years are projected based on projections of population and income growth. In each country or basin, income elasticities (η) of demand for domestic use are synthesized based on the literature and available estimates. These elasticities of demand measure the propensity to consume water with respect to increases in per capita income. The elasticities utilized are defined to capture both direct income effects and conservation of domestic water use through technological and management change. The annual growth rate of domestic water dema ϕ_{dwd} s a function of the growth rate of populat(ϕ_{pop}) nd that of income (GDPC, ϕ_{gdpc}), as

$$\phi_{dwd} = \phi_{pop} + \eta.\phi_{gdpc} \tag{29}$$

where $\partial\phi_{dwd}/\partial\phi_{gdpc} = \eta < 0$ implies that per capita domestic water demand will actually decline with income growth, which happens with some developed countries where current per capita domestic water consumption is high; and $\partial\phi_{dwd}/\partial\phi_{gdpc} = \eta > 0$ implies that per capita domestic water demand increases with income growth, which happens in all developing countries.

Committed flow for environmental, ecological and navigational uses

In the modeling framework here, committed flow is specified as a percentage of average annual runoff. Data is lacking on this variable for most basins and countries, so an iterative procedure is used to specify this variable where data is lacking. The base value for committed flows is assumed to be 10%, with additional increments of 20-30% if navigation requirements are significant (for example, Yangtze River basin); 10-15% if environmental reservation is significant, as in most developed countries; and 5-10% for arid and semi-arid regions where ecological requirements, such as salt leaching, are high (for example, Central Asia). The estimated values for committed flows are then calibrated for the base year relative to basin inflow, outflow and consumptive use.

Demand for water withdrawals

Offstream water demand items described above are all expressed in terms of water depletion/consumption. The demand for water withdrawal (DWW) is calculated as total water depletion demand (DWP) divided by the water depletion coefficient (DC):

$$DWW = DWP / DC = (IRWD + INWD + DOWD + LVWD) / DC \tag{30}$$

The value of the water depletion coefficient in the context of the river basin mainly depends on the relative fraction of agricultural and nonagricultural water use (that is, larger agricultural water use corresponds to a higher value of DC), as well as water conveyance/distribution/recycling systems and pollution discharge and treatment facilities.

Price impact on water demand

A classic Cobb-Douglas function is used to specify the relationship between water demand (W) and water price (P), based on price elasticity (ξ):

$$W = W_0.\left(\frac{P}{P_0}\right)^{\xi} \tag{31}$$

where W_0 and P_0 represent a baseline water demand and water price, respectively. This relationship is applied to agricultural, industrial and domestic sectors, with price elasticity (ξ) estimated for each of the sectors.

Committed flow for environmental, ecological and navigational uses

In the modeling framework here, committed flow is specified as a percentage of average annual runoff. Data is lacking on this variable for most basins and countries, so an iterative procedure is used to specify it. The base value for committed flows is assumed to be 10%, with additional increments of 20-30% if navigation requirements are significant (for example, the Yangtze River Basin); 10-15% if environmental reservation is significant, as in most developed countries; and 5-10% for arid and semi-arid regions where ecological requirements, such as salt leaching, are high (for example, Central Asia). The estimated values for committed flows are then calibrated for the base year relative to basin inflow, outflow and consumptive use.

Water supply

Assuming minimum environmental and ecological flow requirements as a predetermined hard constraint in water supply, we focus on the determination of offstream water supply for domestic, industrial, livestock and irrigation sectors. Two steps are undertaken to determine offstream water supply by sectors. The first is to determine the total water supply represented as depletion/consumption (WDP) in each month of a year; and the second is to allocate the total to different sectors. In particular, irrigation water supply is further allocated to different crops in the basin.

To determine the total amount of water available for various offstream uses in a basin, hydrologic processes such as precipitation, evapotranspiration and runoff are taken into account to assess total renewable water (TRW). Moreover, anthropogenic impacts are combined to define the fraction of the total renewable water that can be used. These impacts can be classified into (1) water demands; (2) flow regulation through storage, flow diversion and groundwater pumping; (3) water pollution and other water losses (sinks); and (4) water allocation policies, such as committed flows for environmental purposes, or water transfers from agricultural to municipal and industrial uses. Therefore, water supply is calculated based on both hydrologic processes and anthropogenic impacts through the model, including the relationships listed above.

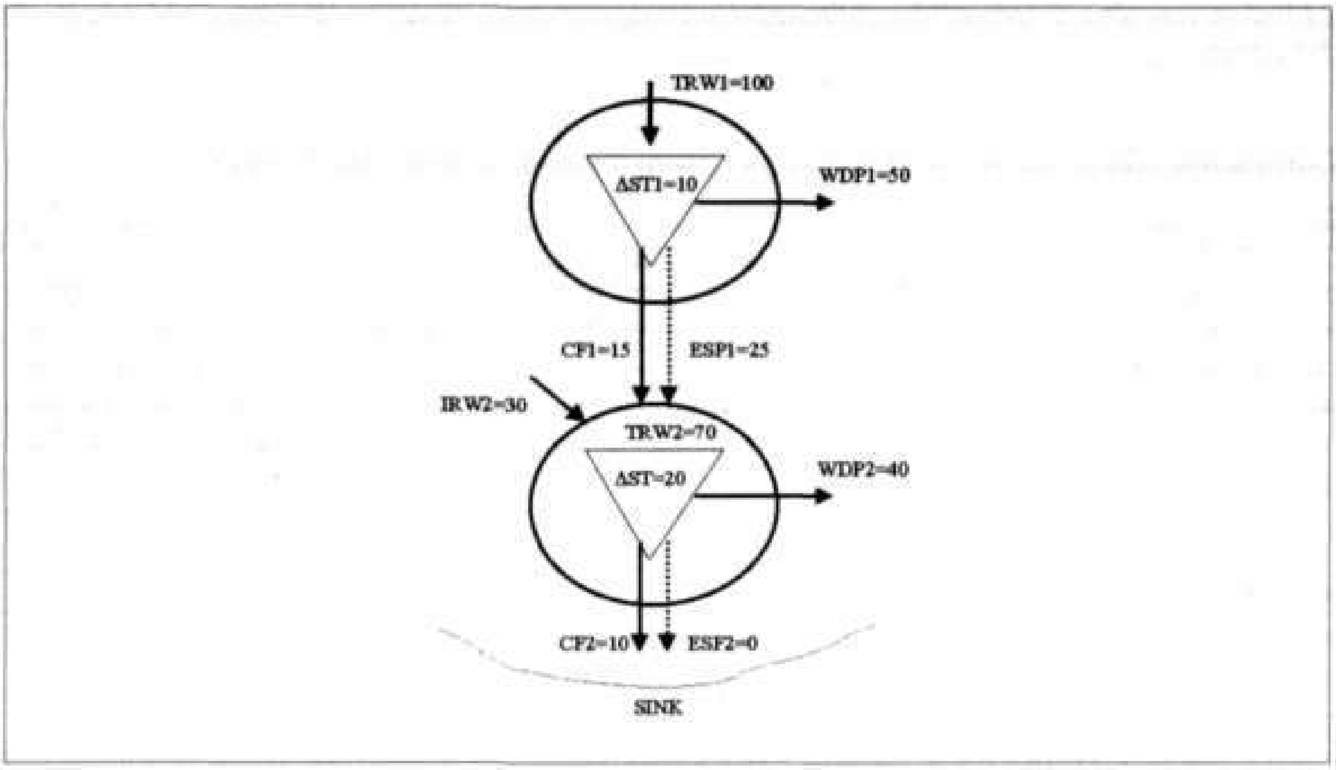
A simple network with a two-basin framework can be used as an example (Figure 2.3). Water availability in the downstream basin depends on the rainfall drainage in the basin and the inflow from the upstream basin(s). Then surface water balance at the basin scale can be represented as:

$$ST^t - ST^{t-1} = ROFF^t + INF^t + OS^t - SWDP^t - RL^t - EL^t \quad (32)$$

in which t is the modeling time interval; *ROFF* is the rainfall drainage in the basin, *ST* is the change of basin reservoir storage; *INF* is the inflow from other basin (s); *OS* represents other sources entering the water supply system, such as desalinized water; *RL* is the total release, including the committed instream flow and spill in flooding periods; *EL* is the evaporation loss (mainly from surface reservoir surface); and *SWDP* is the total water depletion from surface water sources, which is equal to water withdrawal minus return flow. *SWDP* is determined from this water balance equation, with an upper bound constrained by surface maximum allowed water withdrawal (*SMAWW*) as:

$$\sum_t GWDP^t \; I \; DC \leq GMAWW \quad (33)$$

Figure 2.3 Connected flow among river basins, countries and regions.



Source: Authors' assessments.

Notes: TRW indicates total renewable water; IRW, internal renewable water; WDP, water consumption; CF, committed flow; ESP, excess spill; and ΔST, storage change.

Depletion from the groundwater source *(GWDP)* is constrained by maximum allowed water withdrawal from groundwater (GMAWW):

$$\sum_t GWDP^t / DC \leq GMAWW$$

The estimation of SMAWW and *GMAWW* in the base year (1995) is based on the actual annual water withdrawal and annual groundwater pumping in 1995 (WRI 2000). Projections of SMAWW and *GMAWW* are based on assumptions on future surface and ground water development in different countries and regions. In particular, the projection of GMAWW is based on historic pumping and potential groundwater source (measured by groundwater recharge).

A traditional reservoir operation model is developed, including all of the above relationships of natural water availability, storage regulation, withdrawal capacity, and committed flow requirement. The model is formulated as an optimization model. The model is run for individual years with month as the time period. The objective is to maximize the reliability of water supply (that is, ratio of water supply over demand, less or equal to 1.0), as

$$\max \left[\frac{\sum_t (SWDP^t + GWDP^t)}{\sum_t \left(DOWD^t + INWD^t + LVWD^t + IRWD^t\right)} + \omega \cdot \min_t \left(\frac{SWDP^t + GWDP^t}{DOWD^t + INWD^t + LVWD^t + IRWD^t} \right) \right] \quad (35)$$

and as can be seen, the objective function also drives the water application according to the water demand in crop growth stages (months) by maximizing the minimum ratio among time periods (12 months). The weight item ω is determined by trial and error until water supply is distributed to months approximately proportional to monthly water demand.

Once the model solves for total water that could be depleted in each month ($SWDP^t$ and $GWDP^t$) for various off-stream uses under the constraints described above, the next step is to determine water supply for different sectors. Assuming domestic water demand is satisfied first, followed in priority by industrial and livestock water demand, irrigation water supply is the residual claimant. Monthly non-irrigation water demands are calculated based on their annual value multiplied by monthly distribution coefficients. Water supply represented in depletion for different sectors is calculated as:

$$\begin{aligned} WDPDO^t &= \min(DOWD^t,\ SWDP^t + GWDP^t) \\ WDPIN^t &= \min(INWD^t,\ SWDP^t + GWDP^t - WDPDO^t) \\ WDPLV^t &= \min(LVWD^t,\ SWDP^t + GWDP^t - WDPDO^t - WDPIN^t) \text{ and} \\ WDIR^t &= \min(IRWD^t,\ SWDP^t + GWDP^t - WDPDO^t - WDPIN^t - WDPLV^t) \end{aligned} \tag{36}$$

Finally, total water available for crop evapotranspiration *(TNIW)* is calculated by introducing the basin efficiency *(BE)* for irrigation systems and discount of salinity leaching requirement, that is,

$$TNIW^t = BE \cdot WDIR^t / (1 + LR) \tag{37}$$

Total evapotranspiration *(TET)* can be further allocated to crops according to crop irrigation water demand, yield response to water stress (ky), and average crop price (P_c) for each of the major crops considered in a basin, including rice, wheat, maize, other grains, soybeans, potato, sweet potato, and roots and tubers.

The allocation fraction is defined as:

$$\pi^{i,t} = \frac{ALLO^{i,t}}{\sum_{cp} ALLO^{i,t}} \text{ and,} \tag{38}$$

$$ALLO^i = AI^i \cdot ky^i \left[1 - PE^{i,t} / ETM^{i,t}\right] \cdot PC^i \tag{39}$$

in which $ETM^{cp,t} = ET_0^{cp.t} \bullet kc^{cp.t}$ is the maximum crop evapotranspiration; π is a scaled number in the range of (0,1) and the sum of overall crops is set to equal 1. The effective water supply allocated to each crop is then calculated by

$$NIW^{i,t} = TNIW^t \cdot \pi^{i,t} \tag{40}$$

Thus, irrigation water is allocated based on profitability of the crop, sensitivity to water stress, and irrigation water demand (total demand minus effective rainfall) of the crop. Higher priority is given to the crops with higher profitability, which are more drought sensitive and/or that require more irrigation water.

Effective rainfall

Effective rainfall *(PE)* depends on total rainfall *(PT),* previous soil moisture content (SM_o), maximum crop evapotranspiration (ETM) and soil characteristics (hydraulic conductivity *K,* moisture content at field capacity Z_s, and others). *PE* is calculated by an SCS method (USDA SCS 1967), given *PT, ETM,* and effective soil water storage:

$$PE^{cp,st} = f\ (1.253PT^{st\ 0.824} - 2.935)\ 10^{(0.001ETM\ CP.M)} \quad (41)$$

in which f is the correction factor that depends on the depth of irrigation, that is,

$$f - 1.0 \text{ if depth of irrigation per application, } DI \text{, is 75mm,} \quad (42)$$

$$f = 0.133 + 0.201 * \ln (Da) \text{ if } DI\text{<75mm per application, and} \quad (43)$$

$$f = 0.946 + 0.00073 * Da \text{ if } DI\text{>75mm per application.} \quad (44)$$

Depth of irrigation application is 75mm to 100mm for irrigated land, and 150-200mm for rainfed land. If this results in *PE* greater than ET_m or *PT, PE* equals the minimum of ET_m or *PT.* When *PT*< 12.5mm, *PE = PT.*

Global precipitation grids (half degree) (1961-1990, monthly data) from the University of East Anglia are used to extract the total rainfall on the cropland in IMPACT regions/countries/basins. With crop-wise ET_m and total rainfall, crop-wise monthly effective rainfall (time series over 30 years) is calculated by the SCS method described above.

Moreover, the effective rainfall for crop growth can be increased through rainfall harvesting technology. Rainfall harvesting is the capture, diversion and storage of rainwater for plant irrigation and other uses, and can be an effective water conservation tool, especially in arid and semi-arid regions. Water harvesting can provide farmers with improved water availability, increased soil fertility and higher crop production in some local and regional ecosystems, and can also provide broader environmental benefits through reduced soil erosion. Although improved water harvesting is often considered in connection with traditional agriculture, it also has potential in highly developed agriculture. Advanced tillage practices can also increase the share of rainfall that goes to infiltration and evapotranspiration. Contour plowing, which is typically a soil-preserving technique, should also act to detain and infiltrate a higher share of the precipitation. Precision leveling can also lead to greater relative infiltration, and therefore a higher percentage of effective rainfall. A coefficient $(\lambda, \lambda > 1)$ is used to reflect the addition of effective rainfall from rainfall harvesting at various levels:

$$PE^{*CP.ST} = \lambda \cdot PE^{cp.st} \quad (45)$$

Model implementation

The model implementation procedure is shown in Box 2.1. The model is applied for a monthly water balance within one year. It is run through a series of years by solving individual years in sequence and connecting the outputs from year to year. The time series of climate parameters are derived based on historical records of 1961-1990. In addition to a basic scenario that overlays the single historic time series over the 1995-2025 projection period, a number of scenarios of hydrologic time series can be generated by changing the sequence of the yearly records. Water supply uncertainty from various hydrologic levels can then be identified from the statistics of multiple hydrologic scenarios.

The closing storage of one year is taken as the initial storage of the next year, with assumed initial water storage for the base year. For those basins that have large storage, interyear flow regulation is active in this modeling framework.

Water demand for non-irrigation sectors (*DOWD, INWD* and *LVWD)* is updated year by year (see Equations 27, 28 and 29). Infrastructure is updated by projections of reservoir storage, water use efficiency, and maximum allowed water withdrawal (*MAWW*).

Box 2.1 Model implementation procedure.

Base Year (such as 1995)

For each group *i* of (group 1 .. group5)

For each individual/aggregated basin *j* in group *i*

Given water demand and supply parameters in the base year

(including estimated initial reservoir storage and external inflow)

Solve WSM for water supply

Calculate outflow from basin *j*

End of group *i*

End of all groups

Projected years (such as 1996-2025)

For each year *k* of (1996-2025)

For each group *i* of (group 1 .. group 5)

For each individual/aggregated basin *j* in group *i*

Update water demand and supply parameters, including initial reservoir storage from the end of *year k-1,* and inflow from other units in the groups previously solved (for group 1, inflow is equal to 0)

Solve WSM for water supply

Calculate outflow basin ;'

End of group *i*

End of all groups in year *k*

End of all years

The model is run for individual basins, but with interbasin/internation flow simulated. The outflow (*RL*) from one basin becomes a source to downstream basins, which is important to many international river basins such as the Nile (Sudan, Ethiopia, Egypt, Uganda, Burundi, Tanzania, Kenya, Zaire and Rwanda); the Mekong (China, Laos, Burma, Thailand, Cambodia and Vietnam); the Indus (Pakistan, India, Afghanistan and China); the Ganges-Brahmaputra (China, India, Bangladesh, Bhutan, and Nepal); the Amazon (Brazil, Peru, Bolivia, Colombia, Ecuador, Venezuela and Guyana); the Danube (Romania, Yugoslavia, Hungry, Albania, Italy, Austria, Czechoslovakia, Germany, Russia, Poland, Bulgaria and Switzerland); the Niger (Mali, Nigeria, Niger, Algeria, Guinea, Chad, Cameroon, Burkina Faso, Benin and Cote D'lvoire); the Tigris-Euphrates (Iraq, Iran, Turkey and Syria); and the Rio Grande (United States and Mexico).

To trace the flow connection between major international river basins, we classify the 69 basins or aggregated basins (see Figure 2.2) into five groups according to the flow direction between those basins:

Group 1: without upstream inflow,
Group 2: with upstream inflow only from Group 1,
Group 3: with upstream inflow from Group 2, and with/inflow from Group 1,
Group 4: with upstream inflow from Group 3 and with/ inflow from Group 1 and 2, and
Group 5: with upstream inflow from Group 4 and with/ inflow from Group 1, 2 and 3.

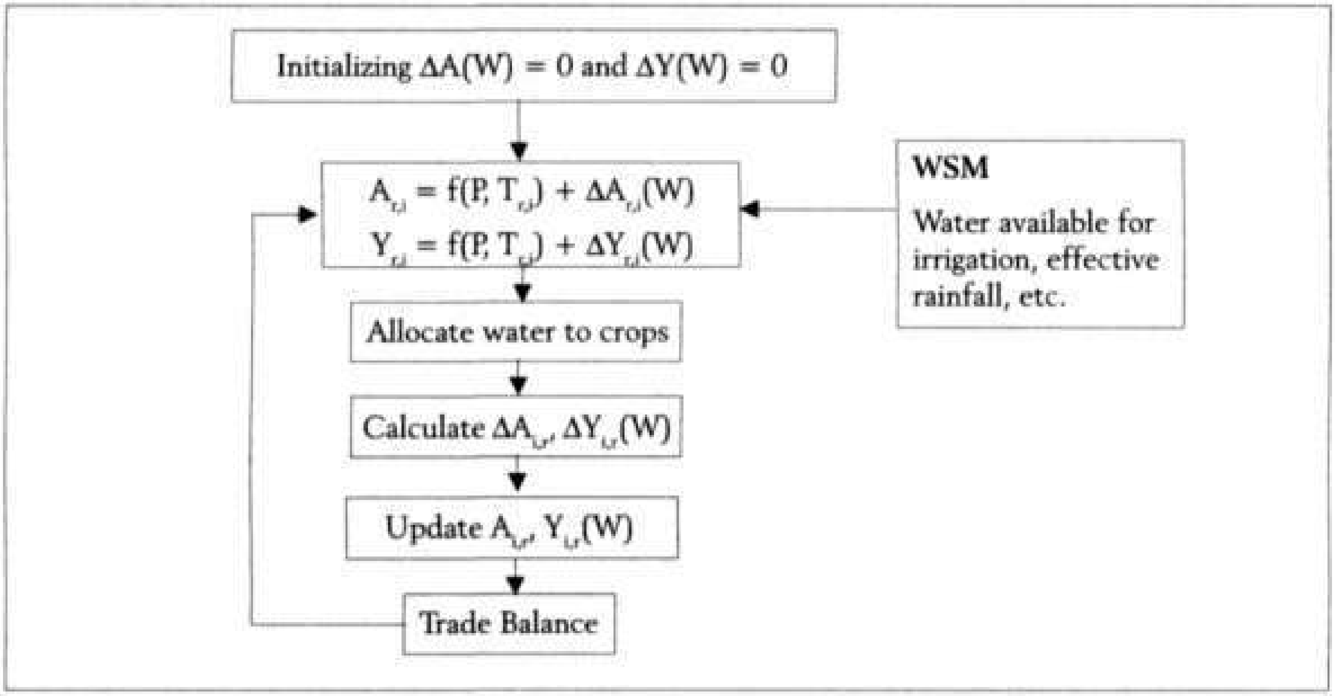
Group 1, without any inflow, is first solved; and then Group 2, with inflow from one or more basins of Group 1, and so on. One group is ready to be solved with inflows from all the groups that have flow release to basins in the current group. The implementation of this spatial connection allows the model to deal with water transfer between basins and water sharing in international river basins.

Connecting IMPACT and WSM

The WSM calculates effective irrigation water supply in each basin by crop and by period *($NIW^{i,t}$)*, over a 30-year time horizon. The results from the WSM are then incorporated into IMPACT for simulating food production, demand and trade.

Figure 2.4 shows the flow chart of the IMPACT-WATER program. For each year, initially, it is assumed that there is no water shortage; $\Delta AC(W)$ and $\Delta YC(W)$ are zero; and crop area harvested and crop yields are determined based on price, labor, fertilizer, other inputs, and technological change. Then water availability for crops is computed, $\Delta AC(W)$ and $\Delta YC(W)$ are calculated, and crop area (A) and yield (Y) are updated, based on Equations 37-38. Next, crop production and stock are updated, and net food trade and the global trade balance calculated (global net trade should equal zero). If the trade balance is violated, then crop prices are adjusted, and the model undertakes a new iteration. The loop stops when net trade equals zero. Thus, crop area and yield are determined endogenously based on water availability, price and other agricultural inputs.

Figure 2.4. Flow chart of the IMPACT-WATER Program.



Source: Compiled by authors.

Input data

Extensive data are required for the IMPACT-WATER modeling framework. The information is drawn from highly disparate databases and requires an interdisciplinary and international collaboration of professionals in agronomy, economics, engineering and public policy. Table 2.1 describes the major data and their sources, which are classified as water supply infrastructure, hydrology, agronomy, crop production, non-irrigation water demand, and water policies. The data have been prepared for river basins (in

China, India and the United States) and countries and regions. Some data have been estimated for a 30-year time horizon including precipitation, runoff and evapotranspiration; other data are calibrated for the base year and are then determined by the model for future years (including irrigated and rainfed crop area and yield, and crop area and yield reduction from water shortages). As indicated above and in Table 2.1, some data came directly from other sources, some are treated based on other sources, and some are estimated according to related literature.

Table 2.1 Input data.

Category	Details	Sources
Infrastructure	Reservoir storage	ICOLD (1998)
	Withdrawal capacity	WRI (2000); Gleick (1993)
	Groundwater pumping capacity	WRI (2000)
	Water distribution, use and recycling situation	Scenario Development Panel, World Water Vision
Hydrology	Watershed delineation	WRI
	Precipitation	CRU (1998)
	Potential evapotranspiration	Alcamo et al. (2000)
	Runoff	Alcamo et al. (2000)
	Groundwater recharge	WRI (2000); Gleick (1999)
	Committed flow	Authors' assessments
	Water pollution (salinity)	Authors' assessments
Agronomy	Crop growth stages	Rice provided by FAO; wheat and maize by CIMMYT; and other crops by USDA
	Crop evapotranspiration coefficient (k_c)	FAO (1998); Doorenbos and Kassam (1979)
	Yield-water response coefficient (k_y)	FAO (1998); Doorenbos and Pruitt (1977)
Crop production	Irrigated and rainfed area (baseline): actual harvested and potential	FAO (1999); Cai (1999)
	Irrigated and rainfed yield (baseline): actual and potential	FAO (1999); Cai (1999)
Non-irrigation water demand	Industry	Shiklomanov (1999) for the Scenario Development Panel, World Water Vision
	Domestic	Shiklomanov (1999) for the Scenario Development Panel, World Water Vision
	Livestock	Mancl (1994); Beckett and Oltjen (1993); FAO (1986)
Water policies	Committed flows	Authors' assessments
	Water demand growth	Authors' assessments
	International water-sharing agreements	Authors' assessments based on WRI (2000)
	Investment	Authors' assessments

Source: Compiled by authors.

Notes: CIMMYT is the International Wheat and Maize Improvement Center; FAO, the Food and Agriculture Organization of the United Nations; ICOLD, International Commission on Large Dams; WRI, World Resources Institute; and USDA, the United States Department of Agriculture.

Geographic Information Systems (GIS) and other methods are used to treat these parameters. For example, original hydrologic data are represented in a grid, and a GIS program is used to extract the value and aggregate grids into IMPACT spatial units. Other data are given in smaller spatial units (such as for China, the United States, and districts in India), and the GIS program is applied to overlay the data at the smaller scales. Many other intermediate programs were developed to estimate the required data or transfer the original data to the format required by the models. Data required for agricultural modeling by IMPACT are described in Rosegrant et al. (2001).

The water demand and supply parameters used in the IMPACT-WATER model have been described in detail by Rosegrant et al. (2002b).

2.2 Data requirement for the addition of new commodities into the IMPACT-WATER model - *Siet Meijer*

The model

The IMPACT-WATER model links the IMPACT model and the Water Simulation model by connecting water demand and supply components to food production, demand and trade components. The water simulation model is based on a river basin approach. See also the book *World Water and Food to 2025: Dealing with Scarcity* by Rosegrant et al. (2002b). This is available online at http://www.ifpri.org/pubs/books/water2025/water2025.pdf or a free hardcopy can be ordered at: http://www.ifpri.org/pubs/books/water2025book.htm

The data that is required to include new commodities in the IMPACT-WATER model, in addition to the data requirements already described for the IMPACT model in Section 1.2, are outlined below. Please note that while the extended IMPACT model covers 32 commodities, the IMPACT-WATER model at this stage covers 16 commodities, and only the 8 crops (wheat, rice, maize, other coarse grains, potatoes, sweet potatoes and yams, cassava & other roots and tubers, and soybeans) are submitted to a water function. However, while IMPACT consists of 36 countries and regions, the IMPACT-WATER model includes 69 spatial units, as certain regions (US, India and China) with intensive water use are subdivided by major basins.

It is also important to remember that most of the input data reported below is additional input data compared to the IMPACT model, except for the area and yield functions for the crops. In the IMPACT-WATER model this data is split up into irrigated and rainfed area and yield, and for both area and yield the actual and potential values are given.

Below are in short the required input data for the water parameters in the model. A more detailed description of these components can be found in *World Water and Food to 2025: Dealing with Scarcity* (Rosegrant et al. 2002b).

Infrastructure

Reservoir storage
Withdrawal capacity
Groundwater pumping capacity
Water distribution, use and recycling situation

Hydrology

Watershed delineation
Precipitation
Potential evapotranspiration
Runoff
Groundwater recharge
Committed flow
Water pollution (salinity)

Agronomy

Crop growth stages
Crop evapotranspiration coefficients (kc)
Yield-water response coefficients (ky)

Crop production

Irrigated and rainfed area: actual harvested and potential area
Irrigated and rainfed yield: actual and potential yield

Non-irrigated water demand

Industry
Domestic, rural and urban
Livestock

Water policies

Committed flows
Water demand growth
International water sharing agreements
Investment

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2.3 Lecture notes - *Siet Meijer*

IMPACT-WATER Model

Overview of the presentation

- Introduction to the basics of the IMPACT-WATER Model
- Equations of the IMPACT-WATER Model
- Linking the IMPACT and IMPACT-WATER Model
- Scenario reasoning
- IMPACT-WATER projection results to 2025 under baseline and alternative scenarios

IMPACT + WSM = IMPACT-WATER

- IMPACT-WATER combines:
  - IMPACT 'Food' Model
  - Water Simulation Model

This extension of IMPACT 'Food' is established through global water databases obtained from:

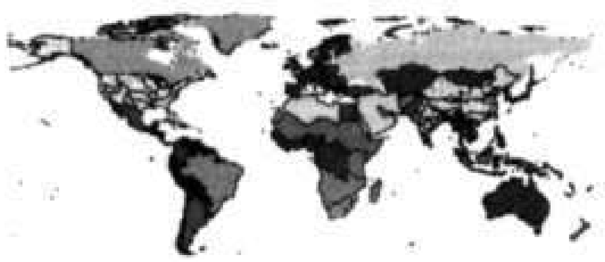
- Global water models
- Integrated basin management studies
- Field water management studies
- Crop water modeling studies

Water scarcity and food security: a global perspective

Research Objectives

- To develop an understanding, on a global basis, of the relationships between water scarcity, food production, and food security
- To assess the impact of alternative scenarios for water availability on food supply, demand, trade, and food security
  - taking into account water policy reforms, and
  - investment in water/irrigation management and development

IMPACT-WATER Model Spatial Unite



69 countries, regions and basins (for China, India and the US)

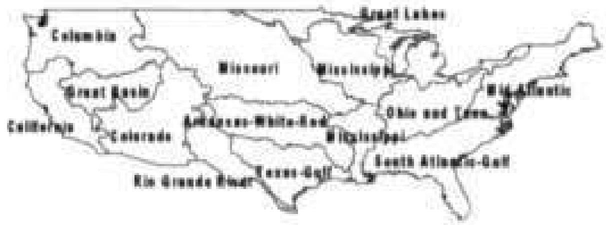
IMPACT-WATER Model Spatial Units of India

IMPACT-WATER Model

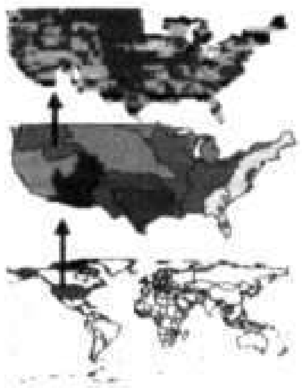
Spatial Units of China

IMPACT-WATER Model

Spatial Units of US



GIS representation



Crop area
ex. wheat

Watersheds

World Map

Water Simulation Model

Impact-WATER methodology

The Water Simulation Model (WSM) simulates effective water for irrigation and rainfed production based on climate parameters, infrastructure and policy inputs, considering

- aggregate storage and water demands at the basin scale and year-to-year storage transfers,
- monthly water balance with storage regulation and committed flow constraints, and
- water supply and demand calibrated by spatial units In the base year.

Water Demand

Water demand

Water Demand for Different Sectors

irrigation Water Demand = f(Irrigated Area, ET, Irrigation Efficiency. Water Price)

Livestock Water Demand - f(Livestock Population, Water Demand per Animal, Water Price)

Industrial Water Demand = f(GNP. Water Use Intensity. Technological Change, Water Price)

Domestic Water Demand = f(income per Capita, Population, Technological Change, Water Price)

Net crop water demand

Net crop water demand (NCWD) in a basin in a year is calculated based on an empirical crop water requirement function

$$NCWD = \sum_{cp}\sum_{ct} Kc^{cp,st} \cdot ET^{ct} \cdot A^{cp} = \sum_{cp}\sum_{ct} ETM^{ct,cp} \cdot A^{cp}$$

in which cp is the index of crops, *ct* is the index of crop growth stages, ET_0 *i*s the reference evapotranspiration, *kc* is the crop coefficient, and *A* is the crop area.

Net irrigation water demand

The net irrigation water demand *(NIRWD),* with consideration of effective rainfall use and salt leaching requirement, is then:

$$NIRWD = \sum_{cp}\sum_{st} (kc^{cp,st} \cdot ET^{ST} - PE^{cp,st})\ AI^{cp} \cdot (1 + LR)$$

where Ai is the irrigated area and LR is the salt leaching factor, which is characterized by soil salinity and irrigation water salinity.

Total water demand

Total Irrigation water demand represented in water depletion *(IRWD)* is calculated as:

$$IRWD = NIRWDIBE$$

in which BE is defined as basin efficiency.

Livestock water demand

Livestock water demand *(LVWD)* In the base year is estimated based on livestock production (QS_{lv}) and water consumptive use per unit of livestock production (w_{lv}).

$$LVWD = QS_{lv} \cdot W_{lv}$$

Industrial water demand

Projection of industrial water demand depends on income and water use technology improvement.

$$IWDI = \alpha + \beta \cdot GDPC + \gamma \cdot T$$

In which *a* is the Intercept; *I)* is the income coefficient, reflecting how Industrial water use intensity changes with *GDPC,* and > is the time coefficient, mainly reflecting the change of water use technology with technology change

Domestic water demand

Domestic water demand (DOWD) includes municipal water demand and rural domestic water demand.

$$\phi_{dwd} = \phi_{pop} + \eta \cdot \phi_{gdpc}$$

DOWD In 1995 Is estimated based on the same sources and method as those used for industrial water demand assessment. Domestic water demands In future years are projected based on projections of population and income growth.

Environmental water demand

Data is lacking on this variable for most basins and countries, so an Iterative procedure Is used to specify this variable where data is lacking.

Committed flow for the environment is specified as a percentage of average annual runoff.

- The base value: 10 percent
- Additional increments 20-30 percent
- 10-15 percent if environmental reservation is significant, as in most developed countries
- 5-10 percent for arid and semi-arid regions

Demand for water withdrawals

Offstream water demand items described above are all expressed in terms of water depletion/consumption. The demand for water withdrawal is calculated as total water depletion demand (DWP) divided by the water depletion coefficient (DC):

DWW = DWP I DC = (IRWD + INWD + DOWD + LVWD)I DC

Demand for water withdrawals

In the base year, DC is calculated by given water depletion (WDP) and water withdrawal (WITHD), and DC in the future is projected as a function of the fraction of non-irrigation water use:

$$DC = p \cdot \left(\frac{WDPDO + WDPIN + WDPLV}{WDPT}\right)^{\psi}$$

This regression function is made based on historical non-irrigation water depletion and total water depletion in different basins or countries, resulting in regression coefficients p>0, and ψ <0 for all basins and countries

Price impact on water demand

A classic Cobb-Douglas function Is used to specify the relationship between water demand *(W)* and water price (*P*), based on price elasticity (ξ):

$$W = W_o \cdot \left(\frac{P}{P_0}\right)^{\xi}$$

where W_0 and P_0 represent a baseline water demand and water price, respectively. This relationship is applied to agricultural, industrial and domestic sectors, with price elasticity (ξ) estimated for each of the sectors.

Cobb-Douglas Function

When K = capital and L = labor, the production function will be:

$q = f(K, L) = AK^{\alpha} L^{ß}$

Depending on the values of a and *p* this production function will exhibit constant, Increasing or decreasing returns to scale.

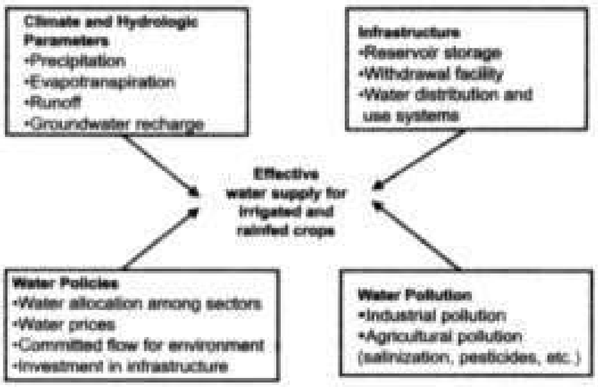
$A(mK)^a \ (mL)^B = m^a + AK^a L^ß = m^{a+ß}$ q. it:

a + ß = 1 constant returns to scale
a + ß >1 increasing returns to scale
a + ß < 1 decreasing returns to scale.
The elasticity ot substitution is 1,

$\sigma = 1$.

Water Supply

Variables influencing agricultural water supply



Determination of off-stream water supply

Two stops are undertaken to determine off-stream water supply by sectors.

- Determining the total water supply represented as depletion/consumption (WDP) in each month of a year, and
- allocating the total to different sectors.

in particular. irrigation water supply is further allocated to different crops in the basin.

Hydrologic impacts on water supply

Hydrologic Impacts:

- Precipitation
- Evapotranspiration
- Runoff
- Groundwater recharge

Anthropogenic impacts on water supply

Anthropogenic **Impacts:**

- Water demands
- Flow regulation through storage, flow diversion and groundwater pumping
- Water pollution and other water losses (sinks)
- Water allocation policies, such as committed flows for environmental purposes, or water transfers from agricultural to municipal and industrial uses.

Surface water balance

A simple network with a two-basin framework can be used as an example. Water availability In the downstream basin depends on the rainfall drainage in the basin and the inflow from the upstream basin(s). Then surface water balance at the basin scale can be represented as:

$$ST^t - ST^{t-1} = ROFF^t + INF^t + OS^t - SWDP^t - RL^t - EL^t$$

Constraints related to these items include that flow release *{RL)* must be equal to or greater than the committed instream flow; monthly reservoir evaporation is calculated based on reservoir surface area, and climate characteristics.

Total water depletion from surface sources

Total water depletion from surface water sources (*SWDP*) is determined from this water balance equation, with an upper bound constrained by surface maximum allowed water withdrawal (*SMAWW*) as:

$$\sum_t SWDP^t \ / \ DC \leq \ SMAWW$$

Water supply

Depletion from the groundwater source (*GWDP*) Is constrained by maximum allowed water withdrawal from groundwater (*GMAWW*):

$$\sum_t GWDP^t \ / \ DC \leq \ GMAWW$$

Reservoir operation model

A traditional reservoir operation model is developed, including all of the above relationships of natural water availability, storage regulation, withdrawal capacity and committed flow requirement. The model is formulated as an optimization model. The model is run for individual years with month as the time period. The objective is to maximize the reliability of water supply (that is, ratio of water supply over demand, less or equal to 1.0), as

$$\max \left[\frac{\sum_t (SWDP^t + GWDP^t)}{\sum_t \left(DOWD^t + INWD^t + LVWD^t + IRWD^t\right)} + \omega \cdot \min_t \left(\frac{SWDP^t + GWDP^t}{DOWD^t + INWD^t + LVWD^t + IRWD^t} \right) \right]$$

Non-irrigation water demand

Monthly non-irrigation water demands are calculated based on their annual value multiplied by monthly distribution coefficients. Water supply represented in depletion for different sectors is calculated as:

$$EFPFO^t = \min\ (DOWD^t\ ,\ SWDP^t + GWDP^t)$$

$$WDPIN^t = \min\ (INWD^t,\ SWDP^t + GWDP^t - WDPDO^t)$$

$$WDPLV^t = \min\ (LVWD^t,\ SWDP^t + GWDP^t - WDPDO^t - WDPIN^t)$$

$$WDIR^t = \min\ (IRWD,\ SWDP^t + GWDP' - WDPDO^t - WDPIN^t - WDPLV^t)$$

Water available for crop evapotranspiration

Finally, total water available for crop evapotranspiration (*TNIW*) is calculated by introducing the basin efficiency (*BE*) for irrigation systems and discount of salinity leaching requirement, that is,

$$TNIW^t = BE\ .\ WDIR^t\ /\ (1 + LR)$$

Definition of basin efficiency

$$BE = \frac{BWC}{WC} = \frac{BWC}{BWC + NBWC}$$

BE	=	basin irrigation efficiency
WC	=	total water consumption
BWC	=	beneficial consumption
NBWC	=	non-beneficial consumption

Water supply allocation

The allocation fraction is defined as:

$$\pi^{i,j} = \frac{ALLO^{i,j}}{\sum_{cp} ALLO^{i,j}}$$ and,

$$ALLO^{t} = AI^{t} \cdot ky^{t} \cdot \left[1 - PE^{i,j} / ETM^{i,j}\right] \cdot PC^{t}$$

in which $ETM^{cp,t} = ET_o{}^{cp,t}\ kc^{cp,t}$ is the maximum crop evapotranspiratlon; *n* is a scaled number In the range of (0,1) and the sum of over all crops is set to equal 1. The effective water supply allocated to each crop is then calculated by

$$NIW^{i,t} = TNIW^{t} \cdot \pi^{i,j}$$

Effective rainfall

Effective rainfall *(PE)* depends on total rainfall (PT), previous soil moisture content (SM_0), maximum crop evapotranspiratlon *(ETM),* and soil characteristics (hydraulic conductivity K, moisture content at field capacity *Z,,* and others). *PE* is calculated by an SCS method (USDA. SCS 1967), given *PT, ETM* and effective soil water storage:

$$PE^{cp,st} = f.\ (1.253PT^{st\ 0.824} - 2.935)10^{(0.001ETM\ cp,st)}$$

Depth of irrigation

in which *f* is the correction factor that depends on the depth of irrigation, that is:

- *f = 1.0 if* depth of irrigation per application, *DI,* is 75mm,
- *f = 0.133 + 0.201*ln (Da) if DI < 75mm* per application, and
- *f = 0.946 + 0.00073* Da* if D*I* > 75mm per application

Depth of irrigation application is 75mm-100mm for irrigated land, and 150mm-200mm for ralnfed land. if the above results in *PE* greater than ET_m or *PT, PE* equals the minimum of ET_m or *PT.* When PT<12.5mm, *PE=PT.*

Global precipitation grids

Global precipitation grids (half degree) (1961–90, monthly data) from the University of East Anglla are used to extract the total rainfall on the crop land in IMPACT regions/countries/basins. With crop-wise ET_m and total rainfall, crop-wise monthly effective rainfall (time series over 30 years) is calculated by the SCS method described above.

Rainfall harvesting technology

A coefficient $(\lambda, \lambda>1)$ is used to reflect the addition of effective rainfall from rainfall harvesting at various levels

$$PE^{*\ cp,st} = \lambda \cdot PE^{cp,st}$$

Definition of water productivity

$$WP_{(kg/m^3)} = \frac{P_{(kg)}}{WC_{(m^3)}}$$

WP = water productivity
P = crop production
WC = water consumption

Definition of water productivity

*WC = f(crop ET, water availability, Irrigation systems, water recycling, etc.)**

$$WC = BWC + NBWC \quad \frac{BWC}{BE}$$

BWC = beneficial consumption
NBWC = non-beneficial consumption
BE = basin Irrigation efficiency

* from Water Simulation Model

Model Implementation

Implementation procedure (1)

Base Year *(such as 1995)*
For each group *I* of (group1 .. group5)
For each individual/aggregated basin *j* in group *i*
Given water demand and supply parameters In the base year
(including estimated initial reservoir storage and external inflow)
Solve WSM for water supply
Calculate outflow from basin *j*
End of group *i*
End of all groups

Implementation procedure

Projected years (such as 1996-2025)
For each year *k* of (1996-2025)
For each group *j* of (group1 .. group5)
For each individual/aggregated basin *j* in group *i*
Update water demand and supply parameters, including initial reservoir storage from the end of *year k-1,* and inflow from other units in the groups previously solved (for group 1, inflow is equal to 0)
Solve WSM for water supply
Calculate outflow basin *j*
End of group *j*
End of all groups In year *k*
End of all years

WSM + IMPACT

=

IMPACT-WATER

Water-food linkages in the model

IMPACT-WATER simulates annual food production, demand, prices and trade for Irrigated and rainfed production, and the agricultural sector model covers 16 commodities

- Food demand = f(prices, income, population)
- Separate area and yield functions for rainfed and irrigated crops
- Crop area and yield functions Including water availability as a variable
- Water allocation among crops

Production, area and yield equations

Production - Area * Yield

Area = A [crop prices, irrigation investment, (beneficial water consumption/ potential evapotransplration)]

Yield = Y [crop prices. input prices, agricultural research Investment, (beneficial water consumption/ potential evapotransplration)]

Crop area and yield water stress relationship

Reduction of ΔYC crop yield is calculated as:

$$\Delta YC = YC^t \cdot ky^t \cdot (1 - ETA^t / ETM^t) \cdot \left[\frac{\min \left((1 - ETA_m^t / ETM_m^t) \right)}{(1 - ETA^t / ETM^t)} \right]^{\beta}$$

in which ß is the coefficient to characterize the penalty Item, which should be estimated based on local water application in crop growth stages and crop yield. Here crop yield reduction is calculated based on seasonal water availability (that is, seasonal ETA), but they are "penalized" if water availability in some crop growth stages (month) is particularly lower than the seasonal level. All other items have been previously defined.

Reduction of harvested crop area

Reduction of crop harvested area is calculated as:

$$\Delta AC^t = 0, \text{ if } \frac{ET_a}{ET_m} > E^t \quad \text{otherwise}$$

$$\Delta AC^t = AC^t \cdot \left[1 - \left(\frac{ETA^t}{ETM^t} / E^{*t} \right) \right] \quad \text{for irrigated areas}$$

$$\Delta AC^t = AC^t \cdot \left[1 - \left(ky^t \cdot \left(1 - \frac{ETA^t}{ETM^t} / E^{*t} \right) \right)^{\gamma} \right] \quad \text{for rainfed areas}$$

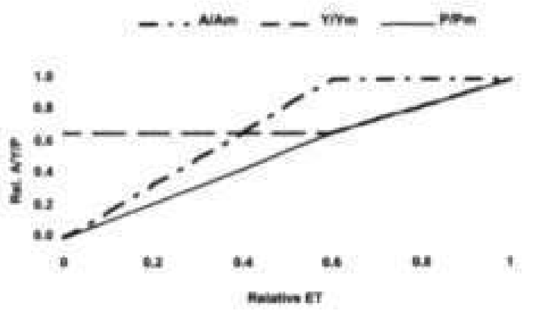
Actual crop evapotransplration

Actual crop evapotransplration (ETA) Includes irrigation water which can be used for crop evapotransplration (*NIW)* and effective rainfall *(PE):*

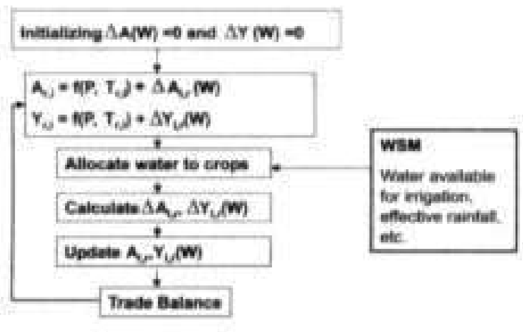
$$ETA^i = NIW^i + PE^i$$

where for rainfed crops, NIW = 0

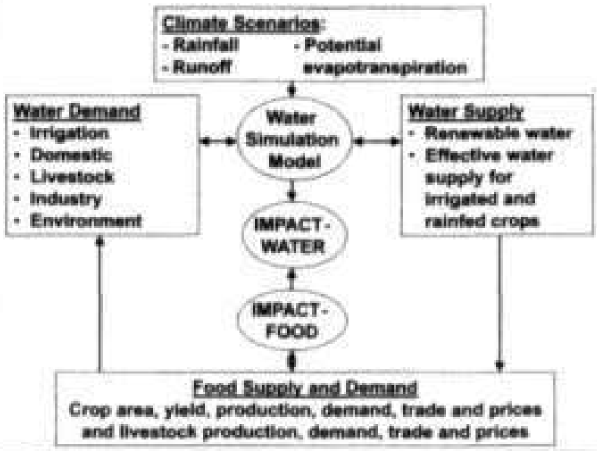
Crop area and yield water stress relationship



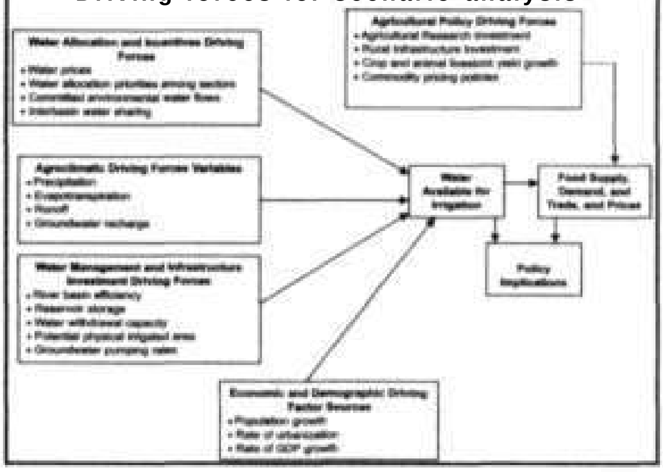
Flow chart of the IMPACT-WATER program



Flow-Chart IMPACT-WATER Model



Driving forces for scenario analysis



Scenario approach

- Three scenarios: Business as usual, water crisis, and sustainable water
- Approach owes Intellectual debt to World Water Vision and Global Studies Group scenarios, but:
  - Limited in time horizon—to 2025
  - Limit changes to underlying policy, management and Investment drivers that directly Influence the water and food sectors
  - Limit the food sector changes to those directly related to water
  - Do not project fundamental changes In values
  - All policy changes postulated directly quantified In model

The business as usual scenario

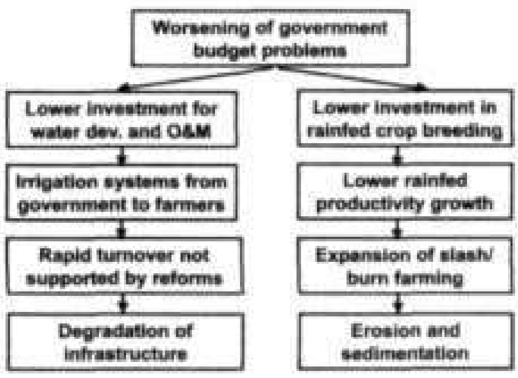
- Assumes continuation of existing trends, meaning:
  - Continued decline in agricultural research investments
  - Limited institutional and management reform
  - Slow harvested area growth rate
  - Production growth primarily through yields
  - Water management efficiency will increase slowly
  - Rainfed agriculture not high priority
  - Investment in irrigation expansion and reservoir storage decline
  - More groundwater pumping
  - Environmental flow — no increase In priority

The business as usual scenario

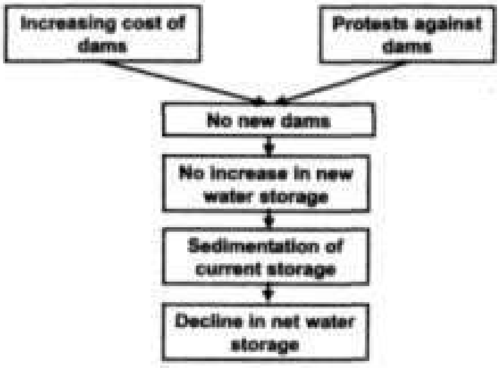
Changes in Key Water Sector Drivers, 1995-2025

Basin Efficiency	+15%
Water Withdrawal Capacity	+23%
Reservoir Storage	+18%
Potential Irrigated Area	+16%

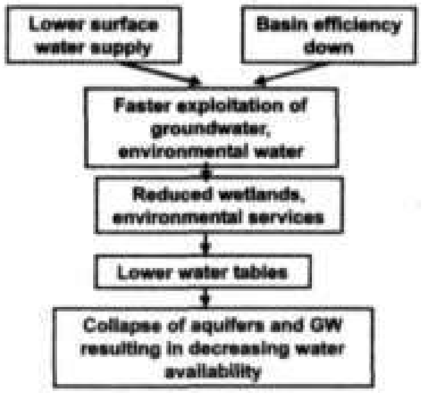
Water crisis scenario



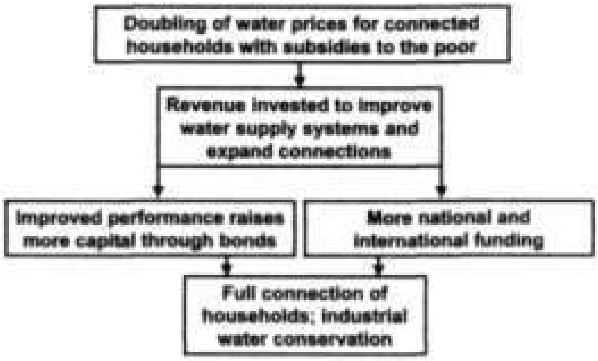
Water crisis scenario



Water crisis scenario



Sustainable water scenario



Scenario assumptions

- Medium UN Population Projections
- Per capita annual GDP growth rates between:
  - 2.1 and 3.4 percent in Latin America
  - 0.8 and 1.7 percent in Sub-Saharan Africa
  - 1.6 and 3.2 percent in West Asia/North Africa
  - 2.1 and 5.2 percent in Asia

Basin efficiency and reservoir storage, 1995-2025, under alternative scenarios

	1995	2025		
		BAU	CRI	SUS
Basin Efficiency	%	% change from 1995		
Developed Countries	0.6	6.3	0.0	11.5
Developing Countries	0.5	8.2	0.0	28.6
World	0.6	7.7	0.0	25.0
Reservoir Storage	km	% change from 1995		
Developed Countries	796	5.5	-5.7	3.4
Developing Countries	2,632	21.9	8.1	10.3
World	3,428	18.1	-1.3	8.7

Maximum allowable water withdrawal, 1995-2025, under alternative scenarios

	1995	2025		
		BAU	CRI	SUS
Surface Water	km^3	% change from 1995		
Developed Countries	976	15.9	27.8	15.9
Developing Countries	2,425	31.8	59.8	31.8
World	3,401	27.2	50.6	27.2
Ground Water	km^3	% change from 1995		
Developed Countries	255	9.0	14.9	4.7
Developing Countries	670	15.4	14.8	-11.3
World	925	13.6	14.8	-6.9

Committed flows for the environment, 1995-2025, under alternative scenarios

- Committed flow for the environment as % of total renewable water:
  - Under SUS committed flow averages between 15-25% higher than under BAU
  - CRI values between 55-65% lower than BAU

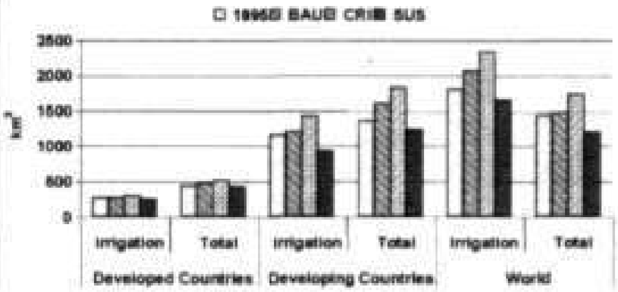
Percentage households with access to piped water, 1995-2025, under alternative scenarios

	1995	2025 BAU	2025 CRI	2025 SUS
Rural Households	% connected			
Developing Countries	29	64	30	100
Developed Countries	89	97	95	100
World	35	66	34	100
Urban Households	% connected			
Developing Countries	76	89	43	100
Developed Countries	99	99	97	100
World	85	92	55	100

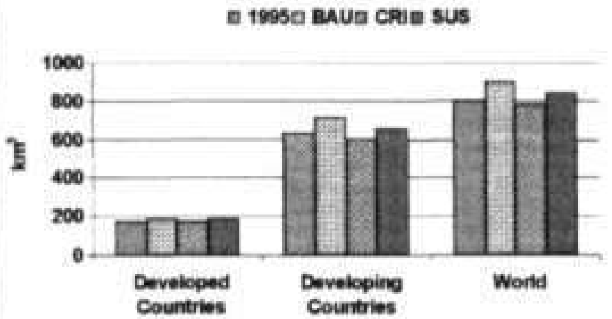
Assumptions on water price changes under CRI and SUS compared to BAU

	CRI	SUS
	% change compared to BAU	
Industrial		
Developed Countries	+25%	+75%
Developing Countries	+50%	+125%
Agricultural		
Developed Countries	0	+100%
Developing Countries	0	+200%
Domestic Connected		
Developed Countries	+25%	+40%
Developing Countries	+50%	+80%
Domestic Unconnected		
Developed Countries	0	0
Developing Countries	0	0

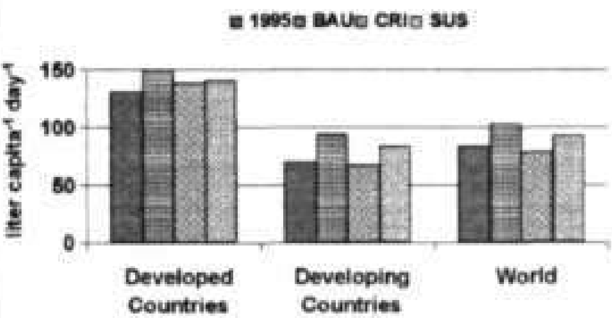
Water consumption, 1995-2025, under alternative scenarios



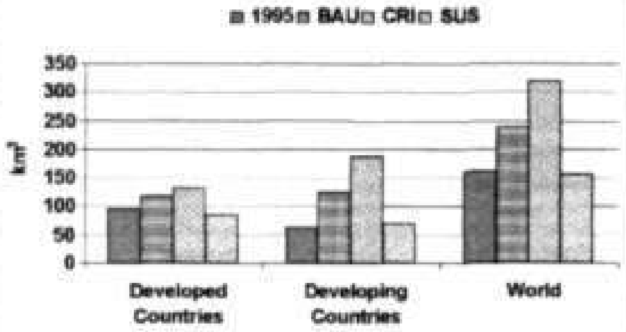
Beneficial irrigation water consumption, 1995-2025, under alternative scenarios



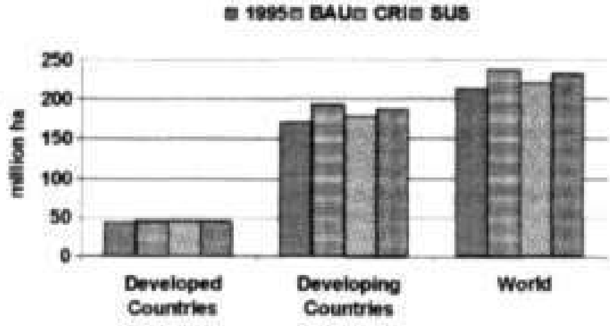
Total per capita domestic water demand, 1995-2025, under alternative scenarios



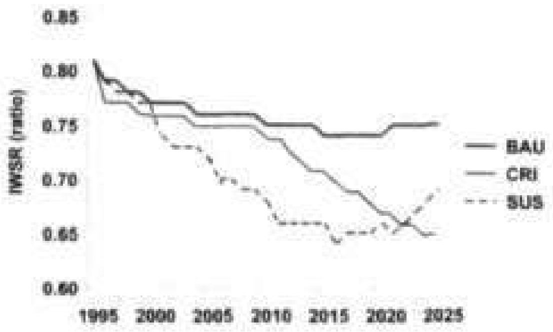
Industrial water demand, 1995-2025 under alternative scenarios



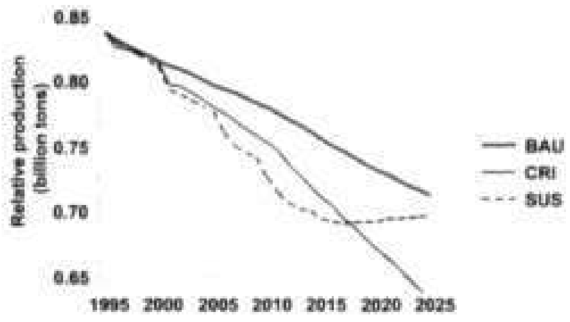
Irrigated cereal area, 1995-2025 under alternative scenarios



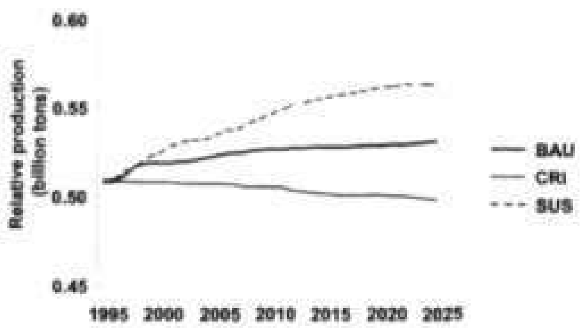
Irrigation water supply reliability index, 1995-2025, under alternative scenarios



Relative global irrigated cereal production, 1995-2025, under alternative scenarios



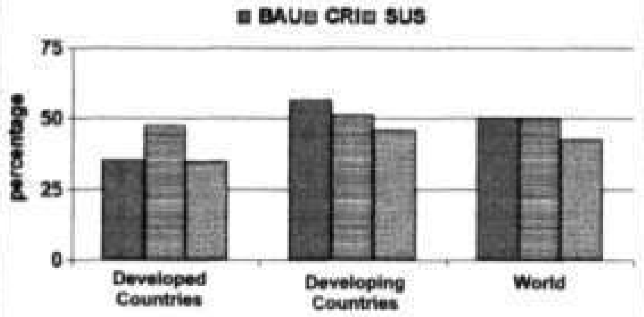
Relative global rainfed cereal production, 1995-2025, under alternative scenarios



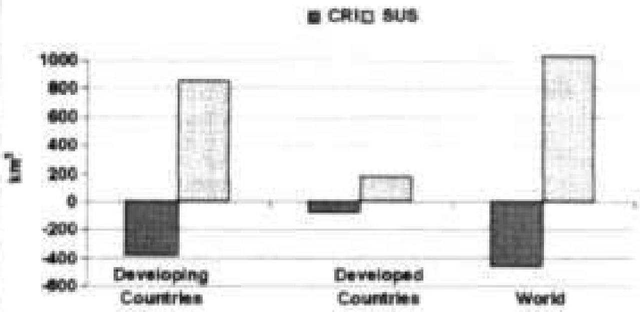
Irrigated and rainfed cereal yield, 1995-2025, under alternative scenarios

	1995	2025		
		BAU	CRI	SUS
Irrigation Yield	kg ha^{-1}	% change from 1995		
Developed Countries	4,439	38.1	29.8	37.2
Developing Countries	3,249	41.6	36.1	37.9
World	3,483	40.3	34.6	37.5
Rainfed Yield	kg ha^{-1}	% change from 1995		
Developed Countries	3,167	25.0	14.8	27.2
Developing Countries	1,806	41.4	35.5	59.4
World	2,179	29.7	20.9	38.4

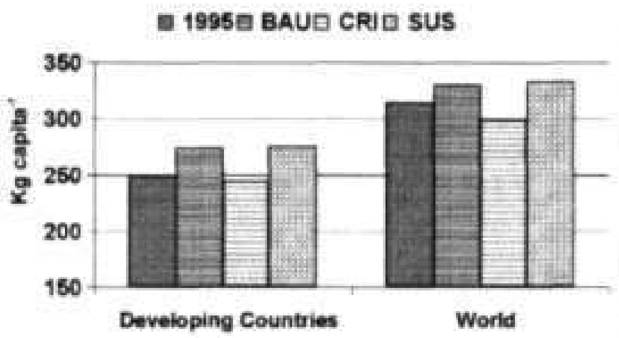
Share of irrigation in total cereal production growth, alternative scenarios



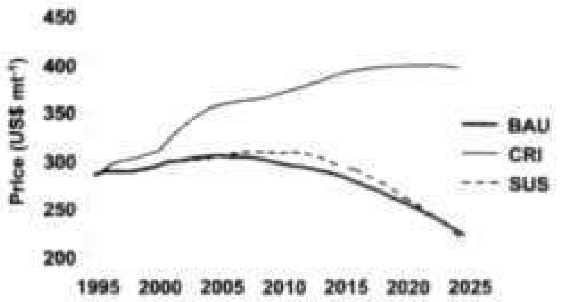
Environmental flows, change compared to business as usual scenario, 2025



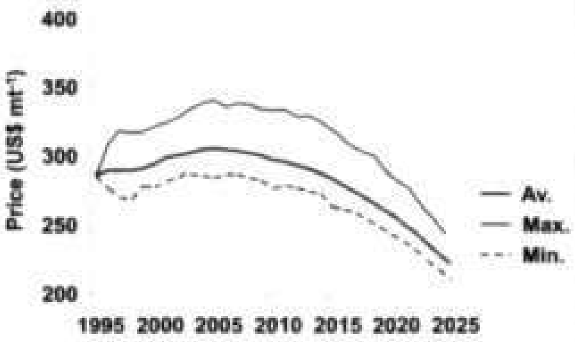
Per capita cereal demand, 1995-2025, under alternative scenarios



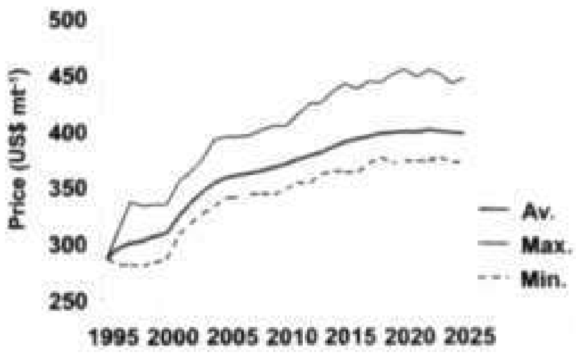
Rice prices, 1995-2025, under alternative scenarios



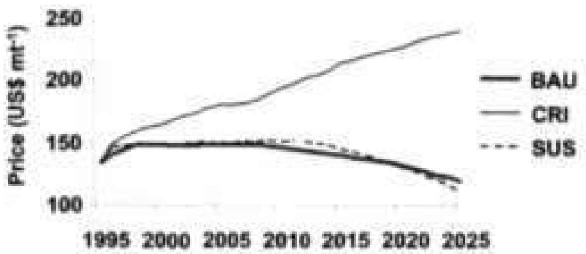
Rice prices for average, max and min, 1995-2025, under the BAU scenario



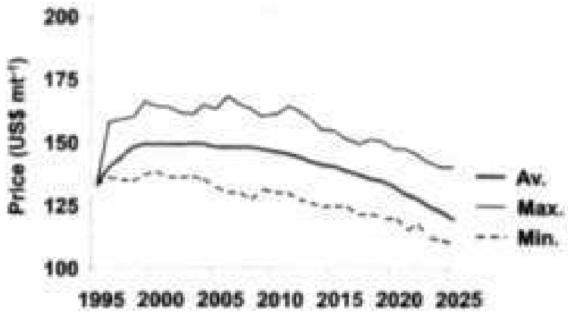
Rice prices for average, max and min, 1995-2025, under the CRI scenario



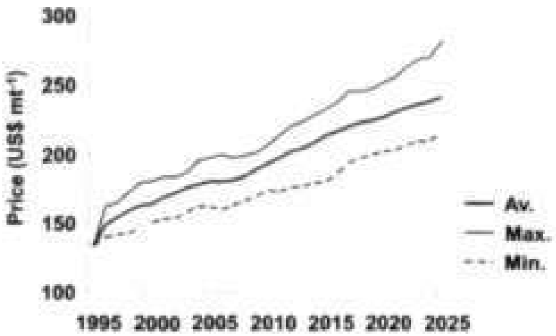
Wheat prices, 1995-2025, under alternative scenarios



Wheat prices for average, max and min, 1995-2025, under the BAU scenario



Wheat prices for average, max and min, 1995-2025, under the CRI scenario



Conclusions

- A large part of the world is facing severe and growing water scarcity
- Even under BAU, irrigation loses water to other sectors, with no improvement in environmental water flows
- With a continued worsening of water policy and investment performance, water scarcity becomes a full-fledged crisis
- Severe Impacts on food production and prices, health, nutrition and the environment

Conclusions

- But the water crisis has solutions
- Highly selective investment in infrastructure to increase the supply of water for irrigation, households and industry
- However, fundamental solution is through:
  - Conserving water and improving the efficiency of water use through water management and policy reform
  - Improving crop productivity per unit of water and land through both water management and agricultural research and rural investment
  - Emphasis on crop breeding and water management in rainfed agriculture

3. Water, Agricultural Trade, Economics and Resource Simulation Model (WaterSiM)

3.1 Model description *-Mark W Rosegrant*

WATERSiM stands for Water, Agricultural Trade, Economics, and Resource Simulation Model. It is still under development, but will be heavily based on the IMPACT-WATER model. The goal of developing this model was to contribute to the achievement of sustainable development of water for poverty alleviation and food security. The purpose is to assess the impact of water- and food-related policies on water scarcity, food production, food security, environment and livelihoods through the year 2025 at the global, regional and local scale. This model will seek to determine irrigation water supply endogenously while simulating the relation between water withdrawal and water consumption. The modeling will also explore the potential for embedding river basin accounting in the solution/policy set, or serve as a method to test solutions for feasibility and to present and explain solutions. A major change is being made to reflect some spatial relations of water uses within a river basin while maintaining the river basin as the basic modeling unit.

New features

The time frame will be 2025/2030, with a possible update to 2000 base year (instead of 1997 as for IMPACT and 1995 for IMPACT-WATER). A climate scenario generation tool will be added.

IMPACT-WATER area function

$$AC_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}}$$
$$\times (1 + gA_{tni}) - \Delta AC_{tni}(WAT_{tni})$$

Harvested area is specified as a response to the crop's own price, the prices of other competing crops, the projected rate of exogenous (nonprice) growth trend in harvested area, and water.

IMPACT-WATER yield function

$$YC_{tni} = \beta_{tni} \times (PS_{tni})^{\gamma_{iin}} \times \prod_{k} (PF_{tnk})^{\gamma_{ikn}}$$
$$\times (1 + gCY_{tni}) - \Delta YC_{tni}(WAT_{tni})$$

Yield is a function of the commodity price, the prices of labor and capital, a projected nonprice exogenous trend factor reflecting technology improvements, and water.

Production function estimations

In WATERSiM, estimations of production functions will be separate for irrigated and rainfed crops. This also implies incorporating fertilizer, labor and land. Water stays as a potential yield/reduction factor approach. With these new crop production functions, we can assess in more detail the impact of economic measures (like water pricing or fertilizer subsidy) on crop production and input use.

Irrigation water demand

The ongoing micro-level analysis of production and water demand (WD) functions is providing a better understanding of the shape of the water demand curve and, hence, the impacts of economic measures such as water pricing on agricultural water demand.

Non-irrigation water demand

Methodology for non-irrigation water demand has also been developed during 2002, based on standard consumption function methodology.

Irrigation WD = f(Irrigated Area, ET, Irrigation Efficiency, Water Price)
Livestock WD = f(Livestock Population, WD per Animal, Water Price)
Industrial WD = f(GNP, Water Use Intensity, Technological Change, Water Price)
Domestic WD = f(Income per Capita, Population, Technological Change, Water Price)

Committed flow for the environment is specified as a percentage of average annual runoff. The base value is 10%; with additional increments of 20-30% for navigation; 10-15% if environmental reservation is significant, as in most developed countries; and 5-10% for arid and semi-arid regions. Committed flows for environmental and navigation purposes have been estimated on a river basin framework, but these values are to be updated based on new data collection and analysis underway at IWMI.

New features

The new features include crop-water technology analysis for specific commodities (from different CGIAR institutes), and production functions for the nonagricultural sector—domestic, commercial (service sector), and tourism, 3-5 industrial sectors (agro-industry, energy, others in aggregate).

Investments

Cost functions for storage, irrigation, and efficiency improvement in existing systems/infrastructure.

Water quality

Estimate lumped (basin wide) pollution loading as a function of fertilizer use, and industrial and domestic production.

Groundwater

Linkages between extraction and base flow/hydrograph, cost functions for groundwater extraction, threshold when it dries up, and endogenizing groundwater pumping.

Model expansion of commodity coverage

Livestock: Beef, pork, sheep & goat, poultry, eggs and milk

Cereals: Wheat, rice, maize and other coarse grains

Roots & tubers: Potatoes, sweet potatoes & yams, cassava and other roots and tubers

Other: Soybean, meals and oils

To be added to WATERSiM

Included in the IMPACT, but not in the IMPACT-WATER model: Vegetables, sub-tropical fruits, temperate fruits, sugar cane, sugar beets, sweeteners, eight capture and aquaculture fish commodities, fish meals and fish oils.

New features: Same basins in the USA

Ohio and Tennessee, Rio Grande, Columbia, Colorado, Great Basin, California, White-Red, Mid Atlantic, Mississippi (down), Mississippi (up), Great Lakes - Red, South Atlantic-Gulf, Texas-Gulf and Missouri.

New features: Same basins in India

Sahyadri Ghats, Eastern Ghats, Cauvery, Godavari, Krishna, Indian-Coastal-Drain, Chotanagpur, Brahmari, Luni RiverBasin, Mahi-Tapti-Narmada, Brahmaputra, Indus and Ganges.

New features: Same basins in China

Huaihe, Haihe, West - Huanghe, East - Changjian, Songliao, Inland, Southwest, ZhuJiang and Southeast.

New features: The developed world

IMPACT-WATER	WATER-SiM
Japan, Australia and EU15 (France, Germany, Belgium, Luxembourg, Netherlands, Austria, Denmark, Finland, Greece, Ireland, Italy, Portugal, Spain, Sweden, and UK)	Japan, Australia-Murray, Australia-Swan, Australia-other, France, Germany, UK, Italy, Spain and Other EC (Belgium, Luxembourg, Netherlands, Austria, Denmark, Finland, Greece, Ireland, Portugal, Sweden, Norway, Switzerland)
Other developed and East Europe	New Zealand, Canada, South Africa, Israel, Poland, Romania, Hungary and other East European Countries (Albania, Bosnia, Bulgaria, Croatia, Czech Republic, Macedonia, Slovakia, Slovenia, Yugoslavia Fr)
Central Asia and Rest of FSU	Kazakhstan, Other Central Asian Countries (Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan), Russia-OB, Russia-Volga, Russia-Yenisei, Russia-Other, Spain and Other EC (Belgium, Luxembourg, Ukraine) and Rest of FSU (Armenia, Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova)

New features: Central and Latin America

Mexico, Brazil, Argentina, Colombia and Latin American Countries	Mexico-RioGrande, Mexico-Coastal, Mexico-South, Other Brazil-Parana, Brazil-Toc, Brazil-Sao Francisco, Brazil-other, Argentina-Parana, Argentina-Salodo, Argentina-other, Colombia and Other Latin American Countries

New features: Sub-Saharan Africa

Nigeria, Northern SSA	South Nigeria, North Nigeria, Sudan, Ethiopia and Other N SSA (Burkina Faso, Chad, Djibouti, Eritrea, Mali, Mauritania, Niger, Somalia)
Central & Western SSA	Democratic Republic of Congo and Other C&W SSA (Benin, Cameroon, Central African Republic, Comoros Islands, Congo Republic, Cote d'Ivoire, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Sao-Tome Prn., Senegal, Sierra Leone, Togo)
Southern SSA	Southern SSA (Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Reunion, Swaziland, Zambia, Zimbabwe)
Eastern SSA	Kenya, Tanzania and Other E SSA (Burundi, Rwanda, Uganda)

New features: WANA

Egypt, Turkey and Other WANA	Egypt, East Turkey, West Turkey and Other WANA (Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, UAE, Yemen)

New features: South Asia

Pakistan, Bangladesh and Other South Asian Countries	Pakistan-Indus, Pakistan-other, Bangladesh, Sri Lanka and Other South Asian Countries (Afghanistan, Maldives, Nepal)

New features: Southeast Asia

Indonesia, Thailand, Malaysia, Philippines, Vietnam, Myanmar and Other SE Asian Countries	Indonesia-East, Indonesia-Middle, Indonesia-West, Thailand, Malaysia, Philippines, Vietnam-North, Vietnam-South, Myanmar and Other Southeast Asia (Brunei, Cambodia, Laos)

New features: East Asia & Rest of the World

South Korea, Other East Asia and Rest of the World	South Korea, Mongolia, Korea D. P. and Rest of the World

3.2 Data requirement for the addition of new commodities into the IMPACT WaterSiM model -*Siet Meijer*

Table 3.1 Data requirements.

Category	Items	Possible sources
Infrastructure	Reservoir storage Withdrawal capacity Groundwater pumping capacity Water distribution, use and recycling situation	ICOLD (1998) and national and sub-national statistics National and sub-national statistics National and sub-national statistics National and sub-national statistics
Agronomy	Crop growth stages Crop evapotranspiration coefficient (k_c) Yield-water response coefficient (k_y)	FAO, CIMMYT, USDA and local studies FAO (1998) and local studies FAO (1979, 1998) and local studies
Crop production	Irrigated and rainfed area (baseline): actual harvested and potential Irrigated and rainfed yield (baseline): actual and potential	National and sub-national statistics for total area and yield; disaggregating approaches will be used for splitting the rainfed and irrigated area/yield; irrigated area map
Non-irrigation water demand	Industry Domestic Livestock	National and sub-national statistics
Environment	Minimum requirements for wetlands downstream Water quality Pollution from municipal and industry	Local studies
Economic data	Per capita income Population	National and sub-national statistics
Irrigation technology	Irrigation efficiency estimation	Local studies

Table 3.2 Definition of basins within the countries USA, China and India.

US Basins	China Basins	India Basins
1. Ohio and Tennessee	1. Huaihe	1. Sahyadri Ghats
2. Rio Grande	2. Haihe	2. Eastern Ghats
3. Columbia	3. Huanghe	3. Cauvery
4. Colorado	4. Changjian	4. Godavari
5. Great Basin	5. Songliao	5. Krishna
6. California	**6. Inland**	6. Indian-Coastal-Drain
7. White-Red	7. Southwest	7. Chotanagpur
8. Mid Atlantic	8. ZhuJiang	8. Brahmari
9. Mississippi, Downstream	9. Southeast	9. Luni River Basin
10. Mississippi, Upstream		10. Mahi-Tapti-Narmada
11. Great Lakes-Red		11. Brahmaputra
12. South Atlantic-Gulf		12. Indus
13. Texas-Gulf		13. Ganges
14. Missouri		

References

FAO (Food and Agriculture Organization of the United Nations). 1998. *Crop evapotranspiration guidelines for computing crop water requirements.* FAO Irrigation and Drainage Paper No. 56. Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). 1979. *Crop yield vs. water.* FAO Irrigation and Drainage Paper No. 33. Rome, Italy.

ICOLD (International Commission on Large Dams). 1998. World register of dams. Paris: International Commission on Large Dams.

WATERSiM Model

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The WATERSiM model

- This modal will seek to determine Irrigation water supply endogenously while simulating the relation between water withdrawal and water consumption
- The modeling will also explore the potential for embedding river basin accounting in the solution/policy set. or as a method to test solutions for feasibility and to present and explain solutions

The WATERSiM model

- A major change is being made to reflect some spatial relations of water use within a river basin while maintaining the river basin as the basic modeling unit

New features

- Time frame will be 2025/2030
- Possible update to 2000 base year (instead of 1997 as for IMPACT and 1995 for IMPACT-WATER
- A climate scenario generation tool will be added

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$$\times (1 + gA_{tni}) - \Delta AC_{tni}(WAT_{tni})$$

Harvested area is specified as a response to the crop's own price, the prices of other competing crops, the projected rate of exogenous (nonprice) growth trend in harvested area, and water

IMPACT-WATER Yield Function

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Production function estimations

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- The ongoing micro-level analysis of production and water demand functions is providing a better understanding of the shape of the water demand curve and, hence, the impacts economic measures such as water pricing have on agricultural water demand

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Methodology for non-Irrigation water demand has also been developed during 2002, based on standard consumption function methodology

Irrigation WD • f(Irrigated Area, ET, Irrigation Efficiency, Water Price)

Livestock WD = f(Livestock Population, WD per Animal, Water Price)

Industrial WD - f(GNP, Water Use Intensity, Technological Change, Water Price)

Domestic WD • f(Income per Capita, Population, Technological Change, Water Price)

Non-irrigation water demand

Committed flow for the environment is specified as a percentage of average annual runoff.

- The base value: 10 percent
- Additional Increments 20-30 percent for navigation;
- 10-15 percent If environmental reservation is significant, as in most developed countries; and
- 5-10 percent for arid and semi-arid regions

Committed flows for environmental and navigation purposes have been estimated on a river basin framework, but these values are to be updated based on new data collection and analysis is underway at IWMI.

New features

- Crop-water technology analysis for specific commodities (from different CGIAR institutes)
- Production functions for nonagricultural sector: domestic, commercial (service sector), tourism, 3-5 industrial sectors (agro-industry, energy, others in aggregate)

New features

Investments

- Cost functions for storage, irrigation and efficiency improvement in existing systems/Infrastructure

Water Quality

- Estimate lumped (basin wide) pollution loading as a function of fertilizer use, and industrial and domestic production

New features

Groundwater

- Linkages between extraction and base flow/hydrograph
- Cost functions for groundwater extraction
- Threshold when it dries up
- Endogenizing groundwater pumping

Model expansion of commodity coverage

- Livestock: Beef, pork, sheep & goat, poultry, eggs and milk
- Cereals: Wheat, rice, maize and other coarse grains
- Roots & Tubers: Potatoes, sweet potatoes & yams, cassava and other roots and tubers
- Other: Soybeans, meals and oils

To be added to WATERSiM

Included In the IMPACT, not in IMPACT-WATER model:

- Vegetables
- Sub-tropical fruits
- Temperate fruits
- Sugar cane
- Sugar beets
- Sweeteners
- Eight capture and aquaculture fish commodities
- Fish meals
- Fish oils

New features: Same basins in the USA

- Ohio and Tennessee
- Rio Grande
- Columbia
- Colorado
- Great Basin
- California
- White-Red
- Mid-Atlantic
- Mississippi (down)
- Mississippi (up)
- Great Lakes - Red
- South Atlantic - Gulf
- Texas - Gulf
- Missouri

New features: Same basins in India

- Sahyadrl Ghats
- Eastern Ghats
- Cauvery
- Godavari
- Krishna
- Indian-Coastal-Drain
- Chotanagpur
- Brahmari
- Luni River Basin
- Mahi-Tapti-Narmada
- Brahmaputra
- Indus
- Ganges

New features: Same basins in China

- Hualhe
- Haihe
- West- Huanghe
- East- Changjian
- Songllao
- Inland
- Southwest
- ZhuJlang
- Southeast

New features: the developed world

IMPACT-WATER
- Japan
- Australia
- EU15 (France, Germany, Belgium, Luxembourg, Netherlands, Austria, Denmark, Finland, Greece, Ireland, Italy, Portugal, Spain, Sweden, UK)

WATER -SiM
- Japan
- Australia-Murray
- Australia-Swan
- Australia-Other
- France
- Germany
- UK
- Italy
- Spain
- Other EC (Belgium, Luxembourg, Netherlands, Austria, Denmark, Finland, Greece, Ireland, Portugal, Sweden, Norway, Switzerland)

New features: the developed world

IMPACT-WATER
- Other developed
- East Europe

WATER-SiM
- New Zealand
- Canada
- South Africa
- Israel
- Poland
- Romania
- Hungary
- Other East Europe (Albania, Bosnia, Bulgaria, Croatia,Czech Republic, Macedonia, Slovakia, Slovenia, Yugoslavia Fr)

New features: the developed world

IMPACT-WATER
- Central Asia
- Rest Former Soviet Union

WATERSIM
- Kazakhstan
- Other Central Asia (Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan)
- Russia-OB
- Russia-Volga
- Russia-Yenisei
- Russia-other
- Ukraine
- Rest of FSU (Armenia. Azerbaijan, Belarus, Estonia, Georgia, Latvia, Lithuania, Moldova)

New features: Central and Latin America

IMPACT-WATER
- Mexico
- Brazil
- Argentina
- Colombia
- Other Latin America

WATERSIM
- Mexico-Rio Grande
- Mexico-Coastal
- Mexico-South
- Brazil-Parana
- Brazil-Toc
- Brazil-Sao Francisco
- Brazil-other
- Argentina-Parana
- Argentlna-Salodo
- Argentina-other
- Colombia
- Other Latin America

New features: Sub-Saharan Africa

IMPACT-WATER
- Nigeria
- Northern SSA

WATERSIM
- South Nigeria
- North Nigeria
- Sudan
- Ethiopia
- Other N SSA (Burkina Faso, Chad, Djibouti, Eritrea, Mali, Mauritania, Niger, Somalia)

New features: Sub-Saharan Africa

IMPACT-WATER
- Central & Western SSA

WATERSIM
- Democratic Republic of Congo
- Other C&W SSA (Benin, Cameroon, Central African Republic, Comoros Islands, Congo Republic, Cồte d'Ivoire, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Sao-Tome Prn., Senegal, Sierra Leone, Togo)

New features: Sub-Saharan Africa

IMPACT-WATER
- Southern SSA

WATERSIM
- Southern SSA (Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Reunion, Swaziland, Zambia, Zimbabwe)

New features: Sub-Saharan Africa

IMPACT-WATER
- Eastern SSA

WATERSIM
- Kenya
- Tanzania
- Other E SSA (Burundi, Rwanda, Uganda)

New features: WANA

IMPACT-WATER
- Egypt
- Turkey
- Other WANA

WATERSIM
- Egypt
- East Turkey
- West Turkey
- Other WANA (Algeria, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, UAE, Yemen)

New features: South Asia

IMPACT-WATER
- Pakistan
- Bangladesh
- Other South Asia

WATERSIM
- Pakistan - Indus
- Pakistan - other
- Bangladesh
- Sri Lanka
- Other South Asia (Afghanistan, Maldives, Nepal)

New features: Southeast Asia

IMPACT-WATER
- Indonesia
- Thailand
- Malaysia
- Philippines
- Vietnam
- Myanmar
- Other SE Asia

WATERSIM
- Indonesia-East
- Indonesia-Middle
- Indonesia-West
- Thailand
- Malaysia
- Philippines
- Vietnam-North
- Vietnam-South
- Myanmar
- Other SE Asia (Brunei. Cambodia, Laos)

East Asia & rest of the world New features:

IMPACT-WATER
- South Korea
- Other East Asia
- Rest of the World

WATERSiM
- South Korea
- Mongolia
- Korea D. P.
- Rest of the World

Data requirement

Infrastructure
- Reservoir storage

(ICOLD (1998) and national and sub-national statistics)
- Withdrawal capacity

(National and sub-national statistics)
- Groundwater pumping capacity

(National and sub-national statistics)
- Water distribution, use and recycling situation

(National and sub-national statistics)

Data requirement IMPACT

Supply data
Area
Production
(calculate yield)
Demand data
Total Demand
Food Demand
Feed Demand
Other Demand

Trade data
Exports
Imports
Price data
World Price
Marketing margins
Producer and
Consumer Subsidy
Equivalents

Data requirement IMPACT

Own and cross price supply elasticities

Livestock supply
Area response
Yield response

Own and cross price demand elasticities

Income demand

Annual income adjustment

Food demand

Feed demand

Data requirement IMPACT

Feed
Feed conversion ratios, share of each feed that goes to livestock
Feed efficiency Improvement factor over time

Growth Rates
Annual area and Yield growth rates for 6 time periods

Calories
Calories by commodity

Data requirement

Agronomy

- Crop growth stages

(FAO, CIMMYT, USDA and local studies)

- Crop evapotranspiration coefficient (k_c)

(FAO (1977, 1998) and local studies)

- Yield-water response coefficient (k_y)

(FAO (1979, 1998) and local studies)

Data requirement

Crop production

- Irrigated and rainfed area (baseline): actual harvested and potential
- Irrigated and rainfed yield (baseline): actual and potential

(National and sub national statistics for total area and yield; a disaggregating approach will be used for splitting the rainfed and Irrigated area/yield; irrigated area map)

Data requirement

Non-irrigation water demand

- Industry
- Domestic
- Livestock

(National and sub-national statistics)

Data requirement

Environment

- Minimum requirements for wetlands downstream
- Water quality
- Pollution from municipal and industry

(Local studies)

Data requirement

Economic data

- Per capita income
- Population

(National and sub-national statistics)

Irrigation technology

Irrigation efficiency estimation

(Local studies)

***TITLE: International Model for Policy Analysis of Agricultural Commodities and Trade**

```
file r1 / test. txt /;
put r l ;

SET
 ITER1 iteration1 /it 1* it 100/
 YITER yearly iterations /  1997*2025/

SCALAR

 COUNTER1  iter counter1 /0/
 YCOUNTER year counter /1997/
 RELACC relative accuracy of approximation /0.01/;

$include SETS.INC

sets jdisp (j) / cm15, cm 14, cm16*cm20/;

* parameters for report writing

$include REPORTP.INC

$include TABLE1.DAT
$include TABLE2.DAT
$include TABLE3.DAT
$include TABLE4.DAT
$include TABLE5.DAT
$include TABLE6.DAT

$include PMETER.INC

$include BTRANS.INC

** yield adjustments
yldelG,cty,' padj3') $myh2(j,cty) = 0;

** production adjustments
adjust (j,cty) = 0;

* apply feff
feff(j,cty)  = delas8(j,cty,' xtra');

parameter dyh (j,cty)
 dan (j,cty)
 dgn (cty)
 DINCG(CTY);
```

```
$include INITIAL.INC

$include ITCEPTO.INC

display DFINTO;

$include TRANSO.INC

* policy scenarios
$include POLICY.INC

****test****
*parameter delfish(j, cty);

*delfish (j,cty) $mqd4(j) = DELASl (j,CTY,income');

* YEARLY LOOP Program

LOOP(YITER,

*display delfish, pp,pc,pt,pi;

YCOUNTER = YCOUNTER+1;

$include GROWTHl.INC

$include LAGS.INC

* assign arbitrary initial values

ttrade = 10;
counter 1 = 0;

$include REPORTD.INC

$include TRANS1. INC

 LOOP (iter1 $(abs(ttrade) gt RELACC),

$include MODEL.INC

counter 1 = counter 1 + 1;

display DFINTO, QL;
 ) ;

$include ITCEPTl.INC

display DFINT,DFINTO,'QL;
```

```
$include GROWTH2.INC

dyh (j,cty) = yhgr (j,cty)-yhgrb (j,cty);
dan (j,cty) = angr (j,cty)-angrb (j,cty);
dgn (cty) = gdpnagx(cty) - gdpnagb(cty);
DINCG(CTY) = INCGR(CTY) - INCGRB(CTY);
 ) ;
```

5. Exercises, Procedures and Results for Different Scenarios (Using GAMS)

5.1 Exercises

During the training program, the trainees were divided into four groups and each group was given one exercise with different scenarios to simulate effects using the IMPACT model for Indian agriculture using the GAMS software package. The groups and scenarios were:

Group	Group Members	Scenarios
I	G V Anupama, R Padmaja and MV Rama Lakshmi	1. A 50% decrease in area and yield growth rates for wheat in India for all six time periods 2. A 50% increase in area and yield growth rates for wheat in India for all six time periods 3. Doubling of the income demand elasticities for all six livestock commodities in India
II	GD Nageswara Rao and B Ramkumar	1. A 50% decrease in area and yield growth rates of rice in India for all six time periods 2. A 50% increase in area and yield growth rates of rice in India for all six time periods 3. Trade liberalization for maize for all countries and regions
III	VK Chopde and BC Roy	1. A 50% decrease in milk yield growth rate and population growth rate of cows in India for all periods 2. A 50% increase in milk yield growth rate and population growth rates of cows in India for all periods 3. Scenario 2 and 20% increase in GDP growth rates in India 4. An 8% GDP growth rate with UN low population projection for India
IV	K Dharmendra and PN Jayakumar	1. A 50% decrease in poultry meat yield and poultry population growth rates in India for all the six time periods 2. A 50% increase in poultry meat yield and poultry population growth rates in India for all the six time periods 3. A 20% decrease in human population growth rates in India for all the six time periods

5.2 General procedure

First, make sure that you have the original baseline input and output data saved somewhere. Open the desired Lotus file and change the data as per the scenario that has to be carried out. Save the changed data in a new directory with DAT extension. Then go to GAMS, open the project file impact.gpr. Then open tmodel.gms and treport 2.gms. First run tmodel.gms, making sure it shows in the upper right line s=base. When tmodel.gms is done, run treport2.gms, making sure it shows r=base in the upper right corner. When this is done, open report 1.123, report2.123 and report6.123 in Lotus file. Then go to the worksheet "print", and right click on the left macro button. Scroll down in the macro and make sure the directory the macro is referring to is the same as the directory you have the baseline saved in. Close the macro, and click on it, so the new data will be extracted from the model output. Save the report in the same directory.

5.3 Summary of findings

Group I

In the first scenario, the wheat area growth rates (%) were decreased by 50% for all six periods (e.g. from 0.3712 (baseline) to 0.1856 for the period 1997-2000), and the wheat yield growth rates (%) were similarly decreased by 50% (e.g. from 1.9928 (baseline) to 0.9964 for the period 1997-2000). Decrease in area and yield growth rates had a huge impact on the supply of wheat in India, but the total demand for wheat was unaltered since other influencing factors such as population growth rates, GDP, and other cereals were kept unchanged. This caused the net import of wheat to be doubled from 9 to 18 million tons in 2020 when compared to the baseline scenario.

In the second scenario, the wheat area growth rates (%) were increased by 50% for all six periods (e.g. from 0.3712 (baseline) to 0.5568 for the period 1997-2000) and the yield growth rates (%) were increased by 50% (e.g. from 1.9928 (baseline) to 2.9892 for the period 1997-2000). The results showed that the increase in area and yield growth rates increased the supply of wheat in 2025 by 2.5 million tons when compared to the baseline scenario. However, the total demand for wheat was unaltered. India, which was an importer of wheat in the baseline scenario, will now become an exporter to the tune of about 15 million tons in 2025 due to increase in the supply of wheat. In both the scenarios, there was no impact on the percentage of malnourished children in India.

In the third scenario, income elasticities for demand were doubled for all the livestock commodities (for beef from 0.20 to 0.40, for pork from 0.25 to 0.50, for sheep and goat from 0.40 to 0.80, for poultry from 0.35 to 0.70, for eggs from 0.21 to 0.42 and for milk from 0.25 to 0.50). The increase in income elasticities has led to an almost doubling of the demand for all the livestock commodities but due to limited responsiveness of supply of these products within India, net trade (import) increased threefold compared to the actual import in the baseline scenario. Among the imported commodities, imports of milk, eggs, sheep and goat were especially high. The percentage of malnourished children reduced from the projected value of 42.5 to 41.3 in 2020 and from 33.3 to 31.6 in 2025.

The world wheat price was affected significantly due to changes in the supply of wheat from India in Scenario 1 and 2. Compared to the baseline scenario, the decrease in supply of wheat from India caused an increase in the world wheat prices while the increased supply in India decreased the world prices. This may be due to the large share that Indian wheat contributes to the world market. When the income elasticities of the livestock commodities were doubled, it had significant effects on the world prices of all the livestock commodities. The world prices that were in a declining trend in the baseline scenario started increasing due to increased demand from the Indian market. Detailed results from Group I simulations are shown in Section 5.4 (Group I Simulation Results).

Group II

In the first scenario, the rice area growth rates (%) were decreased by 50% for all six periods (e.g. from -0.1977 (baseline) to -0.09885 for the period 1997-2000), and the rice yield growth rates (%) were similarly decreased by 50% (e.g. from 1.6023 (baseline) to 0.80115 for the period 1997-2000). The decrease in area and yield growth rates directly influenced the rice supply in India, resulting in a decrease in rice production from the actual projection of 120 million tons to 100 million tons in 2020. Even the demand for rice declined from the projected 120 million tons to 90 million tons in 2020. However, it was observed that the supply and demand did not decline significantly despite the reduction in area and yield growth rates. India, which was not exporting in the baseline scenario, will be exporting about 2 million tons in spite of decline in production. This might be due to the influence of external forces such as world price, consumer preference for other cereals, and improvement in the standard of living.

In the second scenario, rice area growth rates (%) increased by 50% for all six periods (e.g. from -0.1977 (baseline) to -0.2965 for the period 1997-2000) and similarly yield growth rates (%) increased by 50% (e.g. from 1.6023 (baseline) to 2.4034 for the period 1997-2000). The supply of rice increased from 120 to 140 million tons in 2020, whereas the demand for rice had declined from 120 to 90 million tons compared to the baseline. It was observed that there was no change in the demand for rice over time whether the area and yield growth rates increased or decreased by 50%. This surplus production from India led to increased export of about 39 million tons of rice in 2020.

In the third scenario, trade liberalization of maize for all countries and regions had no impact on the supply of maize from India. In 2020, the production level remained unchanged at 13 million tons in the baseline scenarios, while the demand for maize declined from 13 million tons to 11.5 million tons. One reason for this may be the change in price of maize that occurred under the influence of trade liberalization. Due to the decline in demand, India's net export of maize had increased from 0.25 to 2.2 million tons in 2020. There was no change in the number of malnourished children in India in the first scenario. However, in the other two scenarios, the number declined slightly from 42 thousand to 38 thousand in 2020.

The world price of rice was in a declining trend in the baseline scenario, and the same trend continued after reduction in area and yield growth rates in India, although the world price was marginally higher under Scenario 1. However, the reverse trend was seen in the case where the area and yield growth rates increased (Scenario 2). In the third scenario, the world prices that had remained almost constant over the periods in the baseline scenario showed a declining trend after trade liberalization. The world price was relatively higher under Scenario 2. Detailed results from Group II simulation are shown in Section 5.4 (Group II Simulation Results).

Group III

In the first scenario, the milk yield growth rates (%) of cows were decreased by 50% for all six periods (e.g. from 2.4938 (baseline) to 1.2469 for the period 1997-2000) and population growth rates (%) of milking cows were also reduced by 50% for all six periods (e.g. from 0.695 (baseline) to 0.3475 for the period 1997-2000). Due to reduction in milk supply, India, which was not importing milk under the baseline scenario, is projected to start importing about 50 million tons of milk in 2025. This was only associated with a 12% decrease in domestic milk demand. With the decrease in population of milking cows, the cereal feed demand had decreased by 0.8 million tons when compared to the baseline scenario in 2025.

In the second scenario, the milk yield growth rates (%) were increased by 50% for all six periods (e.g. from 2.4938 (baseline) to 3.7407 for the period 1997-2000) and the population growth rates (%) of milking cows similarly increased by 50% for all six periods (e.g. from 0.695 (baseline) to 1.0425 for the period 1997-2000). With the increase in the milking cow population, the cereal feed demand also increased by 1.2 million tons in 2025 as compared to the baseline, but the food demand remained unchanged. Increased supply of milk and the associated decline in prices caused a slight increase in domestic demand. With the increase in milk supply, India, which was not exporting milk as per the baseline scenario in 2025, is now projected to export milk to the tune of 70 million tons in 2025.

In the third scenario, the GDP growth rate (%) was increased by 20% under the assumptions of Scenario 2. With the increase in the GDP growth rate, the demand for milk increased by 40 million tons when compared to the baseline scenario in 2025, although the supply of milk remained unaltered at 250 million tons as in the second scenario. However, the increase in demand had a direct effect on the export of milk. With increase in GDP and milking cow population, the cereal feed demand increased by 1.4 million tons in 2025.

In the fourth scenario, the GDP growth rate was readjusted to an 8% under the assumption of the second scenario. With the increase in GDP and milking cow population, the cereal feed demand increased by 3.5 million tons as compared to the baseline scenario in 2025.

Compared to the baseline scenario, a declining trend was observed in the world milk price, which decreased by 14% in 2025 when compared to 1997. The decrease in milk supply in India in the first scenario caused a 6% increase in the world milk price, while the increased milk supply in India in the second scenario caused a 13% decrease in the world milk price when compared to the baseline scenario in 2025. However, there was no change in the world prices of beef and wheat.

The results also showed that milk intake alone does not influence malnutrition. Other external factors were kept unchanged and this might be the reason for no change in the number of malnourished children in any of the described scenarios compared to the baseline scenario in 2025. Per capita calorie consumption, however, increased for all scenarios compared to the baseline scenario. Detailed results from Group III simulation are shown in Section 5.4 (Group III Simulation Results).

Group IV

In the first scenario, the poultry meat yield growth rates (%) were decreased by 50% for all six periods (e.g. from 1.2687 (baseline) to 0.63435 for the period 1997-2000) and poultry population growth rates (%) were decreased by 50% for all six periods (e.g. from 4.2675 (baseline) to 2.13375 for the period 1997-2000). As a result of the decrease in poultry meat and population growth rates, supply declined by 0.31%, while demand declined by only 0.1%. India, which was importing 0.022 million tons of poultry meat in the baseline scenario in 2025, will import about 0.027 million tons in 2025 due to the decreased supply of poultry meat in India.

In the second scenario, the poultry meat yield growth rates (%) were decreased by 50% for all six periods (e.g. from 1.2687 (baseline) to 1.90305 for the period 1997-2000) and poultry population growth rates (%) were decreased by 50% for all six periods (e.g. from 4.2675 (baseline) to 6.40125 for the period 1997-2000). With the increase in poultry population growth rates, poultry meat supply increased by 90.7% whereas demand increased only by 1.17% in India when compared with the baseline scenario in 2025. The effect on demand was less because the intake of meat products by Indian consumers is low. India, which was an importer, will become an exporter of poultry meat to the tune of 1.7 million tons when compared with the baseline scenario in 2025. This might be due to increased supply and unchanged demand for poultry meat in the country.

In the third scenario, the human population growth rates (%) were reduced by 20% for all six periods (e.g. from 0.016577 (baseline) to 0.013262 for the period 1997-2000). Even the decrease in human population had no significant impact on the supply and demand for livestock commodities. However, there was a shift in net trade — a shift from import to export was observed in beef (from -112 to 54) and for sheep and goats (from -27 to 12) in 2020. Import of pig and poultry meat declined significantly. Although the total cereal supply was unaltered, the total and food cereal demand showed a marginal decline, while there was no change in feed demand. This shows a direct effect of reduction in human population. Rice is the major cereal consumed in India, and a shift from import to export of rice was observed with the reduction in population growth rates. Wheat imports decreased significantly by 67%, maize export increased by 75% and other grains increased by 50% in 2020.

In the first scenario, there was no change in world prices of poultry meat because India's contribution to the world market was low; while in the second scenario, increase in supply of poultry meat significantly decreased the world prices of poultry meat. The decrease in human population in India had no significant effect on the world prices of livestock commodities in the third scenario.

None of the three scenarios showed any change in the number of malnourished children in India; this might be due to low demand elasticities for meat in India and may also be due to the low purchasing power (low average income). Detailed results from Group IV simulation are shown in Section 5.4 (Group IV Simulation Results).

5.4 Detailed results

Group I: Simulation Results

GVAnupama, MV Rama Lakshmi and R Padmaja

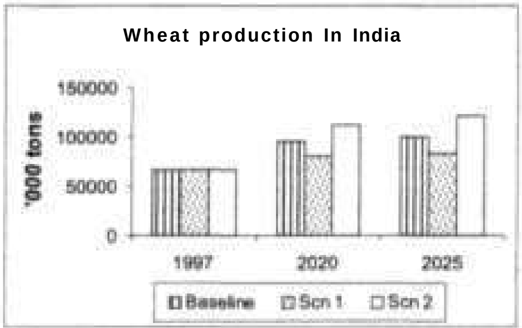
	Wheat Yield Growth Rates					
Years	1997-2000	2001-05	2006-10	2011-15	2016-20	2021-25
Baseline	1.9928	1.2657	1.2775	1.2756	1.2009	1.1292
50 percent decrease	0.9964	0.63285	0.63875	0.6378	0.60045	0.5646
50 percent increase	2.9892	1.89855	1.91625	1.9134	1.80135	1.6938
	Wheat Area Growth Rates					
Years	1997-2000	2001-05	2006-10	2011-15	2016-20	2021-25
Baseline	0.3712	0.2374	0.1765	0.1191	0.0852	0.0582
50 percent decrease	0.1856	0.1187	0.08825	0.05955	0.0426	0.0291
50 percent increase	0.5568	0.3561	0.26475	0.17865	0.1278	0.0873
	Double Income Elasticities for all Livestock					
Years	Beef	Pork	Sheep & Goat	Poultry	Eggs	Milk
Baseline	0.2	0.25	0.4	0.35	0.21	0.25
Double	0.4	0.5	0.8	0.7	0.42	0.5

Scenario 1 and 2: Summary of findings

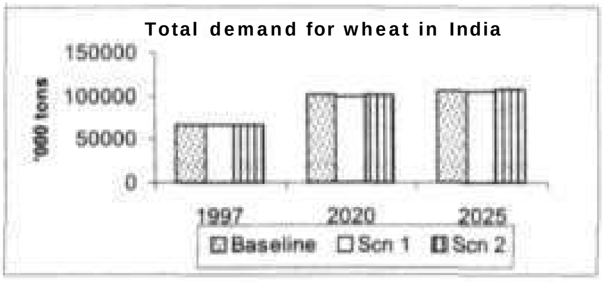
- **Demand for wheat was unaltered with increase or decrease in supply of wheat**
- **There was an increase in export of wheat**
- **Decrease in supply of wheat Increased world wheat prices and increase in supply of wheat decreased world wheat prices**

Comparison of wheat area and yield growth rates (Scenarios 1 & 2)

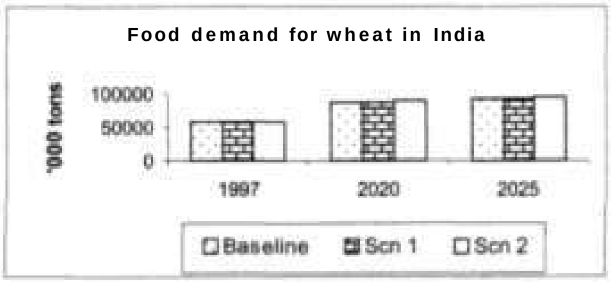
Trends in wheat production: 1997, 2020 and 2025



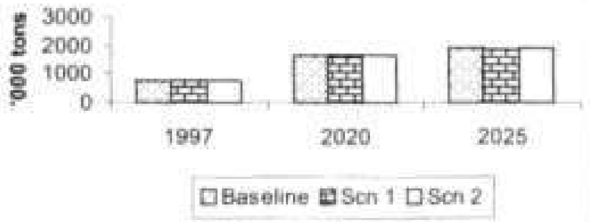
Trends in wheat demand: 1997, 2020 and 2025



Trends in food and feed demand for wheat: 1997, 2020 and 2025

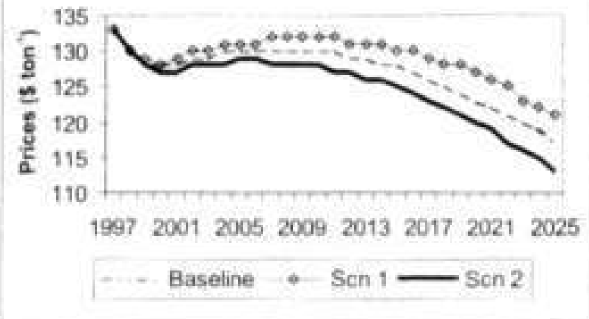


Feed demand for wheat in India



Food and feed demand are not influenced by changes in production

Comparison of world prices for wheat: 1997-2025



Trends in trade for wheat in India: 1997, 2020 and 2025

Trade for wheat in India

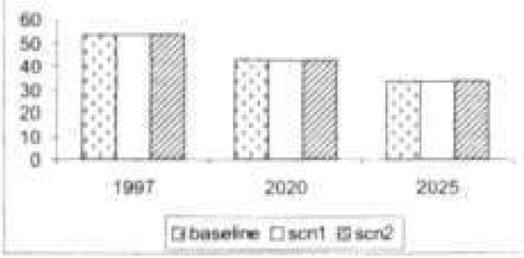
When production went down and the demand remained the same, it resulted in imports.
When production went up and demand remained the same, exports went up.

Impact of wheat production on rice in India under different scenarios

	Baseline		Scenario 1		Scenario 2	
	Wheat	Rice	Wheat	Rice	Wheat	Rice
1997	66105	83498	66105	83498	66105	83498
2020	94780	120100	80261	120138	111665	120056
2025	100064	126802	82420	126857	121118	126737

Mainourished children in India: 1997, 2020 and 2025

Projections of % mainourished children



There was no impact of increase or decrease in wheat production on percentage of malnourished children

Scenario 3: Summary of findings

- Demand for livestock commodities increased
- Production did not increase with demand
- An increase was observed in prices of all the six livestock commodities
- Imports of all the six livestock commodities increased

Trends in beef production and demand in India

	Production		Demand	
	Baseline	Scn 3	Baseline	Sen 3
1997	2771	2771	2599	2599
2020	5365	5436	5477	10098
2025	5971	6082	6015	12775

Trends in pork production and demand in India

	Production		Demand	
	Baseline	Scn 3	Baseline	Sen 3
1997	505	505	505	505
2020	986	991	1046	1708
2025	1114	1122	1173	2149

Trends in sheep & goat production and demand in India

	Production		Demand	
	Baseline	Scn 3	Baseline	Scn 3
1997	680	680	671	671
2020	1368	1409	1396	2402
2025	1554	1621	1567	3044

Trends in poultry production and demand in India

	Production		Demand	
	Baseline	Scn 3	Baseline	Scn 3
1997	515	515	515	515
2020	1573	1581	1621	3835
2025	1933	1949	1956	5630

Trends in egg production and demand in India

	Production		Demand	
	Baseline	Scn 3	Baseline	Scn 3
1997	1614	1614	1596	1596
2020	3490	3557	3496	5868
2025	3976	4092	4063	7606

Trends in milk production and demand in india

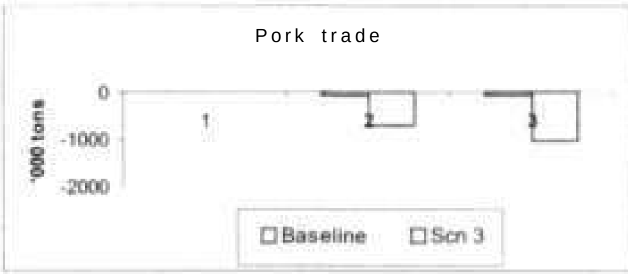
	Production		Demand	
	Baseline	Scn 3	Baseline	Scn 3
1997	71366	71366	71366	71366
2020	147705	155125	148214	229243
2025	167830	179800	169435	287853

World prices for livestock commodities in India (in Scenario 3 compared to baseline): 1997, 2020 and 2025

		Baseline	Scenario 3
Beef	1997	1808	1808
	2020	1746	1864
	2025	1707	1873
Pork	1997	2304	2304
		2246	2305
	2025	2165	2250
Sheep & Goat	1997	2918	2918
	2020	2839	
	2025	2732	
Poultry	1997	735	
	2020	717	
	2025	712	
Eggs	1997	1231	
	2020	1191	
	2025	1155	
Milk	1997	318	
	2020	291	
	2025	278	

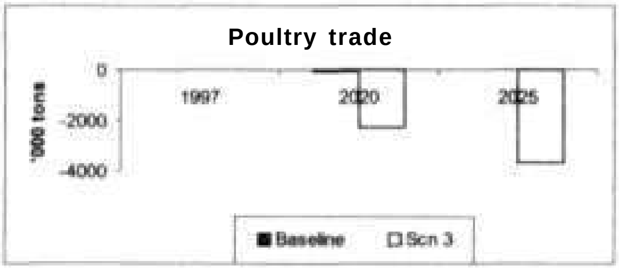
Trends in trade for livestock commodities in India: 1997, 2020 and 2025

Trends in trade for livestock commodities in India: 1997, 2020 and 2025

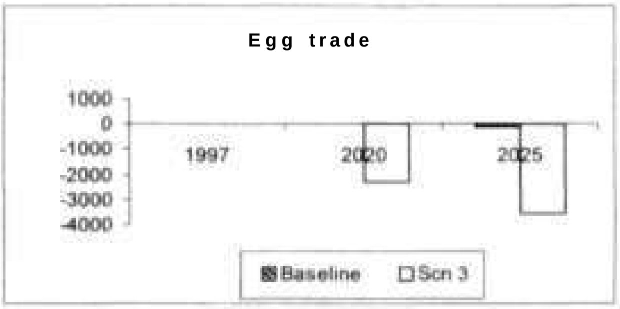


Trends in trade for livestock commodities in India: 1997, 2020 and 2025

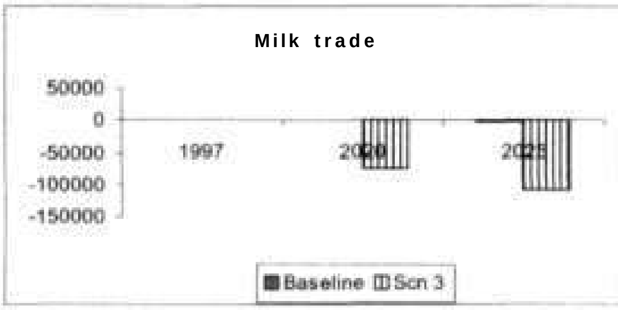
Trends in trade for livestock commodities in India: 1997, 2020 and 2025

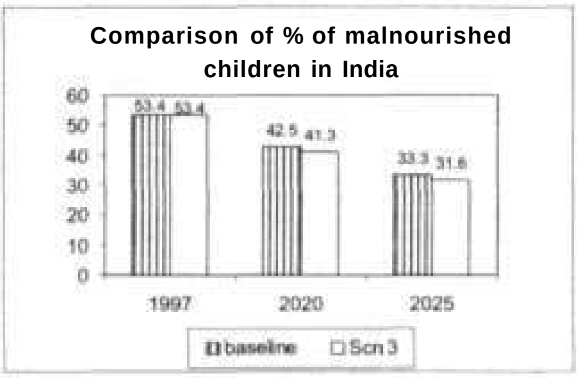


Trends in trade for livestock commodities in India: 1997, 2020 and 2025



Trends in trade for livestock commodities in India: 1997, 2020 and 2025





There was no significant impact on percentage of malnourished children in India when the income elasticities for livestock commodities were doubled

Conclusions

- It was observed that food availability does not have much impact on percentage of malnourished children in india. Other variables like health, education, and sanitation need to be examined.
- Increase or decrease In area and yield growth rates of wheat does not impact demand for wheat In India.
- Changes in wheat supply have no significant impact on rice and beef production.

Group II: Simulation Results

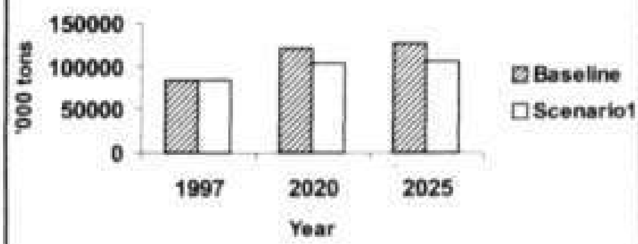
B Ramkumar and GD Nageswara Rao

	Rice yield growth rates					
Years	1997-2000	2001-05	2006-10	2011-15	2016 -20	2021 -25
Baseline	1.6023	1.5428	1.5753	1.4948	1.331	1.19
50 percent decrease	0.80115	0.7714	0.78765	0.7474	0.6655	0.595
50 percent increase	2.40345	2.3142	2.36295	2.2422	1.9965	1.785
	Rice area growth rates					
Years	1997-2000	2001 -05	2006 -10	2011 -15	2016 -20	2021 -25
Baseline	-0.1977	-0.2211	-0.2356	-0.2448	-0.2506	-0.256
50 percent decrease	-0.09885	-0.11055	-0.1178	-0.1224	-0.1253	-0.128
50 percent increase	-0.29655	-0.33165	-0.3534	-0.3672	-0.3759	-0.384

Scenario 1: Summary of findings

- Rice production decreased
- Prices increased
- Demand for rice decreased
- Net rice trade increased
- There was not much change in the number of malnourished children

Rice production in India: Scenario 1

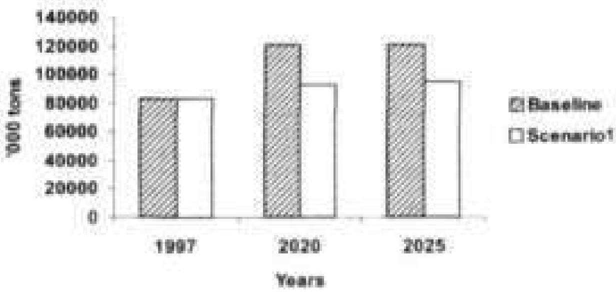


The projected rtce production declined under the scenario where the yield and growth rates were reduced by 50 percent.

World Rice Prices

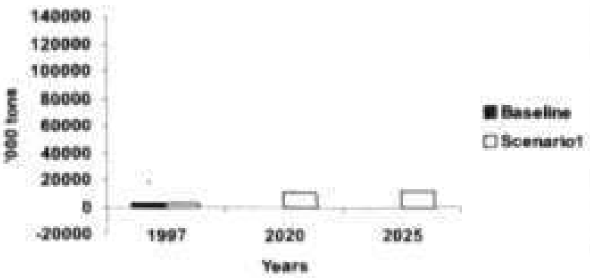
The rice prices increased under the scenario where the yield and growth rates were reduced by 50 percent

Rice demand in India: Scenario 1

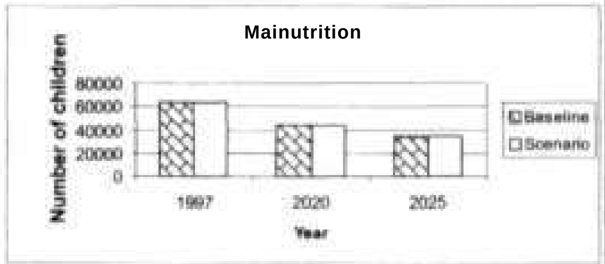


The estimated total demand for rice declined.

Net trade of rice in India: Scenario 1



Mainutrition in children

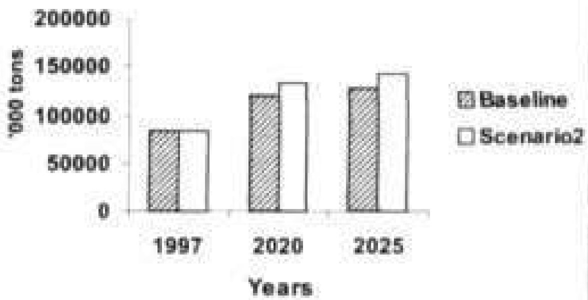


In general, the numbers of malnourished children decreased over the years, and there was not much change In the number of malnourished children in the changed scenario.

Scenario 2: Summary of findings

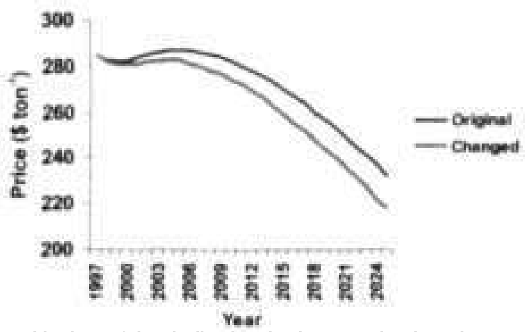
- Rice supply increased
- Prices declined
- Total demand for rice decreased
- Net rice trade Increased
- Number of malnourished children decreased

Rice production in India: Scenario 2



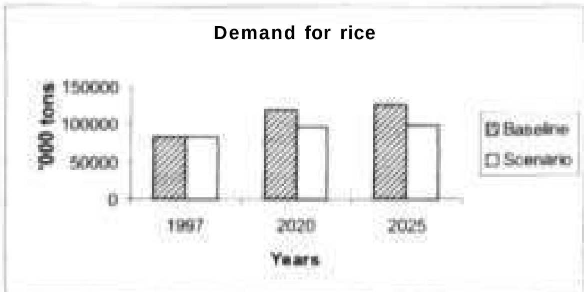
Rice production increased under the scenario where the yield and area growth rates were increased by SO percent.

World rice prices: Scenario 2



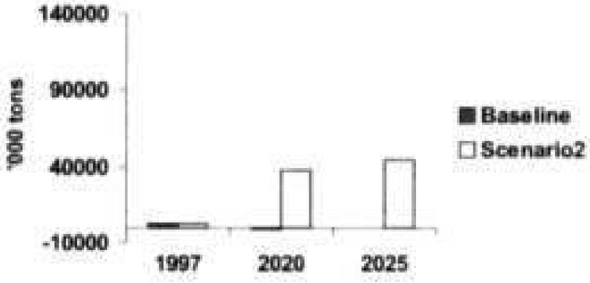
World prices of rice declined under the scenario where the growth rates of rice yield and area were increased by 50 percent.

Rice demand in India: Scenario 2



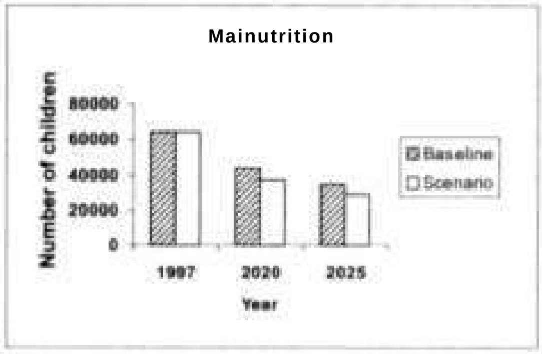
Rice demand decreased even though production increased and prices declined.

Net trade of rice in India: Scenario 2



Rice trade increased under the scenario where rice yield and area growth rates increased by 50 percent.

Number of malnourished children: Scenario 2

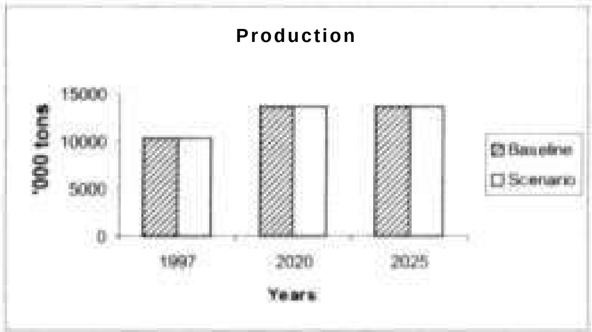


The number of malnourished children decreased under the scenario where yield and area growth rates increased by 50 percent.

Scenario 3: Summary of findings

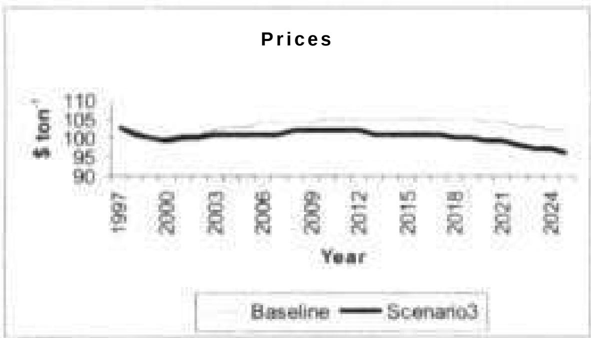
- Maize prices decreased
- There was not much change in maize production
- Demand for maize decreased
- Net maize trade increased
- Number of malnourished children decreased

Maize production in India: Scenario 3



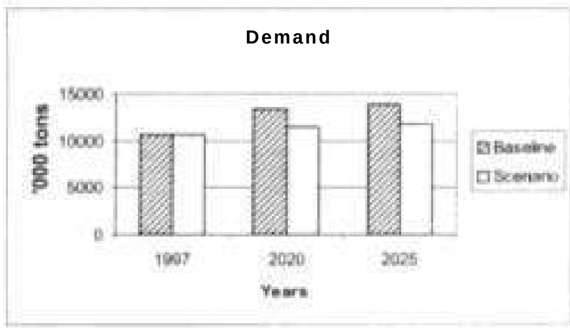
There was not much difference in the maize production.

World maize prices: Scenario 3



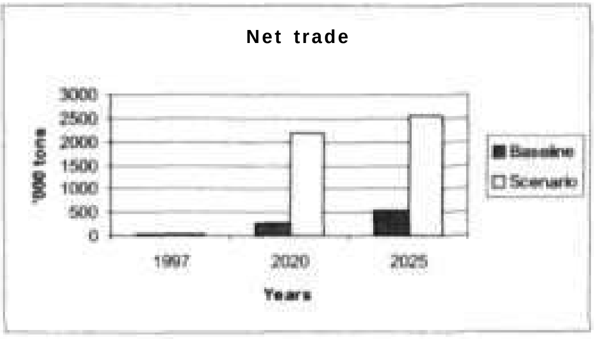
World prices for maize decreased after trade liberalization.

Maize demand in India: Scenario 3



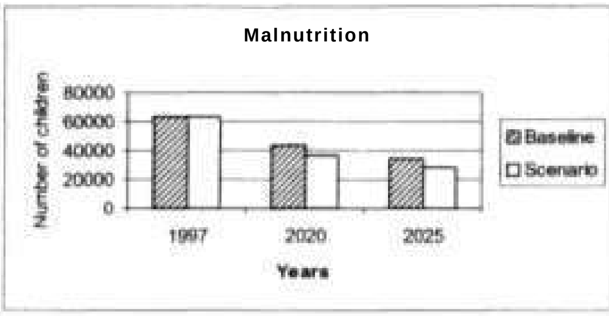
Maize demand declined after trade liberalization.

Net maize trade in India: Scenario 3



Net trade of maize increased after trade liberalization.

Malnutrition in children: Scenario 3



The number of malnourished children decreased under the scenario of trade liberalization.

Group III: Simulation Results

BC Roy and VK Chopde

	Milking cow yield growth rates					
Years	1997-2000	2001-05	2006-10	2011-15	2016-20	2021-25
Baseline	2.4938	2.5623	2.65	2.5623	2.399	2.2458
50 Percent Decrease	1.2469	1.28115	1.325	1.28115	1.1995	1.1229
50 Percent Increase	3.7407	3.84345	3.975	3.84345	3.5985	3.3687
	Milking cow population growth rates					
Years	1997-2000	2001-05	2006-10	2011-15	2016-20	2021-25
Baseline	0.695	0.805	0.87	0.805	0.6841	0.5719
50 Percent Decrease	0.3475	0.4025	0.435	0.4025	0.34205	0.28595
50 Percent Increase	1.0425	1.2075	1.305	1.2075	1.02615	0.85785

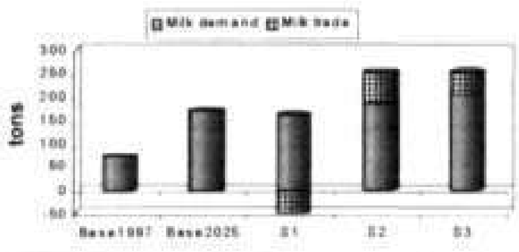
Scenario 1: Summary of findings

- Import of milk increased
- Cereal feed demand decreased
- World milk prices increased

Scenario 2: Summary of findings

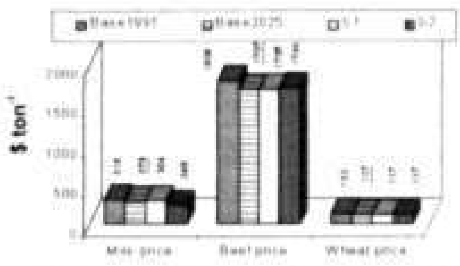
* Cereal feed demand increased
* Export of milk increased
* World milk prices decreased

Impact on domestic demand & net trade of milk



Area and productivity growth influence supply
Supply Influences price
Price and income influence demand
This results in net Import or export

Impact on world price



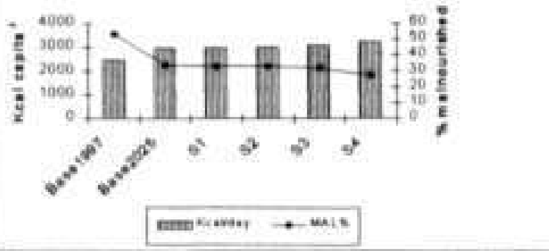
Changes in milk yield/no. of cow growth rates in India has

- no significant impact on world prices for other commodities
- but can influence the world price for milk because of the sheer size of domestic demand

Scenario 3 and 4: Summary of findings

- Demand for milk increased
- Export of milk decreased
- Cereal feed demand increased

Impact on consumption and nutrition



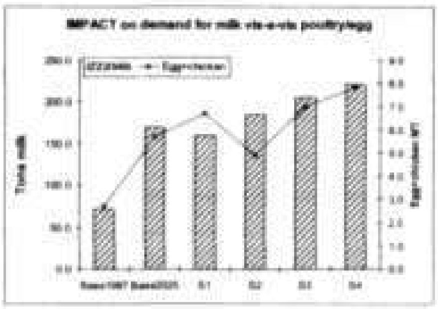
In India, per capita calorie intake will increase significantly under all the scenarios.

But still a large number of people will remain malnourished
(Increase in milk production alone is not going to make much difference as the poor will not be able to increase their milk consumption much)

Population control is the key to solve this problem

Variables	Cereal demand			
	Total	Food	Feed	
	MT	MT	MT	% of total
Base1997	163.7	162.0	1.7	1.04
Base2025	248.0	243.2	4.8	1.94
Scenario 1	250.4	246.4	4.0	1.60
Scenario 2	249.3	243.3	6.0	2.39
Scenario 3	252.3	246.1	6.2	2.46
Scenario 4	255.4	247.1	8.3	3.25

Demand for cereal In India Is going to Increase significantly
(Both population growth & income growth are the driving forces)
Demand for cereal as feed will increase at a faster rate
(Income growth is the main driver for such increase)



Significant increase in demand for animal protein under all the scenarios.

Indian consumers are price sensitive and substitution will occur between milk and egg/chicken (Scenarios 1 & 2).

IMPACT of income growth & population control on consumption pattern

						(kg capita-1 yr-1)	
Variables	Mutton	Chicken	Egg	Milk	Wheat	Rice	Coarse cereal
Base1997	0.7	0.5	1.7	62.2	60.9	85.9	22.4
Base2025	1.2	1.5	2.7	115.1	69.8	89.2	17.2
Scenario 4	1.5	2.4	3.5	144.8	73.0	90.0	15.0
% increase	25.42%	59.46%	30.71%	25.78%	4.57%	0.92%	-12.82%

With Increase in income the per capita demand for
- Livestock products will Increase significantly
- Fine cereal will increase marginally
- Coarse cereal will decrease

Lessons learnt

One may differ on soma of the assumptions made in the model and thus on the baseline projections for 2025, but what Is important to note is that the basic framework of the model is working fine as the results of ail the alternative scenarios are along the expected lines.

Group IV: Simulation Results

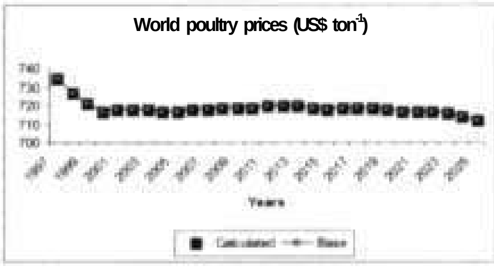
K Dharmendra and PN Jayakumar

	Poultry yield growth rates					
Years	**1997-2000**	**2001-05**	**2006-10**	**2011-15**	**2016-20**	**2021-25**
Baseline	1.2687	1.3591	1.3691	1.3971	1.2307	1.0916
50 percent Decrease	0.63435	0.67955	0.68455	0.69855	0.61535	0.5458
50 percent Increase	1.90305	2.03865	2.05365	2.09565	1.84605	1.6374
	Poultry population growth rates					
Years	**1997-2000**	**2001-05**	**2006-10**	**2011-15**	**2016-20**	**2021-25**
Baseline	4.2675	3.8723	3.7006	3.3793	3.1941	3.0267
50 percent Decrease	2.13375	1.93615	1.8503	1.68965	1.59705	1.51335
50 percent Increase	6.40125	5.80845	5.5509	5.06895	4.79115	4.54005
	Human population growth rates					
Years	**1997-2000**	**2001-05**	**2006-10**	**2011-15**	**2016-20**	**2021-25**
Baseline	0.01657725	0.0141542	0.0116265	0.0101217	0.00979275	0.00899926
20 percent Decrease	0.013262	0.011322	0.009301	0.008097	0.007834	0.007199

Scenario 1: Summary of findings

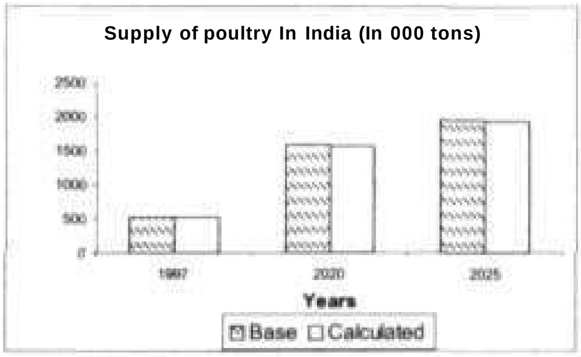
* Supply and demand of poultry meat was reduced
* A meager increase in import of poultry meat was seen
* There was no impact on world poultry meat prices

Trends in world prices of poultry (1997-2025): Scenario 1

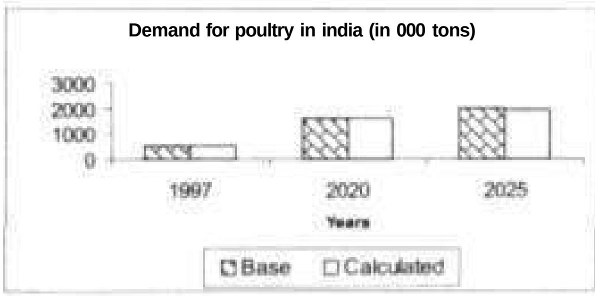


Since the contribution of poultry trade from India in the world market is low, there was no change in the world poultry prices, even after reduction in poultry yield and poultry population growth rates by 50 percent

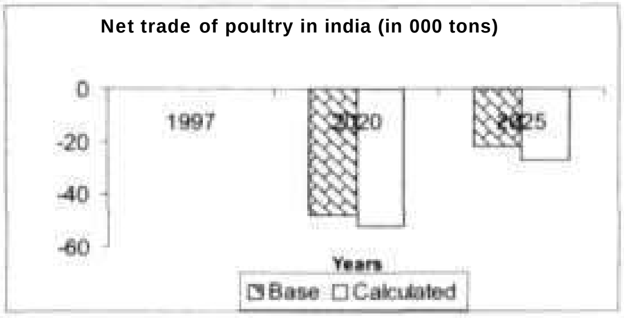
Trends in supply, demand and trade for poultry in India: Scenario 1



Trends in supply, demand and trade for poultry in India: Scenario 1

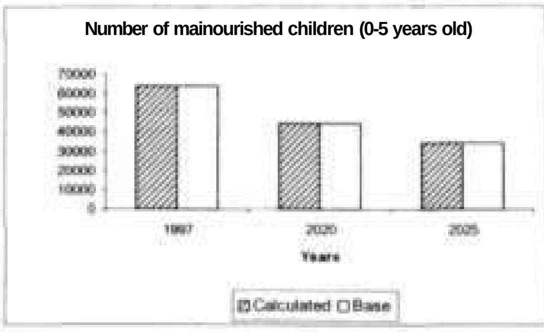


Trends in supply, demand and trade for poultry in India: Scenario 1



Reduction in yield and poultry population growth rates by 50% had no significant effect on supply and demand and net trade.

Number of malnourished children in India: Scenario 1

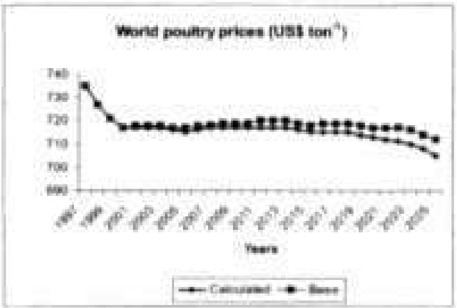


Since poultry meat is consumed in meager quantities by the vulnerable people, there was no impact on the number of malnourished children.

Scenario 2: Summary of findings

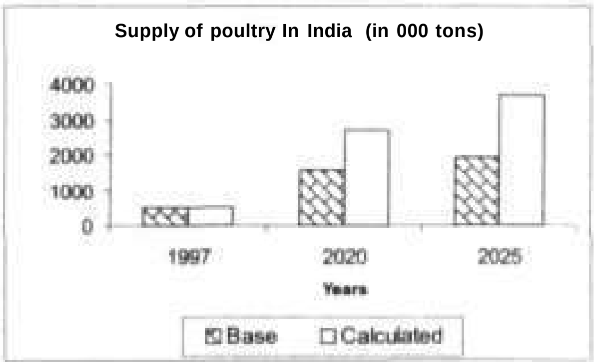
* Supply of poultry meat increased by 90%
* Export of poultry meat increased by about 1.7 million tons
* World poultry meat prices decreased

Trends in world poultry prices (1997-2025): Scenario 2

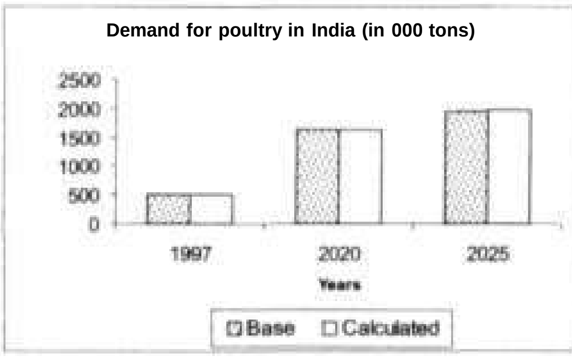


A 50% increase in the yield and poultry population growth rates significantly influenced the world prices.

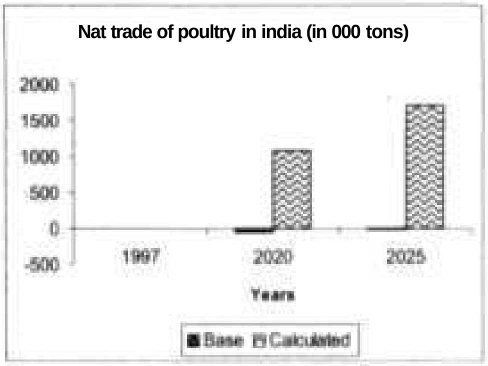
Trends in supply, demand and trade for poultry in India: Scenario 2



Trends in supply, demand and trade for poultry in India: Scenario 2

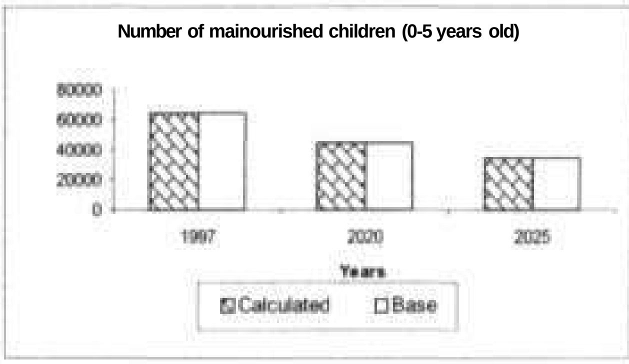


Trends in supply, demand and trade for poultry in India: Scenario 2



By Increasing the yield and poultry population growth rates by 50%, there was a significant change in the supply and trade. However, the change In demand was very low.

Mainourished children in India: Scenario 2

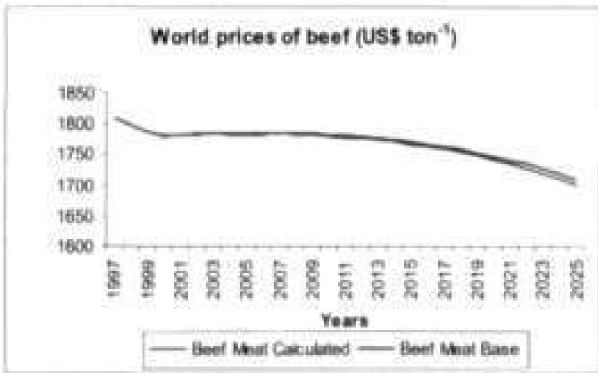


There was no significant change in the number of malnourished children.

Scenario 3: Summary of findings

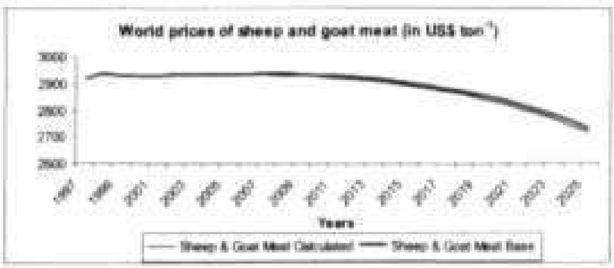
- Export of beef, sheep and goat increased
- There was no change in total cereals supply
- Shift of rice from import to export was seen
- There was no impact on world livestock prices

Trends in world prices for livestock meat (1997-2025): Scenario 3

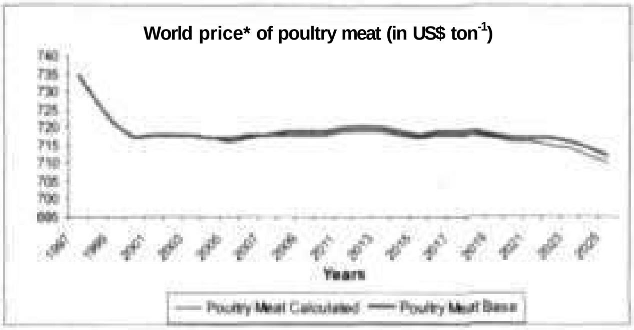


Trends in world prices for livestock meat (1997-2025): Scenario 3

Trends in world prices for livestock meat (1997-2025): Scenario 3

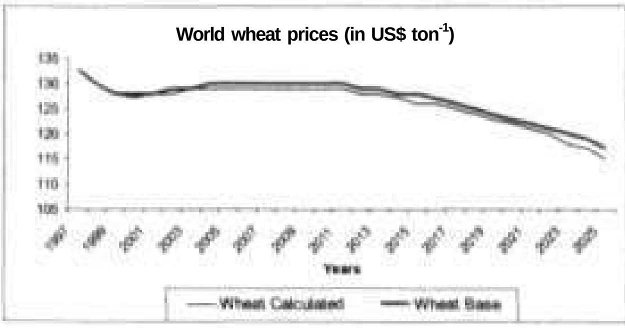


Trends in world prices for livestock meat (1997-2025): Scenario 3

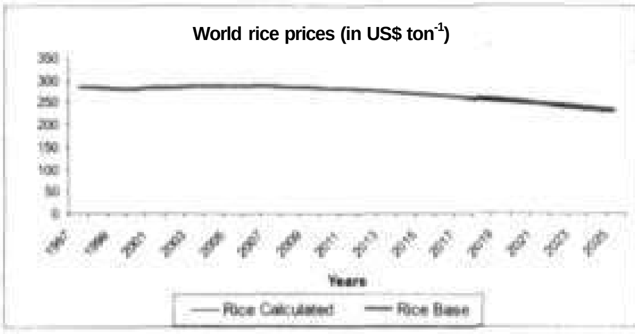


Reduction in human population growth rates by 20% had no significant effect on beef, pig, sheep & goat and poultry meat world prices

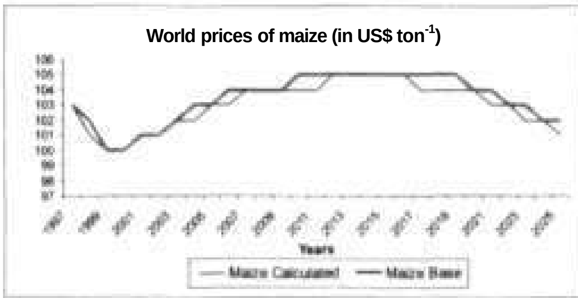
Trends in world prices for cereals (1997-2025): Scenario 3



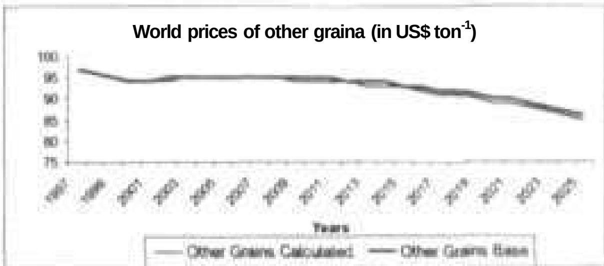
Trends in world prices for cereals (1997-2025): Scenario 3



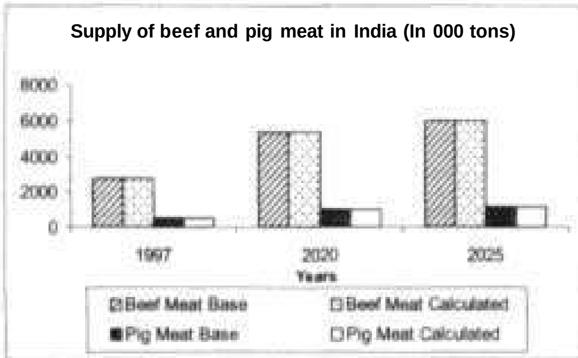
Trends in world prices for cereals (1997-2025): Scenario 3



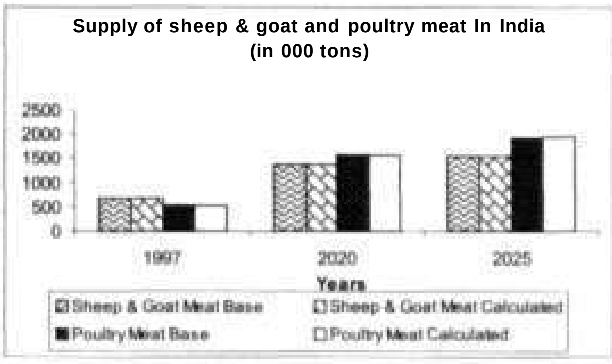
Trends in world prices for cereals (1997-2025): Scenario 3



Trends in supply of livestock meat in India: Scenario 3

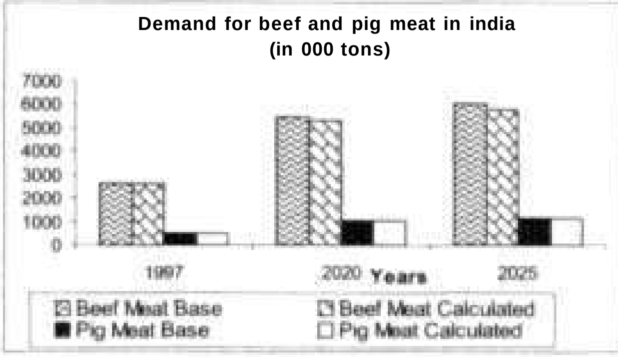


Trends in supply of livestock meat in India: Scenario 3

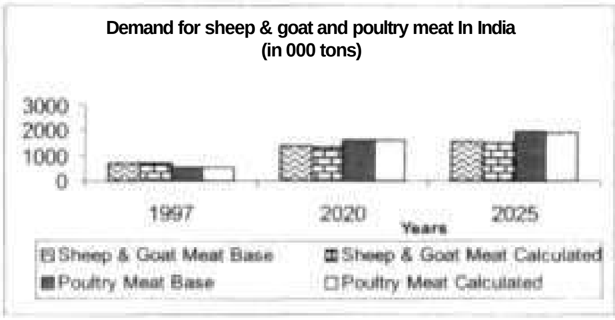


There was no change in supply of livestock meat.

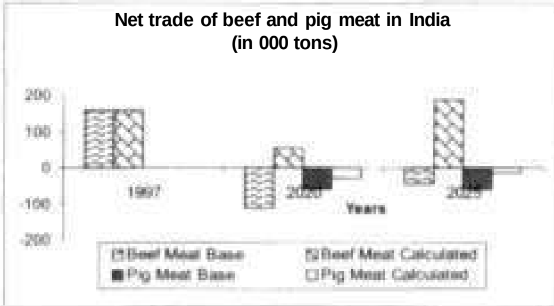
Trends in demand for livestock meat in India: Scenario 3



Trends in demand for livestock meat in India: Scenario 3

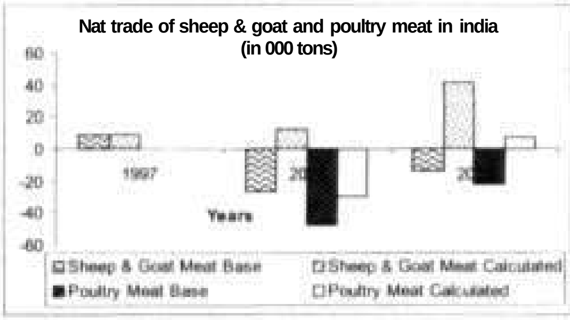


Trends in net trade of livestock meat in India: Scenario 3



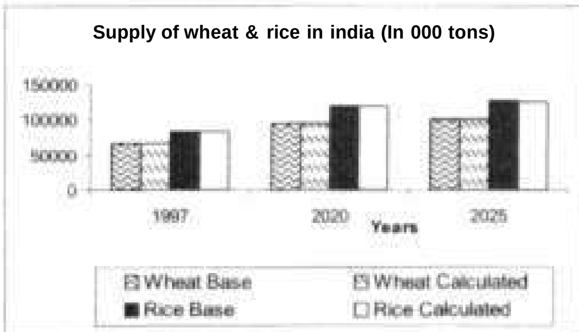
A shift was seen in beef meat trade from -112 to 54 (2020) and from -44 to 185 (2025)

Trends in net trade of livestock commodities in India: Scenario 3

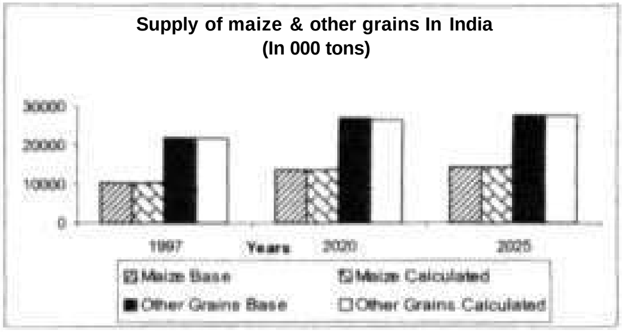


There was a shift in sheep & goat meat trade from -27 to 12 (2020) and from -14 to 41 (2025)

Trends in total supply of cereal in India: Scenario 3

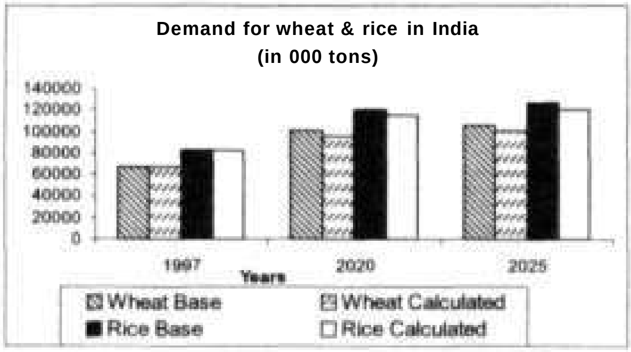


Trends in total supply of cereals in India, Scenario 3

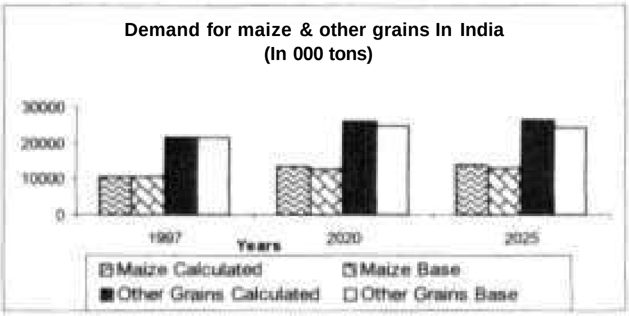


Reduction of human population growth rate by 20% had no effect on supply of cereals In India.

Trends in total demand for cereals in India: Scenario 3

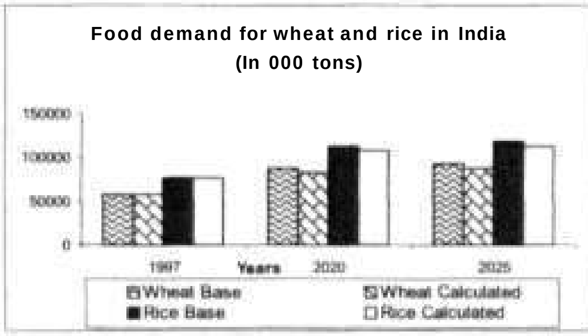


Trends in total demand for cereals in India: Scenario 3

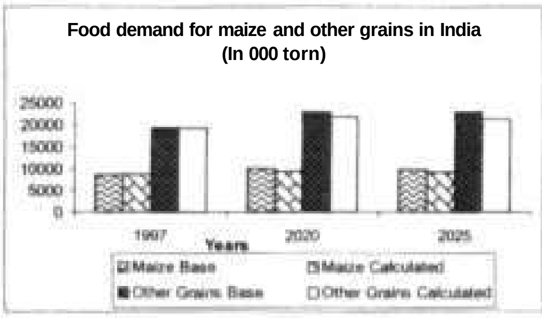


Reduction in human population growth rate by 20% significantly Influenced the demand of cereals in India.

Trends in food demand for cereals in India: Scenario 3

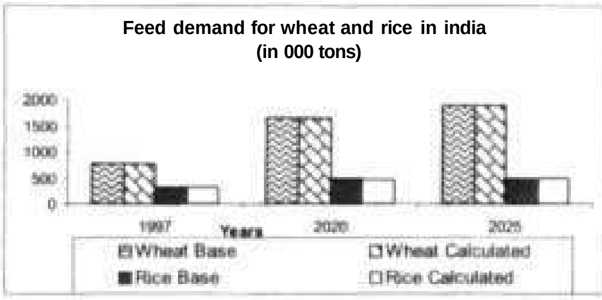


Trends in food demand for cereals in India: Scenario 3

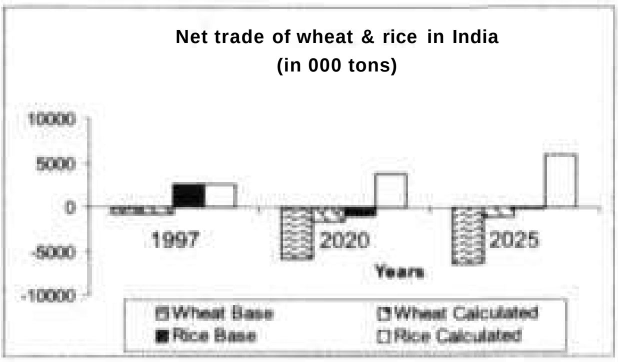


Reduction in human population growth rate by 20% significantly influenced the food demand of cereals in India.

Trends in feed demand for cereals in India: Scenario 3

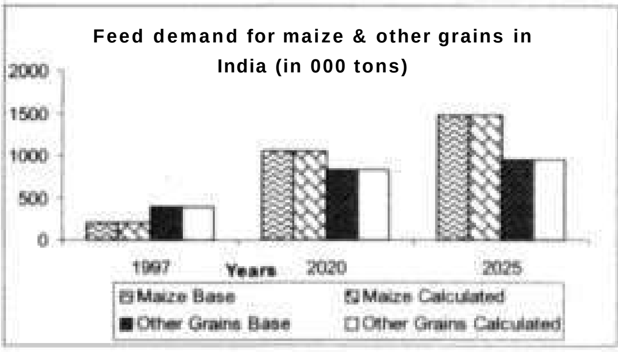


Trends in net trade of cereals in India: Scenario 3



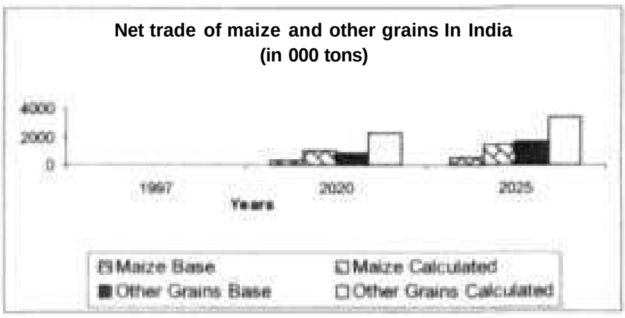
Reduction In human population growth rate by 20% significantly Influenced the wheat and rice net trade in India.

Trends in feed demand for cereals in India: Scenario 3



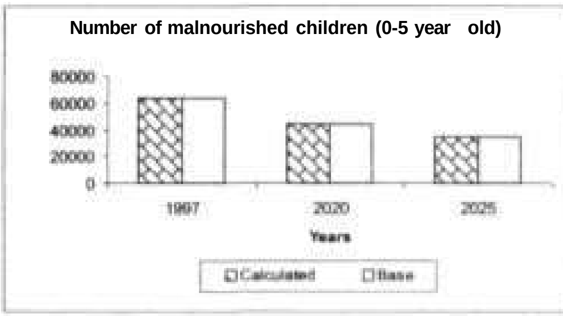
No significant change was observed in feed demand for cereals In India.

Trends in net trade of cereals in India: Scenario 3



Reduction in human population growth rate by 20% significantly influenced the net trade of cereals in India.

Number of malnourished children in India: Scenario 3



There was no significant change in the number of malnourished children.

Training Workshop Schedule (Venue: 212 Bldg, classroom A/B)

Instructor: Siet Meijer (IFPRI), with support from Bekele Shiferaw (ICRISAT)

Friday, January 24th

Opening Session 9:30-9:45 a.m.

Welcome Remarks: Dr Cynthia Bantilan, Global Theme Leader, SAT Futures and Development Pathways

Opening Remarks: Dr Dyno Keatinge, DDG - Research, ICRISAT

10:00 Training starts: 212 Bldg Classroom A and Computer lab

Morning Session: 10:00-12:00

- Introduction to IMPACT model: Usefulness, structure and equations of the model
- Results of projections to 2020 under different scenarios

Afternoon Session 13.30-16.00

- Data requirements for IMPACT model
- Options for introducing new commodities or disaggregating existing commodities
- Demonstrating data requirements in Excel and other formats
- Regional and country disaggregation issues

Monday, January 27th

Morning Session: 9:00-12:00

Introduction to IMPACT-WATER model: Usefulness, structure and equations of the model.

Afternoon Session 13.30-16.00

- Results of IMPACT-WATER projections to 2025 under different scenarios
- Data requirements for IMPACT-WATER model
- Options for including new commodities or disaggregating existing commodities
- Demonstrating data requirements in Excel and other formats
- Regional and country disaggregation issues

Tuesday, January 28th

Morning Session: 9:00-12:00

Continuation of IMPACT-WATER model issues (when necessary).

- Introduction to WATERSiM model
- Current status of the new model
- Data requirements

Afternoon Session 6 13.30-16.00

Open discussion and question and answer session on the three models discussed so far.

Wednesday, January 29th

Morning Session: 9:00-12:00

Technical structure of IMPACT model: GAMS code and input files setup.

Afternoon Session 13.30-16.00

Continuation of technical structure of the IMPACT model: Output data followed by running baseline scenario of the IMPACT model.

Thursday, January 30th

Morning Session: 9:00-12:00

Running simulations with the IMPACT model (exercises).

Afternoon Session 13.30-16.00

Continuation of running simulations with the IMPACT model (exercises).

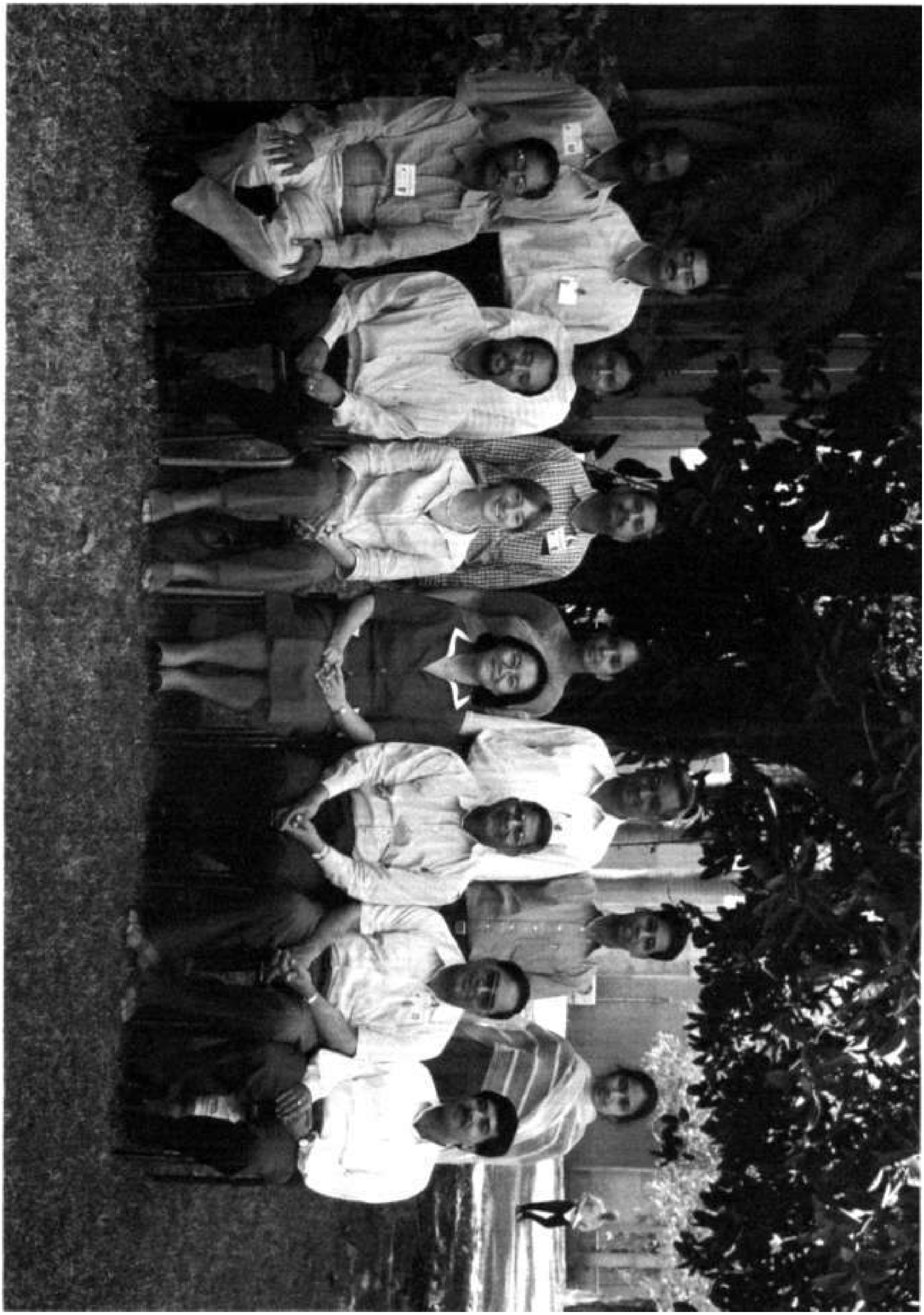
Friday, January 31st

Morning Session: 9:00-12:00

- Options for introducing SAT commodities into the IMPACT and WATERSiM model
- Data requirements and acquisition

Afternoon Session 13.30-16.00

Future strategies for joint development of the model for use in the SAT regions, vote of thanks, and wrap-up.



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RA-00413

About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political, international organization for science-based agricultural development. ICRISAT conducts research on sorghum, pearl millet, chickpea, pigeonpea and groundnut – crops that support the livelihoods of the poorest of the poor in the semi-arid tropics encompassing 48 countries. ICRISAT also shares information and knowledge through capacity building, publications and ICTs. Established in 1972, it is one of 15 Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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