Strategies to use biofuel value chain potential in Sub-Saharan Africa to respond to global change

TECHNICAL PROJECT REPORT

For work undertaken under contract number gtz81109056

International Food Policy Research Institute
Environment and Production Technology Division

Submitted by

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Report Narrative

I. Project Summary:

The work that is described in this brief report entails a close collaboration between the Environment and Production Technology Division (EPTD) of IFPRI and the research consortium organized by the Leibniz Institute for Landscape Analysis (ZALF). The principal research partners that contributed towards the work described in this report are the Wuppertal Institute, and key researchers at ZALF itself. This collaboration was undertaken to enlarge the detail of policy analysis that was undertaken to better illustrate the biofuel feedstock production potential within Tanzania, under different scenarios of global change. In this project, we created a detailed country multi-market model for Tanzania that drew from some key components of the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model of the International Food Policy Research Institute (IFPRI) – but which drew from other statistical information, in order to provide more disaggregation at the sub-regional for Tanzania. This was done in order to provide more insight on the distribution of agricultural production potential within Tanzania, as well as to enhance the modeling of agricultural supply, demand and trade that was necessary for assessing alternative economic scenarios.

The primary role of IFPRI, within this project, has been to deal with the foresight analysis for Tanzania in more detail, so as to better illustrate how important changes in the supply and demand of key agricultural commodities that are driven by global dynamics, could affect the equilibrium outcomes that are being simulated for Tanzania. A set of alternative scenarios were developed, in order to represent a range of possible future policy evolution – either that which tends more towards cleaner energy and more pro-environment policies and interventions; or one in which there is less innovation in both the energy and other important agricultural sectors, like agriculture. The potential for future biofuel market development in Tanzania is then evaluated, under each.

Based on this analysis, we were able to draw a number of key policy recommendations and priorities for future research on this topic. A brief synopsis of these conclusions is given here:

- The existing baseline case, in which US and other OECD biofuel production increases in accordance with current renewable energy policies continues to exert upward pressure on the world market prices for key cereal and oilseed commodities such as maize, rapeseed, soybean and other key oil-bearing crops like palm and sunflower.
- Under a scenario in which pro-environmental policies are embraced across a range of developed and emerging countries – which encourages investments

in more advanced renewable energy sources, that decrease reliance on first-generation biofuels technologies.

- Embedded into this kind of policy environment are biofuels policies that are more focused on reducing carbon intensity – like the LCFS (low carbon fuel standard) policy that exists in sub-regions of the US and a similar carbon-conscious policy in the EU region. Under such a policy there is a higher level of exports of maize and soybeans from the US, relative to the baseline case in which the existing US Renewable Fuel Standard (RFS) is implemented by itself.
- The more pessimistic and regressive scenario – in which technological innovation is slower (in both the energy and other influential sectors of the economy) – shows higher prices for food commodities, globally, which causes higher levels of malnutrition, in general. This is due to lower levels of trade open-ness and greater reliance on energy policies that are more fossil-intensive and which thereby raise world oil prices and encourage the continuance of first-generation biofuels technologies which reduce exports of maize from the US and higher demand of oilcrops used as feedstocks.
- Under these scenarios, the feedstock potential of Tanzania remains similar – at a biophysical level – but face different levels of market-driven incentives.
    - Under the more pro-environment and sustainability scenario, the lower world commodity prices cause lower levels of malnutrition within Tanzania – but offer slightly lower levels of incentives for agricultural production growth, for net producers of cereal and oil-based crops
    - The greater diffusion of 'green' technologies and investments that are made in developing regions like Tanzania, however, helps to support the biofuel sector and provide a more favorable environment for biofuels exports. There are also positive spillovers of technology to the agricultural sector, which encourages growth in crop productivity within Tanzania, and further encourages food production.
    - Within the more pessimistic scenario for technological progress and growth, the higher levels of oil prices (due to greater reliance on fossil fuels) and commodity prices (due to greater reliance on first-generation biofuels technologies) benefit the net producers of those commodities, but does not translate directly into greater biofuels production levels. This is partly due to the less liberal trade environment for biofuel products (in which OECD countries largely protect their markets), as well as to the lower levels of renewable energy investments and technology-sharing between the more advanced economies and the rest of the world.
- While we did not focus on the environmental impacts of biofuels, as has been done in other studies (who are focusing on the GHG emissions from indirect land use change) – we do not that land conversion is higher under the less pro-environment scenario with lower technology diffusion, due to the lower levels of yield growth – which tend to offset land expansion. By contrast, within a scenario in which there is more attention to environmental outcomes, there are greater efforts to achieve production growth through productivity increases, so

as to avoid conversion of land cover and loss of biodiversity and other important dimensions of ecosystem and environmental quality.

- We also explored some general principles of biofuel policy design, that draw from insights generated by recent literature on bioenergy policy and potential in East Africa, as well as from analysis carried out in countries in Sub-Saharan Africa that aspire to growth their biofuel sector, like Tanzania does. Among these insights, were the following:
  - A successful biofuels sector needs to achieve economies of scale in the production of a sufficient quantity of feedstock at high levels of productivity. The feedstock productivity levels are essential for achieving manageable costs for the sector to remain profitable into the future
  - There must also be sufficient demand generated for the final biofuel product, as well as for the feedstock product that will be used for processing. This requires there to be certainty that feedstock producers will be able to find buyers for their agricultural goods – and that the biofuel blenders will be able to find a stable and remunerative market for the blended product. Un-ambiguous and clear government policy is needed to attain these levels of certainty, and to attract sufficient investments needed for establishing the infrastructure of the sector, itself.
  - Where domestic demand is insufficient to provide the necessary levels of demand for the biofuels sector – than international markets must be identified and accessible, in order to provide the consistent levels of export demand that are necessary to sustain the sector.
  - Where prices of crude oil and fossil fuel alternatives are at levels which make biofuels uncompetitive, than sufficient levels of subsidies – in the form of tax concessions, direct support to the sector or import taxes are necessary. The feasibility of these will depend on the fiscal ability of the country to sustain continued support over the necessary span of time (before he sector can become self-sustaining, as was the case of Brazil), or the international policy regime (which may penalize trade measures that are deemed too protective).

In addition to this brief project report, we are completing a more comprehensive summary and overview report of the effect of alternative policies and scenarios on Tanzania's agricultural growth and biofuel potential. This will be shared with ZALF and the rest of the research consortium, and will be used as a basis for a special journal issue submissions, as well as for further analytical work in this area.

II. Principle sources of data and key methodologies utilized:

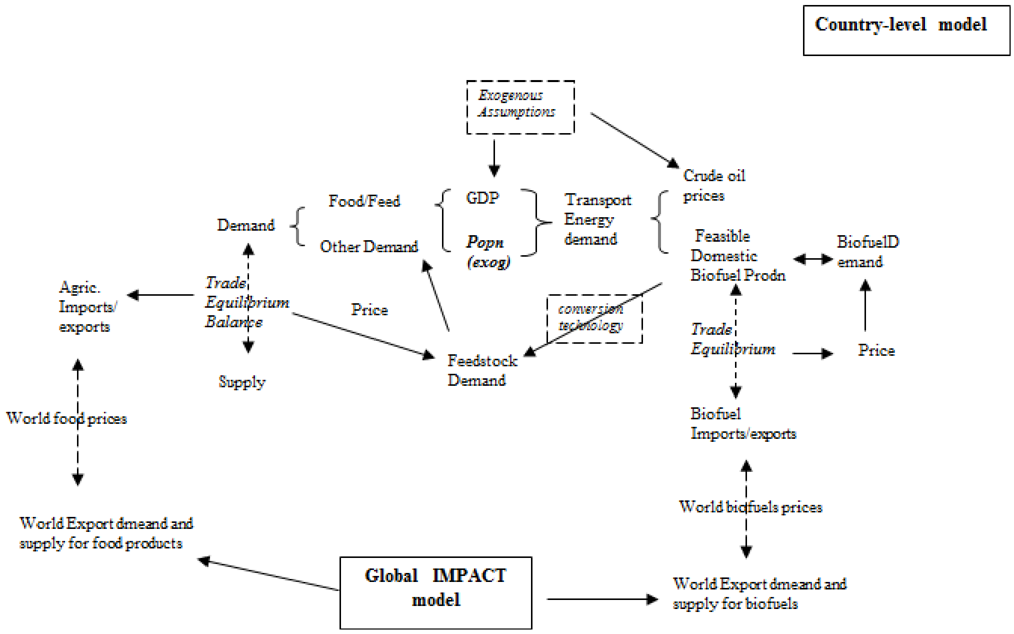
In order to carry out the quantitative analysis that was embedded in the workplan of IFPRI, within this project, a number of data sources had to be utilized, in order to expand the modeling framework for Tanzania to account for sub-regional details, as well as to incorporate the impacts of biofuels. The key sources of data that are used within the analytical model can be summarized as follows:

- Country -level commodity balances for supply, utilization and trade that cover all of the major livestock grain, pulse, root & tubers, vegetable/fruit and oilseed crops that are covered in the IMPACT model.
- The disaggregation of area and yield between irrigated and rainfed crops is drawn from data provided by IFPRI's spatial analysis team (see www.harvestchoice.org for details of these data products), as well as secondary sources such as FAO's Aquastat database and the spatial information on irrigated crops provided by Petra Doll and others at Frankfurt University (see: http://www.geo.uni-frankfurt.de/ipg/ag/dl/datensaetze/1_irrigation_map/index.html)
- The disaggregation of land between arable cropland, shrubland, grassland and other types of land cover is based on GLC2000 data that was further processed by the research team of Ximing Cai and colleagues (see Cai *et al*. 2011 for details).

Other details of the IMPACT model are contained in Appendix B of this report.

The simulation of alternative scenarios and policies was carried out by a simplified, national-level, multi-market model that accounts for sub-regional production and consumption, within Tanzania, and which is linked to the global-level commodity markets through the price effects that are simulated by the IMPACT model – which also simulates the total net exports of biofuel feedstock crops from the US and other biofuel-producing countries into international markets. The country-level multi-market model and the global IMPACT models are, in effect, connected through international prices and trade flows, such that changes in OECD policy of biofuels result in a different pattern of agricultural production and exports from the US and other countries, that are then felt on the world market by countries such as Tanzania. The schematic of this linkage is shown in Figure 1 below.

Figure 1: Linkages between the global and country-level models



As is shown above, the international land use change effects that arise from changes in US domestic biofuel policy is simulated by the IMPACT model, whereas the Tanzania multi-market model simulates the biofuel-driven market effects that occur within the various sub-regions of Tanzania. As will be discussed in greater detail, later in the paper, there are some limitations with the 'soft' linkage between the two models, as full integration with simultaneous feedback of price effects was not possible within the timeframe of the project. There are also some differences in the structural simulation of price transmission and trade outcomes, between the models, as well as in the treatment of price expectations by agricultural producers over the projection horizon. Notwithstanding these limitations, however, the combination of these two models and their market components still serve to define the total global environmental effects on land use that are of such concern to many researchers looking at the long-term sustainability of agricultural and energy policies within aspiring biofuel producers like Tanzania.

III. Key project activities in Jan 2011-Feb 2012 period:

A brief synopsis of research and outreach activities that have been undertaken by IFPRI staff in the reporting period of Jan 2011 to Feb 2012, are summarized as follows:

- Continued development of a country-level, multi-market model for Tanzania that has sub-national disaggregation of production and consumption, across administrative regions and all key crops. This entailed:

  - Collection of sub-national data from secondary sources
  - Coding of model equations in GAMS and organization of data and data-processing procedure
  - Calibration of model to existing data and comparison of projections to available data
- Finalization of alternative scenarios to be used in global and country-level scenarios
- Continued development of the global biofuels model in IMPACT, to be linked to country-level simulations
- Participated in final Better-iS project workshop, held in Bagamoyo, Tanzania, 5-9 December 2011. Made presentation on climate change and bioenergy impacts in East Africa and Tanzania – and chaired/moderated session of workshop on climate change adaptation
- Made further revisions to modeling, based on comments received at project meeting. Generated updated scenario results from the IMPACT model, and for use in country-level model
- Finalized revision of book chapter on biofuel impacts in Africa, forthcoming in 2012, based on insights from the project.
- Policy paper to be written, based on model outputs and ongoing dialogue over appropriate biofuels policy in Africa.

The combination of the developments listed above helped to build a comprehensive framework within which to examine the research questions of the project.

IV. Planned future activities based on project outputs

In addition to the outputs that were generated within the timeframe of the project, a number of future extensions and activities are already foreseen – which build directly upon the tools, methodology and lessons learned in the course of the project. Below, a few of these are listed:

- An additional journal paper which deals more directly with the policy dimensions of biofuels policy in Tanzania, to accompany other outputs which focus more on the technical aspects of the model-based assessment and the major results
- Further efforts to improve the country-level multi-market model, which will likely carry over into the 'GLOBE' project which will be commencing soon in Tanzania
- Other synthesis papers which will look at the food security dimensions of biofuels in Tanzania, which will be used for publications within IFPRI, as well as other outlets.

There will likely be other opportunities for extending the work done under this project that have not yet been realized, based on feedback that will come as the publications that are 'in the pipeline' are released, circulated and commented on by members of the agricultural and environmental policy research community.

V. Financial Narrative:

All expenditures for the project (implemented under project number gtz07.7860.5-001.00) were made according to the original IFPRI and project budget, and will be documented in separate financial reporting, as per the contract agreement.

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Appendix A: Tables and Figures

Table 1. Research Staff Participating in Project

Researcher	Affiliation	Activities Undertaken
Siwa Msangi*	Senior Research Fellow, EPTD	research management, simulation analysis and model modifications
Miroslav Batka	Research Assistant, EPTD	Data collection and analysis
Simla Tokgoz	Research Fellow, EPTD	Global biofuels model development
Wei Zhang	Research Fellow, EPTD	Global biofuels model development
Alex Hansen	Stanford University, Earth Systems Program	Project consultant – data collection, Tanzania model development and literature review
Amarachi Utah	American University, Economics program	Project intern and consultant – collection of data, literature review and documentation

* team leader

Appendix B: The IMPACT Model

1. Introduction

The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) was developed in the early 1990s to contribute towards the discussion over what actions are required to meet the future needs for food and feed in the world, reduce malnutrition, and maintain strong levels of agricultural growth and productivity (Rosegrant et al., 1995). In 2002, the model was expanded through inclusion of a Water Simulation Model, as water was perceived as one of the major constraints to future food production and human well-being (Rosegrant, et al., 2002). This augmentation led to the name “IMPACT-WATER”, although we will continue to refer to it as IMPACT in the following description.

2. Model structure and data

The IMPACT model combines an extension of the original International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) with a global water simulation model, based on extensive and state-of-the-art global water databases (Rosegrant et al., 2002). The water module projects the evolution of availability and demand, with a base year of 2000 (average of 1999-2001), taking into account the availability and variability in water resources, the water supply infrastructure, and irrigation and non-agricultural water demands, as well as the impact of alternative water policies and investments. Water demands are simulated as functions of year-to-year hydrologic fluctuations, irrigation development, growth of industrial and domestic water uses, and environmental and other flow requirements (committed flow). Off-stream water supply for the domestic, industrial, livestock, and irrigation sectors is determined based on water allocation priorities, treating irrigation water as a residual; environmental flows are included as constraints.

The “core” of IMPACT is its food module is specified as a partial-equilibrium, multi-commodity market model, which has global coverage over 115 countries or regions. For each of these regions, supply, demand and prices for agricultural commodities are determined for 32 crop, livestock, and fish commodities, including all cereals, soybeans, roots and tubers, meats, milk, eggs, oils, oilcakes and meals, sugar and sweeteners, fruits and vegetables, and low-value and high value fish. The model is solved annually, by determining a static, global equilibrium in which the net trade in each commodity is balanced at the global level (see Figure B1), and key parameters updated for each time step. The 115 country and regional spatial units are further intersected with 126 river basins—to allow for a better representation of how sub-regional variation in production is driven by available water supply—generating results for 281 Food Producing Units (FPUs). Crop harvested areas and yields are calculated based on crop-wise irrigated and rainfed area and yield functions. These functions include water availability as a variable and connect the food module with the global water simulation model.

The “food” side of the IMPACT 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 investments.

IMPACT projects the share and number of malnourished preschool children in developing countries as a function of average per capita calorie availability, the share of females with secondary schooling, the ratio of female to male life expectancy at birth, and the percentage of the population with access to safe water (see also Rosegrant et al., 2001; and Smith and Haddad, 2000).

The “water” side of the IMPACT model interacts with the “food” module by simulating the reductions in area and yield that result from deficits in water supply – given that the total water requirements for maximum potential yield may not be met, given other non-agricultural demands for water that must be satisfied within the given basin. Whereas the “food” model simulates trade in a non-spatial way, the “water” model allocates water in each spatial unit, according to the crop irrigation, livestock, industrial and municipal demands that are projected. A simple schematic showing the linkage of the “food” and “water” modules of IMPACT is provided in Figure B2.

The model is written in the General Algebraic Modeling System (GAMS) programming language and manages all of its data in Microsoft excel, with a convenient interface to GAMS. The underlying solution for IMPACT is found by solving for a fixed point, through the use of the Gauss-Seidel algorithm. This procedure minimizes the sum of net trade at the international level and seeks a world market price for a commodity that satisfies market-clearing conditions. IMPACT generates annual projections for irrigated and rainfed crop area, yield, production, demand for food, feed and other uses, prices, and trade; and livestock numbers, yield, production, demand, prices, and trade. IMPACT, through its water module, also generates projections for irrigation, livestock, and nonagricultural water withdrawals and depletion.

The model incorporates data from FAOSTAT (FAO 2003), commodity, income, and population data and projections from the World Bank (World Bank 2000), the Millennium Ecosystem Assessment (MA, 2005), and the UN (UN 2008) and USDA (USDA 2000), a system of supply and demand elasticities from literature reviews and expert estimates (see Rosegrant et al. 2001), and rates for malnutrition from ACC/SCN

(1996)/WHO (1997) and calorie-child malnutrition relationships developed by Smith and Haddad (2000).

Table B1: Overview of major components in IMPACT

IMPACT	
Model structure	• Based on partial equilibrium theory (equilibrium between demand and supply of all commodities, while factors of production respond exogenously) • Underlying sources of growth in area/numbers and crop productivity • Algebraic supply and demand functions for commodities, specified with elasticities of response to income and price, so that interactions of complementarity and substitution can take place. Also price-based response of yield to key factor inputs (labor and fertilizer). • Interactive connection between Water and Food modules provided by a one-way response to levels of water availability simulated by the water module
Parameters	Input parameters • Base year, 3-year centered averages for area, yield, production, numbers for 32 agricultural commodities and 115 countries and regions, and 281 Food Producing Units • Elasticities underlying the country and regional demand and supply functions • Commodity prices • Key Drivers of socio-economic, biophysical and technological change Output parameters • Annual levels of food supply(production, area and yield), demand (for food and feed), trade, international food prices, calorie availability, and share and number of malnourished children. Also water supply and demand (withdrawals and depletion), both agricultural and nonagricultural.
Driving Force	Economic and demographic drivers • Income growth (GDP) • Population growth Technological, management, and infrastructural drivers • Productivity growth (including management research, conventional plant breeding) • Area and irrigated area growth • Livestock feed ratios • Changes in nonagricultural water demand • Supply and demand elasticity systems Policy drivers, including commodity price policy as defined by taxes and subsidies on commodities, drivers affecting child malnutrition, and food demand preferences, additional crop feedstock demand for biofuels
Initial Condition	• Baseline – 3-year average centered on 2000 of all input parameters and assumptions for driving forces
Model operation	• Gauss-Seidel algorithm to find a fixed point where net trade sums to zero • Implemented within the GAMS programming language with necessary data in Excel formatted files

3. Some Applications of IMPACT

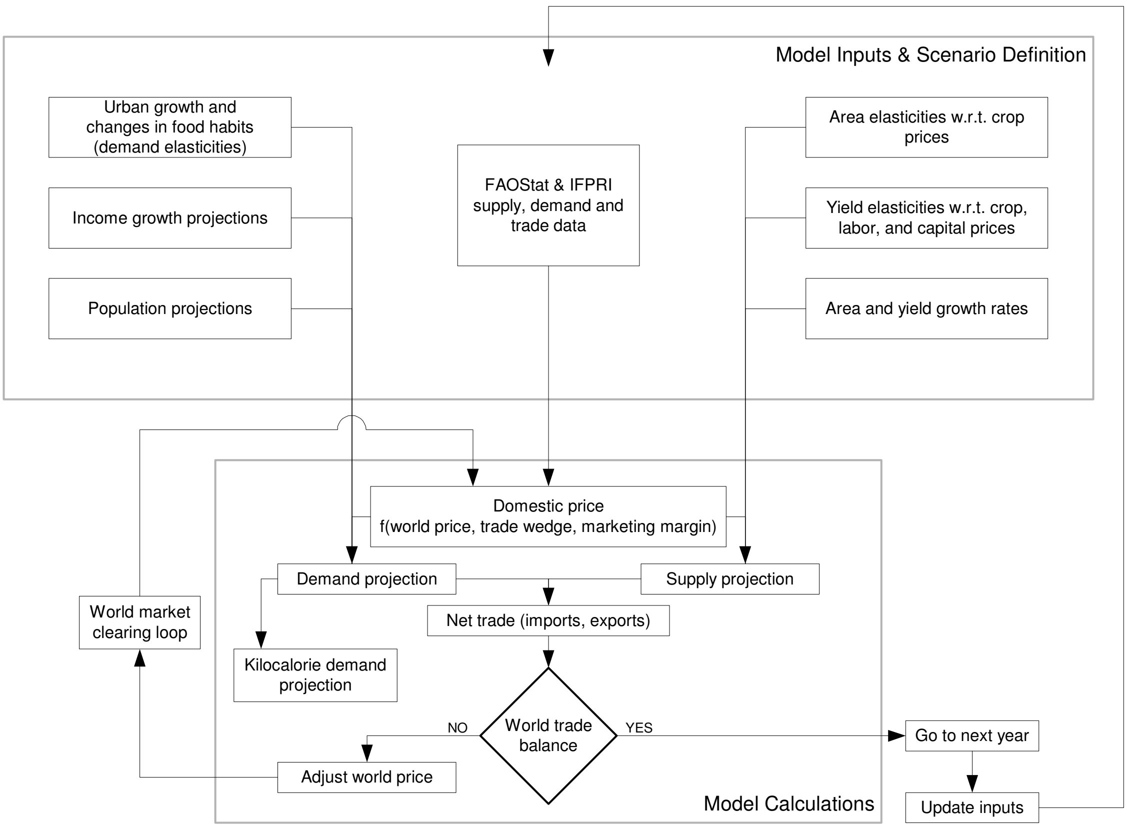
IMPACT has been used for analyzing the current and future roles of agricultural commodities and impacts on food security and rural livelihoods, including the future of fisheries (Delgado et al. 2003); the role of root and tuber crops (Scott, Rosegrant and

Ringler 2000a,b); and the ‘livestock revolution’ (Delgado et al. 1999). IMPACT has also been applied for regional analyses as well as selected country-level studies, for example, China (Huang, Rozelle and Rosegrant 1997); India; Indonesia (SEARCA/IFPRI/CRESECENT 2004), Sub-Saharan Africa (Rosegrant et al. 2005) and Central Asia (Pandya-Lorch and Rosegrant 2000).

IMPACT has also been used to analyze structural changes, including the impact of the Asian economic and financial crisis (Rosegrant and Ringler 2000); longer-term structural changes in rural Asia (Rosegrant and Hazell 2000); as well as dietary changes (Rosegrant, Leach, and Gerpacio 1999); and the water-augmented IMPACT has been used to describe the role of agriculture and water for achieving the Millennium Development Goals (Rosegrant et al. 2005; von Braun, Swaminathan, Rosegrant 2004).

Model runs have been carried out for individual centers of the Consultative Group on International Agricultural Research, the World Bank, the Asian Development Bank; and the model has been used for agricultural scenario analysis of the Millennium Ecosystem Assessment (MA 2005; Alcamo et al. 2005), and is currently being used for the Global Environmental Outlook (GEO-4) assessment carried out by UNEP. Other work includes investigations into regional and global scale impacts of greenhouse gas mitigation in agriculture and theoretical large-scale conversion to organic food production.

Figure B1: Overview of the “food” side of the IMPACT model



COUNTRY AND REGION DEFINITIONS

Developed Countries and Regions

Western World

1. Adriatic: Albania, Bosnia & Herzegovina, Croatia, Greece, Macedonia, Montenegro, Serbia, and Slovenia
2. Alpine Europe: Austria, Switzerland
3. Australia
4. Belgium Luxemburg
5. British Isles: United Kingdom and Ireland
6. Canada
7. Central Europe: Bulgaria, Czech Republic, Hungary, Moldova, Romania, Slovakia
8. France
9. Germany
10. Iberia: Spain and Portugal
11. Italy
12. Netherlands
13. New Zealand
14. Poland
15. Scandinavia: Denmark, Finland, Norway, and Sweden
16. United States

Former Soviet Union (FSU)

17. Baltic: Belarus, Estonia, Latvia, Lithuania, and Russia
18. Caucus: Armenia, Azerbaijan, and Georgia
19. Kazakhstan
20. Kyrgyzstan
21. Russia
22. Tajikistan
23. Turkmenistan
24. Ukraine
25. Uzbekistan

26. Israel
27. Japan
28. South Africa

Developing Countries and Regions

Central and Latin American

29. Argentina
30. Brazil
31. Carribean_Central_America: Costa Rice, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Dominican Republic, Haiti, Cuba, and Belize
32. Central_South_America: Bolivia and Paraguay
33. Chile
34. Colombia
35. Ecuador
36. Mexico
37. Northern_South_America: French Guiana, Guyana, Suriname, and Venezuela
38. Peru
39. Uruguay

Sub-Saharan African

40. Angola
41. Benin
42. Botswana
43. Burkina Faso
44. Burundi
45. Cameroon
46. Central African Republic
47. Chad
48. Congo
49. Djibouti
50. DRC: Zaire
51. Equatorial Guinea
52. Eritrea
53. Ethiopia
54. Gabon
55. Gambia
56. Ghana
57. Guinea
58. Guinea-Bissau
59. Ivory Coast
60. Kenya
61. Lesotho
62. Liberia
63. Madagascar
64. Malawi

65. Mali
66. Mauritania
67. Mozambique
68. Namibia
69. Niger
70. Nigeria
71. Rwanda
72. Senegal
73. Sierra Leone
74. Somalia
75. Swaziland
76. Tanzania
77. Togo
78. Uganda
79. Zambia
80. Zimbabwe

West Asia and North Africa (WANA)

81. Algeria
82. ***Cyprus***
83. Egypt
84. Gulf: Kuwait, Oman, Saudi Arabia, United Arab Emirates, and Yemen
85. Iran
86. Iraq
87. Jordan
88. Lebanon
89. Libya
90. Morocco
91. Sudan
92. Syria
93. Turkey
94. Tunisia

South Asian

95. Afghanistan
96. Bangladesh
97. India
98. Nepal
99. Pakistan
100. Sri Lanka

Southeast Asian

101. Bhutan
102. Indonesia
103. Malaysia
104. Myanmar
105. Papua New Guinea
106. Philippines
107. Southeast Asia: Cambodia and Laos
108. Thailand
109. Vietnam

East Asia

110. China
111. Mongolia
112. North Korea
113. Singapore
114. South Korea

115. Rest of the world: Alaska, Andorra, Antarctica, Bahrain, Brunei, Fiji, Gaza Strip, Greenland, Iceland, Jamaica, Lichtenstein, New Caledonia, Puerto Rico, Qatar, San Marino, Solomon Islands, Vanuatu, and West Bank

COMMODITY DEFINITIONS

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 containing 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 both food and feed uses.)
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. It is not traded internationally in its fresh state because tubers deteriorate very rapidly).
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 or pellets) and yams (A starchy staple foodstuff, normally eaten as a vegetable, boiled, baked or fried).

14. 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).

15. Oils: vegetable oils and products, animal fats and products (Obtained by pressure or solvent extraction. Used mainly for food).

16. 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. soya milk, meat, etc.

Vegetables and Fruits

17. 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 chicory); melons, cantaloupes; mushrooms; okra; onions, dry; onions, shallots (green); peas, green; pumpkins, squash, gourds; spinach; string beans; tomatoes, fresh; watermelons.
18. Tropical and Sub-Tropial Fruits: avocados; citrus fruit nes (including inter alia: 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.
19. Temperate Fruits: apples; apricots; berries, nes (including inter alia: 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

20. 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 and consist either wholly or essentially of sucrose.

21. 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 and consist either wholly or essentially of sucrose.

22. 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.

23. Millet: This is a dryland cereal which was previously aggregated into "other grains" in earlier versions of IMPACT. It has now been disaggregated for further policy analysis with ICRISAT

24. Sorghum: This is a dryland cereal which was previously aggregated into “other grains” in earlier versions of IMPACT. It has now been disaggregated for further policy analysis with ICRISAT

25. Chickpeas: This is a dryland pulse crop which is usually aggregated into “pulses” in most models. It was added to IMPACT, for further policy analysis with ICRISAT

26. Pigeon peas: This is a dryland pulse crop which is usually aggregated into “pulses” in most models. It was added to IMPACT, for further policy analysis with ICRISAT

27. Groundnuts: This is an important crop for both human consumption, and is sometimes used as animal feed. A substantial portion of groundnuts is used for oil, while direct consumption is mainly for use in confectionary products. It has now been disaggregated for further policy analysis with ICRISAT, as it is an important crop in dryland regions.

28. Cotton: This is the first fibre, non-food crop introduced into IMPACT. Because of its importance as a cash crop in many countries, and its competition for agricultural area with other food crops, we have included it in IMPACT.

29. Other: This is comprised of other miscellaneous crops not covered by the categories above, but which make up a significant portion of the water consumption in agriculture. The composition of this category varies from country-to-country, but consists of some plantation crops and ‘other pulses’ not covered in the previous classifications.