Modeling Tools for Agricultural Development Interventions: A Review of Tools and Research Models

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The purpose of this research request is to review research and decision-making tools that model the impacts of agricultural interventions. We begin with a short explanation of what model features are being described. A table summarizing these differences is Appendix 1. We then review decision-support tools and user-end modeling tools (menu-driven tools with an interface designed for easy use), as well as academic and professional research models for assessing the potential impacts of agricultural interventions. This review also includes decision tools and models for analyzing agricultural and environmental policies outside of technology impacts in Sub-Saharan Africa and South Asia. The other tools mentioned here, for example a tool that considers nutritional intervention impacts, are included to help provide a broader understanding of the structure and availability of user-end, decision-making tools. In the final section of this brief, we review the most complex models used more in academic research than for in-field decision-making.

Search terms used in this request included a combination of terms including: agricultural decision-making tools, impact assessment models, economic impact models, gross margin models, agricultural intervention impact models, impact modeling, DREAM, farm decision-making tools/models, GIS tools for decision-making, and agricultural assessment models.

Model Characteristics

The purpose and background of each model or tool is introduced, followed by three sections. The structure section refers primarily to the software behind the model, the data requirements and output measures section reports on required data inputs (e.g. whether secondary datasets or if primary data and a range of variables can be managed) and whether the output measures are physical, such as soil quality or nutrient levels, or economic, such as prices or changes in consumer value or producer profit. The final section describes the intended or most likely users of the models and tools described. This document includes links to websites, which provide details on specific decision tools and intervention impact models.

General and Partial Equilibrium Models: One important distinction among models is whether they analyze the economic impact and welfare implications of an activity on a single market, or across multiple markets. General and partial equilibrium models ideally use representative consumer and producer data to model the behavior of supply, demand, and prices in an economy. General equilibrium models specify the economic relationships across multiple goods markets in mathematical terms. These models predict how changes in one market affect variables such as prices, outputs, and economic welfare in another related market, given certain levels of technology, policies, and consumer preferences. In the simplest terms, general equilibrium models seek to find equilibrium prices and quantities for goods in all markets, whereas, partial equilibrium models focus on a particular subset of the economy. In a general equilibrium model, for example, the effect of an above average wheat yield would be examined by looking at changes in prices and quantities in the local wheat market and other markets likely to be affected (e.g. the sorghum market or wheat import market that provide substitute crops, or the labor market that provides seasonal agricultural labor). In a partial equilibrium model, only the effect on the wheat market is considered. Hareau, Norton, Mills, and Peterson (2005) used a general equilibrium model to analyze the welfare effects associated with transgenic technologies for both the irrigated and non-irrigated rice ecosystems in Asia. Elbehri and MacDonald (2004) used a general equilibrium model to analyze the impacts of introducing bt cotton on West and Central Africa.

Decision-support Systems

Decision-support systems are practical tools for decision-making typically comprised of databases, economic analysis software packages, environmental impact packages, a user-friendly interface, data uploading tools, and simple graphical and numeric displays of the results. The Food and Agricultural Organization (FAO) has a "Decision Support Tools" webpage for agricultural technology that lists electronic support tools that enable planners, researchers and extension agents to make informed decisions and interventions regarding technology assessment, transfer, validation, adaptation and adoption. Although most of the tools are not designed to model the impact of agricultural interventions, they provide examples of how user-end, decision support tools are designed and used in practice. The page lists the International Food Policy Research Institute (IFPRI)'s DREAM model, which we reviewed previously (EPAR Brief No. 95), as well as:

<u>Labor Saving Technologies and Practices Decision Support Tool:</u> The purpose of this tool is to enable rural communities to identify and assess labor saving technologies and practices which can reduce or spread the workloads and improve their livelihoods. It is of particular relevance to communities where a shortage of labor or other sources of power is undermining household food and nutrition security, and the sustainability of rural livelihoods.

> *Structure:* Online catalogue.
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> *Data requirements and output measures:* This catalogue provides information and ideas, rather than an economic modeling tool.
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> *Intended Users:* Government staff, local NGO staff, members of community organizations.

<u>Financial Tool for Bamboo and Rattan Business:</u> A simple financial tool for studying the viability of bamboo and rattan businesses. It provides an example of how a simple spreadsheet tool can be used in decision making.

> *Structure:* Excel spreadsheet, available on the FAO's website.
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> *Data requirements and output measures:* Users enter data on sales, prices, production, market environment, operating expenses, borrowing, depreciation, etc. The spreadsheet calculates a three-year balance sheet showing assets and liabilities, given the data entered by the user.
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> *Intended Users:* Researchers, NGO staff, community-based organizations, and others looking into the viability of bamboo and rattan businesses. Some familiarity with Excel is likely needed.

The tools referenced above are available on the FAO's "Decision Support Tools" webpage here: http://www.fao.org/teca/content/decision-support-tools

Decision Support System for Agrotechnology Transfer (DSSAT): The International Center for Soil Fertility (IFDC) has a report titled "Decision Support Tools for Smallholder Agriculture in Sub-Saharan Africa: A Practical Guide." The report provides case studies of how DSSAT and other decision-support systems can be used to analyze options for alternative agricultural management systems and the diffusion of new technologies to smallholder farmers in Sub-Saharan Africa. DSSAT is a software package and decision-support system that combines crop, soil, and weather data to simulate multi-year outcomes of crop management strategies for different crops at any location where data is available. Versions of the DSSAT crop simulation model have been in existence for over 15 years.

> *Structure:* The model is available by purchase ($1,000-$1,200 for an institution). System requirements include: computer running MS-Windows, Pentium2 with 128MB RAM minimal, Pentium4 with 512MB RAM recommended, CD-Rom Drive, and 300MB of free hard disk space.
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> *Data requirements and output measures:* Minimum data from the user includes: weather data (air temperature, rainfall, etc.), soil data (soil classification, surface slope, soil color, permeability, and drainage class), and management/experimental data (information on planting date, dates when soil conditions were measured prior to planting, planting density, row spacing, planting depth, crop variety, irrigation, and fertilizer practices). The DSSAT model output files include an overview of input data and conditions, simulated crop performance, and simulation results including daily growth and development, water balance, and balance of main plant nutrients.
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> *Intended Users:* Professional researchers with intermediate to advanced knowledge of modeling tools.

More information on the DSSAT tool, as well as information on purchasing the tool, can be found here: http://www.icasa.net/dssat/minimum.html

Other tools in the IFDC report can be reviewed here: pdf.usaid.gov/pdf_docs/PNACW808.pdf

The FAO's website also lists several decision-tools under development to evaluate the impact of policy interventions specifically associated with livestock policy including:

Sheep Industry Gross Margin Model: This program, housed by one of Australia's leading sheep industry organizations, provides an interesting example of a user-end, gross margin decision-making tool designed for farmers and extension officers. The Sheep Industry Gross Margin Model is intended to serve as a budgeting, management, and planning tool for sheep farmers.

> *Structure:* The model is available for download on the Sheep CRC website. It operates in Excel, uses macros and has only been developed in a PC version.
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> *Data requirements and output measures:* Users enter a series of farm-level information into an Excel spreadsheet including data on number of livestock, feed supply, animal health, cost of livestock management, labor, wool, etc. The model calculates gross margins on sheep enterprises, given different cost, price, and management scenarios. Gross margin is the difference between sales and costs excluding fixed costs divided by total sales revenue. This measurement shows the proportion of each dollar that a business enterprise retains as profit.

Intended Users: Sheep farmers, extension officers, other decision-makers in sheep farm management.

More information, as well as the sheep industry tool, can be accessed here:
http://www.sheepcrc.org.au/industry-tools-and-information/software/gross-margin-model.php

EXTRAPOLATE (EX-ante Tool for RAnking POLicy AlTErnatives): A user-end, participatory tool designed to help evaluate the impacts of different livestock policy measures. The tool is currently being field tested in FAO Pro-Poor Livestock Policy Initiative (PPLPI) focus areas including exploring the impact of policy change in the dairy sector in Uganda, the small ruminant sector in Andhra Pradesh and Senegal, the pig sector in Vietnam and the alpaca and llama sector in Peru. An example is helpful in explaining how this model can be used. In Kenya, the EXTRAPOLATE model was used to analyze the potential impacts of using a Lactoperoxidase system (LPS) as a milk preservation technique for farmers with poor market access. The purpose of running the model was to assess the impacts of the policies on the livelihood status of the stakeholder groups. Users "score" constraints according to the relevance for each group, indicate how strong each of the outcomes may be on livelihood status of the defined groups, and enter information on how the policies might impact the constraints (e.g. what will implementing the policies do to farmer milk sales?). The results of the model show how the livelihood status of the defined stakeholder groups are impacted by the implementation of the two policies analyzed in this example.

Structure: Software program that can be downloaded to a personal computer. The various elements in the model included information about stakeholders (e.g. groups, livelihood characteristics), constraints (e.g. legal considerations, gender issues, costs), outcomes (e.g. household milk consumption, profitability, milk sales), and policies being investigated (e.g. local policies to promote use of LPS and legalization of LPS for international trade).

Data requirements and output measures: The model is not readily available for use and insight into the data requirements and outputs is limited to the information on the FAO's website. According to the FAO, the tool is intended to serve as a "filter" that allows the user to evaluate, in an ex-ante fashion, alternative policy measures using three main sub-models. The first sub-model is based on the stakeholder livelihood status. The second is linked to a sustainable livelihoods capital asset framework. The third allows the user to define variables for the analysis.

Intended Users: May include in-field decision-makers, researchers, project managers, NGOs, and community-based groups. Currently, being used at the FAO field sites mentioned above.

More information on the EXTRAPOLATE model can be accessed at the FAO website:
http://www.fao.org/ag/againfo/programmes/en/pplpi/dsextra.html

The Technology Impact and Policy Impact Calculation Model (TIPI-CAL v4.0): A household-level, decision-support tool developed to analyze the impacts of technology and policy changes on farm households for up to a 10-year period. The purpose of the tool is to provide PPLPI decision-makers at the FAO with a tool for analyzing the impacts of technology and policy changes on farm households.

Structure: Unclear as the model is not readily available on the FAO website.

Data requirements and output measures: The model is not readily available for use and insight into the data requirements and outputs is limited to the information on the FAO's website. According to the FAO, the model is a dynamic farm production and accounting model that covers all economic activities within rural households, at farm (e.g. dairy, crop, and other farm enterprises such as goat and sheep rearing or fish farming) and off-farm levels. More specifically, the model can represent five different categories of family labor, various types of farm assets, a maximum of ten off-farm activities, and six types of living expenses. The user has the option to specify the share of returns used for home consumption. The outputs of the model pertain to the potential impacts of changes in technology and policy on farm production and income.

Intended Users: FAO staff.

More information on this tool can be found on the FAO's website:
http://www.fao.org/AG/AGAInfo/programmes/en/pplpi/dstipical.html

We also found decision-support tools that model agricultural technology and management practices in the United States, specifically. These tools include programs designed to help evaluate decisions including farm expansion plans and agricultural management techniques. These models prove helpful in understanding the way that decision-support tools are designed and used in agricultural decision-making; however, they may not provide the capability needed to model impacts of agricultural interventions in developing countries. One example of these types of models is:

GPFARM (Great Plains Framework for Agricultural Resource Management): A decision-support tool and farm simulation model that brings together data on agronomy, animal science, economics, weed science, and risk management in the Great Plains of the United States. The purpose of the tool is to provide an organized framework for farm/ranch strategic planning related to agricultural resource management. Management options that can be considered using the GPFARM tool include integrated crop-livestock production, crop rotations, grazing, irrigation, tillage practices, and water conservation, among others.

Structure: The model is available on the United States Department of Agriculture's (USDA) website. The tool's main components include: a Windows-based graphical interface, Access databases containing the soil, crop, weed, climate, equipment, chemicals, and economic parameters required by the model, as well as a multi-criteria, decision-making module.

Data requirements and output measures: Users enter a series of information on farm/ranch production systems and management options. After all needed information is entered, the tool provides a summary report with tables and graphs for temporal and spatial comparison of different agricultural management scenarios. The GPFARM output can be viewed within one scenario or across all scenarios. The outputs include expected costs and returns for farm/ranch production.

Intended Users: Researchers, farmers, and others involved in resource management in the Great Plains.

This tool can be reviewed in more detail on the USDA's website:
http://www.ars.usda.gov/Business/docs.htm?docid=6345

More Complex Intervention Impact Modeling Tools

Modeling tools such as DREAM and IMPACT, reviewed previously (EPAR Brief No. 95), are more sophisticated and require considerable data input, knowledge of database systems, and a relatively advanced knowledge of economics and modeling techniques to use them effectively in decision-making. Because the availability of additional user-end tools for analyzing the impacts of agricultural interventions is limited, we review other impact analysis tools here including:

FARMSIM/AfricaNUANCES: FARMSIM is a farm-level decision-making shell of NUANCES (Nutrient Use in ANimal Cropping systems – Efficiencies and Scales). The FARMSIM framework has been adopted and used for decision making in several regions of the world and its use in Africa has been growing. AfricaNUANCES, is a project coordinated by the Plant Production Systems Group at Wageningen University in the Netherlands. The project aims to generate an integrated framework of databases and computer models that can be used to analyze current livelihoods, explore options for development, and reveal trade-offs between objectives farmers are facing in Sub-Saharan Africa. A 2009 study by Tittonell et al. adapts the FARMSIM framework and uses resources from NUANCES to link crop, soil, and livestock simulation models in a farm-level modeling shell. This tool is used to simulate the short and long-term outlook for representative farms in Kenya given alternative livelihood strategies (i.e. farm types). More specifically, the study used the FARMSIM model to evaluate the potential impact of options for gradual and sustainable agricultural intensification. Although the published research paper provides some information on structure and data requirements, the model is not available for immediate use and the specific data requirements are not entirely clear.

> *Structure:* Experimental data and calibrated process-based models are used to generate relationships between the different FARMSIM modules. The program includes the follow modules, which simulate farm-level activity: Crop and Soil ('FIELD'), Livestock ('LIVSIM'), Crop and Soil ('FIELD'), Cash availability ('CASHSIM'), Livestock ('LIVSIM'), Family development ('FAMSIM'), Feed for livestock ('FEEDSIM'), Food availability ('FOODSIM'), Manure handling and storage ('HEAPSIM'), and Labour availability ('LABSIM'). These sub-models incorporate farm-level processes and interactions and operate in different time steps (monthly, daily, etc.). As the study by Tittonell et. al (2009) notes, the FARMSIM models, the data requirements needed can relatively easily be satisfied for most African farming systems.
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> *Data requirements and output measures:* The data inputs and output measures associated with these empirical frameworks are highly dependent on the way the models are structured and used in research. The modeling framework and databases described here are not readily available for download and the data requirements and output will vary considerably. The study by Tittonell et al. (2009) provides a useful example of how the NUANCES databases and the empirical framework described here was structured and used in a professional research study.
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> *Intended Users:* Professional researchers and decision-makers.

The professional research paper by Tittonell et al. (2009) is listed in the references section of this review and more information on AfricaNUANCES can be found on the website: http://www.africanuances.nl/

Model for Assessing the Impact of Nutritional Interventions (MODEXC): A user-end, modeling tool developed by the International Center for Tropical Agriculture (CIAT), with assistance from a BMGF grant, to analyze the impact of nutritional interventions such as biofortification. The model uses the Disability Adjusted Life Year (DALY) framework, an overall measure of disease burden commonly used in public health impact assessments. CIAT's website says the tool allows researchers to assess the impacts of higher micronutrient contents, such as beta-carotene (precursors of vitamin A), iron, or zinc, on human health conditions. MODEXC uses three criteria to determine the economic benefits associated with nutritional interventions: net present value of economic surpluses, internal rate of return of research investments, and benefit--cost analysis.

Structure: The model was developed in Visual Basic® for Applications (VBA), coded in Excel 2000. The current version of the model relies on three worksheets and a combination of menus and submenus. The model can be ordered on the CIAT website; however, we were unable to get access to the full version of this model to review to for this request.

Data requirements and output measures: Researchers use economic surplus models to forecast how the introduction of a new technology might lead to an increase in consumer surplus (improvements in economic well being) and producer surplus (higher than normal/market determined profits). This model calculates changes in producer and consumer surplus associated with a nutritional intervention.

Intended Users: No intended users are stated but it appears that professional researchers in public health and health impact sciences currently use the model.

A user manual, publications, and examples of research can be found on the CIAT website: http://webapp.ciat.cgiar.org/impact/modexc.htm

The Farm Level Income and Policy Simulation Model (FLIPSM): This model is a FORTRAN-based statistical tool that simulates annual economic activities, at the farm-level, given certain price and yield risks. The model was originally used to simulate the impacts of farm policy changes on cotton and wheat farms in the United States in the 1980s and has more recently been used to simulate the impacts of alternative agricultural technologies and policies in Africa and the Philippines.

A brief review of the literature indicates that the model has been used primarily in the United States. During the 2002 farm bill debates, the model was used to analyze over 20 policy alternatives being considered by the House Agricultural Committee. In 1996, the model was used to analyze payoffs to an infection/treatment method for controlling East Coast Fever in cattle.

Structure: The FLIPSIM is available by request from Texas A&M University. The model uses information from farmers to describe a representative farm, ranch, or dairy in a particular region.

Data requirements and output measures: FLIPSIM incorporates data on asset values, debts, costs, machinery, family size and off-farm income in the previous year to calculate values for the current year. Actual farm information is obtained from a panel of farmers in a 3 to 4 hour session during which the panel members provide information on: size of the operation (acres, head, etc.), tenure (acres owned and leased), asset values, enterprises (crops, livestock, dairy, etc.), costs of production for each enterprise, fixed costs for the overall operation, yields and a history of yields and farm program participation, machinery replacement strategies, policy history, etc. The model is capable of simulating a farm with 1-20 crop enterprises and 1-8 livestock enterprises over a 10 year planning horizon for 100 or 500 iterations. The livestock enterprises included are: dairy, cow/calf, cow/calf/retained ownership, stocker steers, beef cattle feedlot, sheep, mohair goats, and meat goats.

Intended Users: Professional researchers and decision-makers use the model to evaluate farm policy options.

More information and examples of its use can be found here: http://www.afpc.tamu.edu/models/flipsim/

Integrated Poverty Assessment for Livestock Promotion (IPALP): A decision-support tool developed by the FAO in collaboration with the University of California, Berkeley, IPALP links national or sub-national computable general equilibrium models with multi-market and household specifications to analyze the impact of interventions affecting the livestock sector and smallholder livestock farmers. According to the FAO, IPALP covers four component areas of economic assessment: (a) analysis of initial macro-economic conditions, (b) micro-economic analysis of initial conditions, (c) dynamic simulation of policies and external economic conditions (e.g. development strategies, trade policy, WTO accession, market reform, tax policies), and (d) micro-economic assessment of policies, in accordance with national and international policies and market forces, to identify patterns of local economic adjustment and their implications for poverty alleviation. The model was used to analyze the impacts of an economy-wide policy of WTO-style trade liberalization, with and without concomitant livestock promotion using a national and sub-national accounting matrix.

Structure: Unclear as the model is not readily available on the FAO website.

Data requirements and output measures: The model is not readily available and information is limited to the description on the FAO website.

Intended Users: Researchers and FAO staff.

More inormation can be accessed on the FAO's website here:
http://www.fao.org/AG/AGAInfo/programmes/en/pplpi/dsipalp.html

Global Trade Analysis Project (GTAP): GTAP is a project at Purdue University that offers access to computer code for GTAP models, as well as related databases and software. The standard GTAP model is a multi-region, multi-sector, computable standard general equilibrium model (with some applications to partial equilibrium analysis) that assumes perfect competition and constant returns to scale. The GTAP model has been used for a variety of applications (agricultural analysis, trade, labor markets, etc). For example, it has been used to analyze the trade and distributional impacts of GM crops in India and the potential impacts of a free trade agreement between the United States and Korea.

Structure: The GTAP website has information on accessing computer code, software, and databases. Given that these models and databases serve as a starting point for academic researchers, the inputs are highly dependent on the project for which they are being used and the model/database combinations being used.

Data requirements and output measures: The GTAP project provides code for models, databases, and software. Therefore, the data requirements and outputs are highly dependent upon the type of custom model that is built using the available resources. Data used in these models likely includes information on producers, consumers, prices of goods, quantities consumed, taxes, economic constraints, etc.

Intended Users: Professional and academic researchers as a starting point for designing custom econometric models. The models are not designed to be easy-to-use, user-end, decision-making tools.

More information can be found here: https://www.gtap.agecon.purdue.edu/

Trade-off Analysis Project, Oregon State University and Montana State University: The TOA Project is a collaborative academic effort to provide modeling tools to support informed policy decision-making related to economic, environmental and health tradeoffs in agricultural systems and the quantitative analysis of agricultural system sustainability. The standard TOA model serves as an agricultural policy decision-making tool designed to quantify tradeoffs among key sustainability indicators under alternate policy and technology conditions. Trade-off analysis models can range from simple decision-support tools to complex, econometric models of trade-offs in agricultural and environmental policy analysis. The TOA Project, run by researchers at Oregon State University and Montana State University, provides a modeling framework designed to use economic, environmental, and agricultural data and models at field scale (e.g. farming region) and aggregate economic and environmental outcomes to allow for analysis of economic/environmental tradeoffs. This framework has been used in numerous academic publications to analyze the potential impacts of alternative agricultural management practices, as well as interventions.

The TOA has been used for a range of agricultural studies. For example, it was used to analyze tradeoffs among net revenues, pesticide leaching, and health risks in the Carachi Province in Ecuador from introducing an Integrated Pesticide Management (IPM) system.

Structure: The standard TOA model is available by download on the project website. The models "use spatially-explicit econometric simulation models linked to spatially-referenced bio-physical simulation models to simulate land use and input use decisions and their impact on the environment, poverty, human health, and food security." The TOA can be thought of as a shell, which contains multiple models and requires users to enter data to define tradeoffs and scenarios. The tool incorporates several models including: the DSSAT suite of crop models, Century model for carbon sequestration (process through which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in and soils), the WEPP model for estimating erosion, models linking pesticide use and management with human health, GIS components, and several other elements. The main part of the TOA model lists the primary steps for setting up a study including: model estimation, sample field, define scenario, define tradeoff, run simulation, environmental impact, aggregation, and graph.

Data requirements and output measures: All data in the model is entered by the user. Typically, field level survey data is needed. However, the model guide states that the specific data requirements depend on the analysis being performed. An alternative approach does not simulate field management for the survey fields but draws fields out of the "total population of fields." As a result, the selection of fields for the simulation runs will always be a representative sample for the region, but the data requirements are large, as data for all fields is needed. The model's output provides graphical representations of tradeoff curves. In the IPM study in Ecuador, for example, the results include tradeoff curves showing a comparison of tradeoffs between leaching and net revenues when an IPM system is used versus a base case management system scenario. Another chart represents the effect of tillage erosion on the tradeoff curve by comparing leaching and value of production in a no tillage erosion scenario and a with tillage erosion scenario.

Intended Users: Like the GTAP tools, the TOA resources are not designed to be simple, user-end decision-making tools. Rather, TOA provides resources and modeling tools for professional researchers to build custom econometric models for analyzing tradeoffs related to agricultural system sustainability.

A more detailed explanation of the model and demos are available here: http://www.tradeoffs.nl/

Other trade-off analysis models exist in the literature. For example, Tittonell et al. (2007) use an inverse modeling technique to analyze the trade-offs among resource productivity, resource use efficiency, and conservation patterns for a maize farm in western Kenya.

Ex-Post Academic Research Models

Several of the papers discussed below provide examples of academic and professional research methods used to evaluate agricultural intervention impacts. The models used in these and other academic and research publications are often not available for public use and are typically designed to evaluate intervention impacts ex-post.

Computable General Equilibrium Models: IFPRI provides a manual to contribute to and facilitate the use of computable general equilibrium (CGE) models in the analysis of issues related to food policy in developing countries and GAMS (the General Algebraic Modeling System), a CGE modeling framework. The manual provides a detailed explanation of standard CGE models, a description of how they can be used to analyze food security issues, as well as a CD-ROM that includes the GAMS software (free demo system), the GAMS input files for the model, sample databases, simulations, solution reports, and a social accounting matrix aggregation computer program. The GAMS code gives the users (most likely professional and academic researchers) considerable flexibility in model specification.

IFPRI's model is written for application at the country level but it can be applied to a region within a country (such as a village) or to a farm household involved in production and consumption activities. The model incorporates features developed over recent years through IFPRI's research projects. Features include incorporating household consumption of non-marketed ("home") commodities, explicit treatment of transaction costs for commodities that enter the market sphere, and a separation between production activities and commodities that permits any activity to produce multiple commodities and any commodity to be produced by multiple activities. GAM software, input files, sample databases, and user manual can be found on the IFPRI website located here: http://www.ifpri.org/publication/standard-computable-general-equilibrium-cge-model-gams-0

Ex-post Impact Assessment (epIA) Models: These types of assessment models attempt to measure the impacts of an earlier program or project intervention. The literature on epIAs range from macro-oriented analysis that consider the impact of agricultural technologies or policies on aggregate economic return to micro-oriented analysis that consider the disaggregated (e.g. across industries, households, income classes, etc.) economic return of specific technologies or policies. CGIAR provides a helpful report, "Strategic Guidance for Ex Post Impact Assessment for Agricultural Research," which provides a comprehensive explanation of epIA models, a typology of epIA impact assessments in agricultural research, a step-by-step guide to conducting epIA studies, and numerous examples of ex-post assessment methods for agricultural research and development. The report outlines, for example, how an epIA model was used to assess the impact of introducing a new soybean variety in the Philippines and map out the impact of the technological change on initial users and later users, as well as show community-level impacts. This complete guide can be accessed through the FAO's website here: http://www.fao.org/docrep/011/i0276e/i0276e00.HTM

Double Difference Method: This approach compares the relative changes in metrics of interest both over time and between different populations (one intervention treatment group and one control group) to establish how trends have been influenced by an intervention. A helpful article by Martin Ravallion at the World Bank, "The Mystery of Vanishing Benefits: An Introduction to Impact Evaluation," provides a detailed explanation of double difference methods, as well as examples of impact evaluation studies that employ this method. An IFPRI paper by Omilola (2009) provides an example of how the double difference method can be used to analyze the impacts of agricultural interventions. Omilola explores the impact of new agricultural technology on poverty reduction by comparing adopters and non-adopters of the technology (a combination of tube wells and pumps) in Nigeria.

The International Fund for Agricultural Development (IFAD) reviews additional mechanisms for economic and environmental assessments of farm-level agricultural technology including those described below. Like the models reviewed above, these are academic models, not user-end tools. However, these types of models could potentially serve as the basis for a user-end impact modeling system. Examples of literature that used the methods described by IFAD are also included here and listed in the references section.

Gross margin budgets: These types of models calculate the relative cost and revenue differences between the proposed technology and the existing production systems, within a set of gross-margin budgets. This type of method has been used in impact studies by the FAO of alternative weeding systems in the Teso farming region of Uganda. Several academic papers have been published in accordance with this project including a 2004 assessment by Aliguma, which used participatory budgeting (farmer involved) and gross margin analysis to compare the use and non-use of alternative technologies in weeding annual crops.

Linear programming: Another method builds a set of representative-farm linear programming models, which incorporate the output from the gross-margin analyses but also consider the overhead and other costs associated with the adoption of new technology. For example, Ameleke et al. (2007) employed linear programming methods to assess the farm-level impact of incorporating forages, including dual purpose *Cajanus cajan* (*C. cajan*), into the crop-livestock system in the Coastal Savannah Zone of Ghana. The specific intervention was based on growing forages as part of the crop-livestock system and feeding them to milking cows and their calves to increase milk production and growth. The impact of policy options such as educating farmers to accept and use *C. cajan* grain as food for livestock and thereby increase its production was considered in the analysis.

Regression analysis: A common method involves performing a multiple regression analysis of farm production data using information obtained from technology adoption surveys. A production function may also be used to isolate the impacts of varietal technology on total factor productivity. The IFAD webpage, which outlines these three approaches, also describes several survey data based research studies that analyze the impact of improved barley technologies in several countries using multiple regression analysis in this manner. The IFAD webpage can be accessed here: http://www.ifad.org/lrkm/tans/5.htm#objectives

Conclusion

This research request reviewed a range of decision-making tools, user-end research models, and evaluation methods used to assess the potential impacts of agricultural technology in developing countries. The tools and approaches reviewed here vary considerably by complexity, function, and intended use. The descriptions provided in this document give a broad view of the types of models and tools that are available to analyze the impact of agricultural interventions. Any of these tools or research areas can be reviewed in more detail in a future request, if desired.

Please direct comments or questions about this research to Leigh Anderson, at eparx@u.washington.edu.

References

Aliguma, L. (2004). *Impact Assessment of weeder technologies in the Teso Farming system (TFS).* NARO – SAARI – DAP PROJECT. Food and Agricultural Organization (FAO) of the United Nations.

Ameleke, G.Y., Okantah S.A., Sottie, E.T., Marfo-Ahenkora E. A & Aboe, P.A.T. (2007). Did farmers' livelihood improve? An impact assessment of incorporating forages into the crop-livestock system in the coastal savannah zone of Ghana. *AAAE Conference Proceedings (2007) 147-150.*

Antle, J., Stoorvogel, J., Crissman, C. & Bowen, W. (n.d.). Tradeoff Assessment as a Quantitative Approach to Agricultural/Environmental Policy Analysis. *Proceedings for the Third International Symposium on Systems Approaches for Agricultural Development.* Retrieved from www.condesan.org/memoria/REG0700.pdf

International Center for Soil Fertility and Agricultural Development (IFDC). Decision Support Tools for Smallholder Agriculture in Sub-Saharan Africa. Edited by Bontkes, S. & Wopereis, M.C.S. Retrieved from pdf.usaid.gov/pdf_docs/PNACW808.pdf

Consultative Group on International Agricultural Research (CGIAR). (n.d.). "Impact Assessment Methods." Retrieved from http://impact.cgiar.org/methods/key_readings.asp

Elbehri, A. & MacDonald, S. (2004). Estimating the Impact of Transgenic Bt Cotton on West and Central Africa: A General Equilibrium Approach. *World Development*, 32 (12), 2049-2064.

Environmental Protection Agency (EPA). (n.d.) "Carbon Sequestration in Agriculture and Forestry." Retrieved from http://www.epa.gov/sequestration/faq.html

Food and Agricultural Organization (FAO) of the United Nations. (n.d.) "Decision Support Tools." Retrieved from http://www.fao.org/teca/content/decision-support-tools

Gilbert, J. (n.d.). *GTAP Model Analysis: Simulating the Effect of a US-Korea FTA Using Computable General Equilibrium Techniques.* International Institute of Economics. Retrieved from www.iie.com/publications/chapters_preview/326/appbiie311x.pdf

Gohn, A. & Moschini, G.C. (2006). Evaluating the market and welfare impacts of agricultural policies in developed countries: comparison of partial and general equilibrium measures. *Applied Economic Perspectives*, 28 (2), 195-211.

Hareau, G., Norton, G.W. & Mills, B.F. (2005). Potential benefits of transgenic rice in Asia: a general equilibrium approach. *Quarterly Journal of International Agriculture*, 44, 229-46.

Hoogenboom, G., J.W. Jones, C.H. Porter, P.W. Wilkens, K.J. Boote, W.D. Batchelor, L.A. Hunt & G.Y. Tsuji. (2003). *DSSAT Version 40, Vol 1: Overview*. University of Hawaii, Honolulu.

Kostandini, G., Mills, B., Omamo, W. & Wood, S. (2007). Ex-Ante Analysis of the Benefits of Transgenic Drought Tolerance Research on Cereal Crops in Low-Income Countries. *Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007.*

Nyangito, H., Richardson, J. Mundy, D. & Namken, A. (1996). Economic Impacts of East Coast Fever

Immunization Analysis. *Agricultural Economics*, 13, 163-177.

Omilola, B. (2009). Estimating the Impact of Agricultural Technology on Poverty Reduction in Rural Nigeria. *International Food and Policy Research Institute (IFPRI)*. Retrieved from http://www.ifpri.org/publication/estimating-impact-agricultural-technology-poverty-reduction-rural-nigeria

Oregon State University. (n.d.) Trade-off Analysis Project, Publications. Retrieved from http://tradeoffs.oregonstate.edu/toa/publications

Purdue University. (n.d.) "Global Trade Analysis Project (GTAP)." Retrieved from https://www.gtap.agecon.purdue.edu/

Ravallion, M. (2001). The Mystery of Vanishing Benefits: An Introduction to Impact Evaluation. *The World Bank Economic Review*, 15 (1), 115-140.

Stoorvogel, JJ., Antle, J.M, Crissman, C.C. & Bowen, W. The Tradeoff Analysis Model Version 3.1: A Policy Decision Support System for Agriculture. Montana State University. Retrieved from www.stoorvogel.info/tradeoffs/download/to31.pdf

Texas A&M University. (n.d.) "Description of FLIPSIM: The Farm Level Income and Policy Simulation Model." Retrieved from http://www.afpc.tamu.edu/models/flipsim/

Tittonell, P., van Wijk, M.T., Herrero, M., Rufino, M.C., Ridder, N., Giller, K.E. (2009). Beyond resource constraints–Exploring the biophysical feasibility of options for the intensification of smallholder crop-livestock systems in Vihiga district, Kenya. *Agricultural Systems*. 1-19.

Tittonell, P., van Wijk, M.T., Rufino, M.C., Vrugt, J.A. & Giller, K.E. (2007). Analysing trade-offs in resource and labour allocation by smallholder farmers using inverse modelling techniques: A case-study from Kakamega district, western Kenya. *Agricultural Systems*, 95, 76-95.

Qaim, M. & De Janvry, A. (2003). Genetically modified crops, corporate pricing strategies, and farmers adoption: the case of Bt cotton in Argentina. *American Journal of Agricultural Economics*, 85, 814–828.

United States Department of Agriculture (USDA). (n.d.). "GPFARM: Great Plains Framework for Agricultural Resource Management." Retrieved from http://www.ars.usda.gov/Business/docs.htm?docid=6345

Walker, T, Maredia, M., Kelley, T., La Rovere, R., Templeton, D., Thiele, G. & Douthwaite, B. (2008). Strategic Guidance for Ex Post Impact Assessment of Agricultural Research. *Consultative Group on International Agricultural Research (CGIAR)*. Retrieved from www.fao.org/docrep/011/i0276e/i0276e00.HTM