United States
Department
of Agriculture

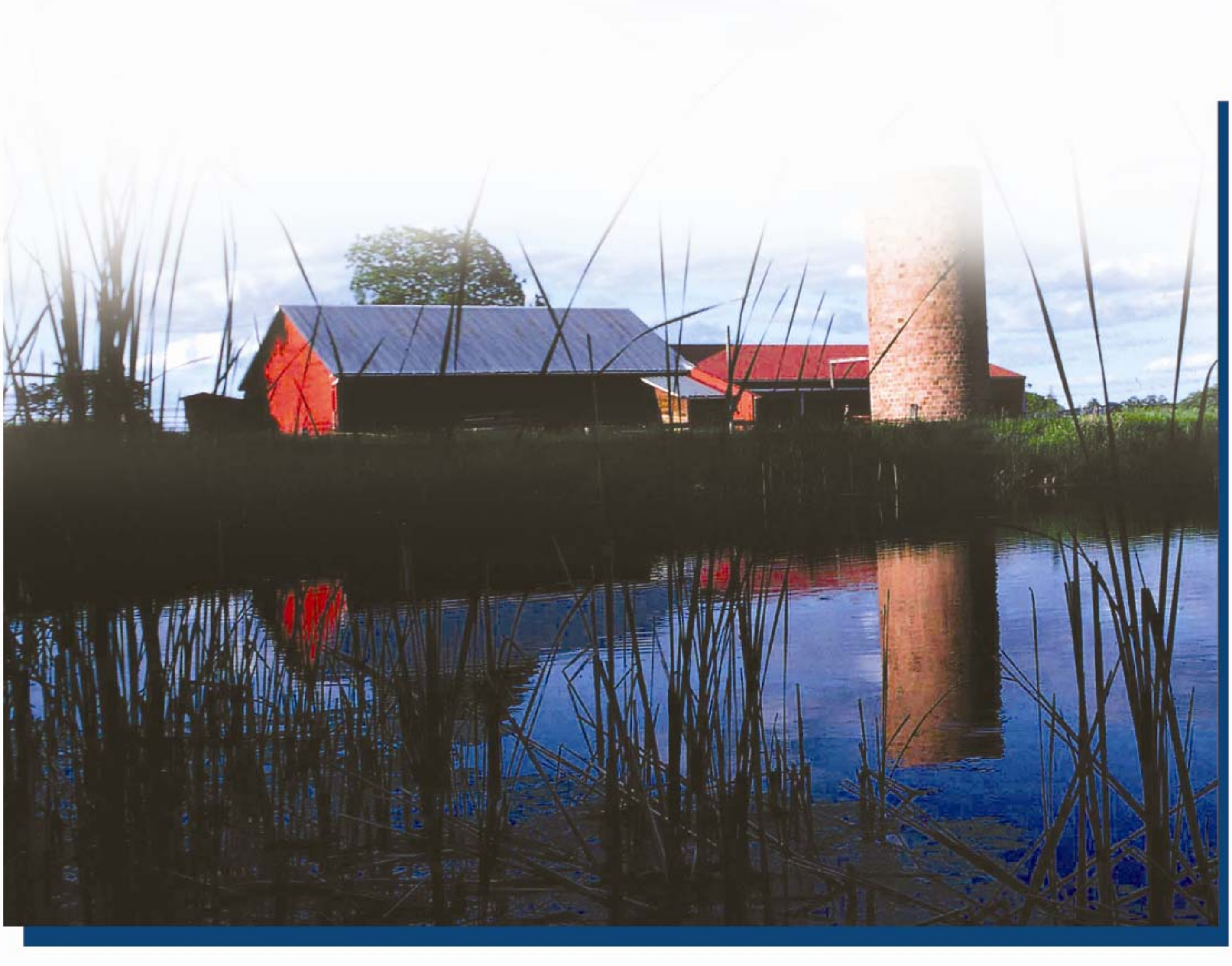
Economic
Research
Service

Technical
Bulletin
Number 1916

March 2007

Regional Environment and Agriculture Programming Model

Robert Johansson, Mark Peters, and Robert House



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National Agricultural Library Cataloging Record:

Johansson, Robert C.
Regional environment and agriculture programming model.
(Technical bulletin (United States. Dept. of Agriculture) ; no. 1916)

1. Agriculture—Environmental aspects—United States—Mathematical models.
2. Agriculture—Economic aspects—United States—Mathematical models.
3. Agriculture and state—United States—Computer simulation.
4. Environmental policy—United States—Computer simulation.
5. Programming (Mathematics)
6. Spatial analysis (Statistics)
I. Peters, Mark.
II. House, Robert.
III. United States. Dept. of Agriculture. Economic Research Service.
IV. Title.

HD1750

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USDA
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Department
of Agriculture

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A Report from the Economic Research Service

www.ers.usda.gov

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**Robert Johansson, Mark Peters,
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Abstract

This bulletin presents the Regional Environment and Agriculture Programming Model (REAP), which was formerly known as USMP (U.S. Mathematical Programming Regional Agriculture Sector Model). This bulletin is a reference document for analysts and model users. It includes an outline of the objectives of REAP, describes the methodology used to achieve these objectives, and provides details on how REAP works. This bulletin provides the theoretical and modeling system specification, descriptions of the data used, and a guide for setting up and running model simulations. REAP is designed for spatial analyses of U.S. agricultural and environmental policies. REAP has been applied to soil conservation and environmental policy design, water quality, environmental credit trading, irrigation policy, climate change mitigation policy, trade and the environment, livestock waste management, wetlands policy, new or alternative fuels from agriculture products, crop and animal disease, and regional effects of trade agreements.

Keywords: Agriculture, environment, policy, mathematical programming, agricultural sector model.

Acknowledgments

The model and this documentation have undergone numerous changes and innovations over its current lifespan, more than 20 years now. We thank the many researchers who provided their expertise in developing the potential of this simulation model. These researchers include Howard McDowell, Terry Hickenbotham, Terry Disney, Ralph Heimlich, Vince Breneman, Jonathan Kaplan, Paul Faeth, Mindy Selman, Jimmy Williams, and many others at the U.S. Department of Agriculture and the World Resources Institute. We would also like to acknowledge Marca Weinberg, Kitty Smith, and Mary Bohman, USDA, Economic Research Service, for providing administrative support throughout the development of this technical documentation project. We also thank David Abler, Agapi Somwaru, Kazim Konyar, and an anonymous reviewer who provided excellent suggestions and edits throughout this project. And finally, thanks to Sharon Lee and Wynnice Pointer-Napper, USDA, Economic Research Service for editorial and design assistance.

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Recommended citation format for this publication:

Johansson, Robert, Mark Peters, and Robert House. *Regional Environment and Agriculture Programming Model*, TB-1916. U.S. Dept. of Agriculture, Econ. Res. Serv. March 2007.

Contents

Summary

Development of the U.S. Mathematical Programming Regional Agricultural Sector Model (USMP) began in 1985 to augment economic and environmental policy analysis at the U.S. Department of Agriculture's Economic Research Service. Analysts needed a way to represent the interactions among product prices, choice of production practices, and demand for crop and livestock products when analyzing the potential effects of policies designed to address environmental issues associated with agriculture. The effects of environmental and energy policies were so widespread and the interaction among the various commodities so complex that it was impossible for analysts, using the available analytical tools and research results to project the ultimate effect of specified policies on agricultural producers or even to determine whether the policies would achieve their desired goals. This bulletin presents the current version of the USMP model—now the Regional Environment and Agriculture Programming Model (REAP)—its theoretical and modeling system specification, descriptions of the data used, and a guide for setting up and running model simulations.

What Are the Issues?

Many agricultural policy issues stem from agricultural production and its interface with the environment. Modeling efforts are important for informing policymakers on how these issues might influence the heterogeneous set of farms, farmers, and environmental resources that characterize U.S. agricultural production. Agricultural policy issues analyzed using REAP include soil conservation and environmental policy design, water quality, environmental credit trading, irrigation policy, climate change mitigation policy, trade and the environment, livestock waste management, wetlands policy, new or alternative fuels from agriculture products, crop and animal disease, and regional effects of trade agreements.

What Does the Model Do?

REAP is designed for general-purpose economic, environmental, technological, and policy analysis of the U.S. agriculture sector. REAP facilitates scenario—or "what if"—analyses by showing how changes in technology, commodity supply or demand, or farm, resource, environmental, or trade policy could affect a host of performance indicators important to decisionmakers and stakeholders. Analysts perform "what if" analyses by solving for a baseline, or status quo, economic equilibrium, then imposing specific policy, technology, trade, or other changes on the system and solving REAP again to compute a new economic equilibrium consistent with the scenario changes. Performance indicators include regional values for land use, input use, crop and animal production and prices, farm income, government expenditures, farm program participation, and environmental emissions such as erosion, nutrient and pesticide loadings, and greenhouse

gases. The scenarios analyzed do not predict a dated forecast or projection, but rather present the likely effect of proposed changes in policies, regulations, and markets on the agriculture sector's performance, holding constant all other conditions affecting the sector.

REAP is a price-endogenous mathematical programming model. As such, it incorporates the assumptions of neoclassical economics, supplemented by the best available estimated behavioral and biophysical relationships (e.g., for agricultural commodity supply and demand or nitrogen run off). Many regularly updated data sets—production practices surveys, multiyear baselines, macroeconomic trend projections, and regional resource and land databases—are applied to construct and update REAP. To generate a baseline scenario, disaggregated regional data are used to map the baseline data projections into REAP's smaller units of analysis. The relationships between production practices and environmental performance indicators represented in the model are derived by using biophysical models.

How Does the Model Work?

- REAP cropping enterprises, or activities that include rotation, tillage, and fertilizer choices, are linked to the Environmental Policy Integrated Climate Model (EPIC), a biophysical model of crop production. In addition to the effect of production practices on yields, EPIC is used to compute environmental indicators such as nitrogen loss and greenhouse gas emissions per acre for each REAP crop system, thereby augmenting economic analysis of "what if" scenarios with their environmental effects as well.

- Land use, crop mix, multiyear crop rotations, tillage practices, and nitrogen fertilizer application rates are all endogenously determined in REAP's 45 production regions. Scenario analysis explores the response of all these variables to "what if" changes in policy incentives, regulations, market conditions, technology, and so forth.

- Crop and livestock primary and secondary products are all integral parts of the model and interact in the solution process. Cattle, poultry, and swine feed rations are formed from activities that process crops into protein, energy, and trace elements necessary for the respective animal diets. Policy and market shocks that directly affect either the crop or livestock industry ultimately result in a market equilibrium that reflects the repercussions for agricultural industries and markets.

- REAP provides comparative static analysis from any base year in the historical/baseline data, which is approximately 1988-2015. REAP is typically calibrated to a current or future year selected from the 10-year USDA baseline. For example, REAP is to be calibrated to the 2010 baseline for scenario analysis of changes introduced in 2010. Near-term analyses of policy, market, or technology shocks reflect short- or medium-term sector responses; long-term analyses reflect longer run adjustments.

- The explicit linkages in REAP between production activities and environmental emissions indicators can be exploited to extend analysis to alternative environmental policy scenarios. For example, REAP was extended in 1999 to provide analysis of the effects of the Kyoto Protocol on U.S. agriculture. REAP has also been extended by the World Resources Institute to examine excess fertilizer nutrient (phosphorus) pollution in the Great Lakes, hypoxia, climate change, and point/nonpoint emissions trading.

- Data used are readily available. Most core model data are prepared and regularly updated by agencies of the U.S. Department of Agriculture. REAP applies USDA and ERS data and estimates to agriculture sector analysis. This includes ERS cost of production data, USDA acreage and production data, baseline data, and changes to commodity program policy instruments (e.g., fixed and counter-cyclical payments, target prices, loan rates, loan deficiency payments, and domestic agrienvironmental programs).

Introduction

This bulletin describes the Regional Environment and Agriculture Programming Model (REAP), which was formerly known as USMP, or the U.S. Mathematical Programming Regional Agriculture Sector Model (box 1). This bulletin is a reference document for analysts and model users.[1] In this bulletin, we outline the objectives of REAP, describe the methodology used to achieve these objectives and provide details on how REAP works.

Many agricultural policy issues stem from agricultural production and its interface with the environment. REAP is a powerful tool for analyzing the effects of policy on both agricultural structure and the environment. This model has been applied to:

- soil conservation and environmental policy design (Cattaneo et al., 2005; Claassen et al., 2001);
- water quality (Doering et al., 1998; Ribaudo et al., 2001; Peters et al., 1997; Greenhalgh and Faeth, 2001; Greenhalgh and Sauer, 2003);
- environmental credit trading (Ribaudo et al., 2005);
- irrigation policy (Horner et al., 1990);
- climate change mitigation policy (Peters et al., 2001; Faeth and Greenhalgh, 2000; Faeth and Greenhalgh, 2002; Lewandrowski et al., 2004);
- trade and the environment (Johansson et al., 2005; Cooper et al., 2005);
- livestock waste management (Ribaudo et al., 2003; Aillery et al., 2005; Johansson and Kaplan, 2004; Kaplan et al., 2004);
- wetlands policy
- new or alternative fuels from agriculture products (Marshall and Greenhalgh, 2006; House et al., 1993);
- crop and animal disease (Livingston et al., 2004; Disney and Peters, 2003); and
- regional effects of trade agreements (Burfisher et al., 1992).

REAP combines information on agricultural commodity supply and use relationships with policy instruments and environmental parameters. The model simulates how changes in government agricultural or environmental policy could result in changes to production practices and the effects of those changes on commodity markets, net returns, and the agriculture sector’s environmental performance.

The model includes the major commodity crops, a number of livestock enterprises, and a variety of different processing technologies used to produce retail products from agricultural inputs. The data used to drive REAP are drawn from a number of national databases: the USDA production practices survey, the USDA multiyear baseline, and the National Resources Inventory.

REAP divides the United States into production regions, derived from the intersection of the USDA Farm Production Regions, Land Resource Regions, and soil erodibility classification. For each of those regions, land use, crop mix, multiyear crop rotations, tillage practices, and nitrogen fertilizer application rates are all endogenously determined by REAP’s constrained optimization process. The biophysical effects of those rotations and tillage practices are then estimated by using a crop biophysical simulation model called the Environmental Policy Integrated Climate (EPIC) model.

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[1] REAP retains basic historical policy mechanisms (i.e., no-longer-used government commodity or conservation programs which may be switched off or on) to facilitate analysis if a variant of an old program returns to current policy. However, completely rebasing REAP to the policy and market conditions of a historical year (e.g., for historical counterfactual analysis) might require substantial effort.

Changes in policy, demand, or production/processing technology can, therefore, be imposed upon the model and the results examined to determine their effects on the following:

- regional supply of crops and livestock;
- commodity prices;
- crop management behavior and use of production inputs;
- farm income; and
- environmental indicators such as nutrient and pesticide runoff, soil loss, greenhouse gas emissions, soil carbon fluxes, and energy use.

Due to the highly aggregated nature of the model and the coarseness of the estimation, REAP results are generally used to evaluate the relative effects of various policy options and not to predict absolute changes in production or environmental parameters.

Economic Modeling

The REAP model is a comparative-static, regional, mathematical programming model of U.S. agriculture. The model is written and maintained in GAMS (General Algebraic Modeling System). REAP seeks to determine the set of prices and quantities that establish equilibrium in several related markets by maximizing net social benefit. The model takes as its data the technological coefficients on production activities, levels of fixed resources, demand relationships for final products, and supply relationships for purchased inputs and generates a solution that gives the equilibrium prices and quantities of final goods, the pattern of use of the factors of production, prices for purchased inputs, and imputed prices for owned resources and production activities. The equilibrium established by the model is partial because consumer income and the prices of commodities produced outside the sector are held fixed. In specifying this model, we assume that the sector is composed of many competitive agents none of whom can, through their individual actions, influence prices.

The constrained optimization estimates profit-maximizing levels of factor inputs, environmental emissions, crop and livestock production, processed agricultural products, commodity and processed product prices, and final demand sectors, including domestic use, exports, and government and commercial stocks (fig. 1). Geographic coverage for crop production encompasses 90 regions determined by the intersection of the 10 USDA Farm Production Regions, 25 USDA Land Resource Regions, and soil erodibility classification (fig. 2). Geographic coverage for livestock production encompasses 10 regions based on the 10 USDA Farm Production Regions. Twenty-three inputs and their costs (e.g., land, nitrogen fertilizer, energy, and labor) are represented, as well as 44 agricultural commodities (e.g., hogs for slaughter and corn) and processed products (e.g., soybean meal, retail cuts of pork, and ethanol) (table 1).

Crop production activities in each region are differentiated by crop, rotation, and tillage practice. Each production activity contains information on input use, output, and environmental indicators. Production, land use, land use management (crop mix, rotations, and tillage practices), and nitrogen fertilizer application rates are endogenously determined. Allocation of cropland to crop rotations and associated tillage practices is represented with constant elasticity of transformation functions. The transformation function determines the rate at which production practices can be substituted for each other. Regional supplies of crop-specific acreage are represented with positive mathematical programming (PMP) cost functions, while the availability of cropland is represented with simple kinked supply functions. In this framework, cropland is simultaneously allocated to specific crops, specific crop rotations, and specific tillage practices. A constant elasticity of transformation (CET) function, which controls the allocation of land to tillage practices, is defined for each crop rotation. These tillage transformation functions are then nested within the CET transformation functions that control the allocation of land to crop rotations. The parameters of the CET and PMP functions are specified so that model supply response at the national level is consistent with supply response in the USDA's Food and Agriculture Policy Simulator (FAPSIM)(Price, 2004). FAPSIM is an econometrically estimated national-level dynamic simulation model of the U.S. agriculture sector. The nitrogen fertilizer application rate for each production activity is linked to yield by using a nitrogen yield response function.

Livestock production in each region is represented within an activity analysis framework. Production practices are differentiated by livestock type and type of operation. Livestock production activities incorporate yields and input use (including feed nutrient requirements and input costs), and they generate manure and its associated nutrient composition per unit of production activity. Species-specific PMP cost functions are defined for each region. Regional supplies of pasture are represented with simple kinked supply functions derived from pasture supply elasticities.

Major government agricultural programs, including income and price support and the Conservation Reserve Program (CRP), are also represented within REAP. Conservation compliance restrictions on use of highly erodible land (HEL) can also be incorporated into an equilibrium solution. For many environmental policy analyses, conservation compliance is particularly important as it limits expansion of production onto HEL by requiring producers to forgo fixed, counter-cyclical, and CRP payments if they choose to bring new HEL into production.

Processing of primary crop and livestock products is represented at the national level. Processing activities represented for crops include conversion of crops into livestock feed, crushing of soybeans into oil and meal, and conversion of corn into ethanol and associated byproducts (corn gluten feed, corn gluten meal, corn oil, and distiller's dried grains). Livestock and crop production are connected through the competition for land and conversion of crops into livestock feed. The conversion of crops into livestock feed is represented with a feed mix model that converts crops into their nutritional components, e.g., metabolizable energy and protein, and uses them to produce feed rations for beef and dairy cattle, hogs, and poultry. Rations are differentiated by the proportions of crops, soybean meal, and corn byproducts they contain. Rations defined are based on historical ranges of crop and meal proportions and substitution of corn byproducts for feed grain and soybean meal into those rations. Dairy products are processed into fresh milk, cheese, butter, and evaporated dry milk.

On the demand side, domestic use, trade, ending stocks and price levels for crop and livestock commodities, and processed or retail products are determined endogenously. Trade is represented with export demand and import supply functions. Hence, trade volumes respond to changes in the endogenously determined prices.

Foundations

REAP is a nonlinear, price-endogenous, mathematical programming model of the U.S. agricultural sector. Mathematical programming models have been widely used to model the interaction between agriculture production and the environment at the farm, watershed, and sector level.

Samuelson (1952) was the first to demonstrate that the spatial equilibrium problem could be cast and solved as a constrained maximization problem. Takayama and Judge (1971) demonstrated how linear supply and demand equations could be incorporated and solved as a quadratic programming model. McCarl and Spreen (1980) discussed the properties of price equilibrium models that could be formulated with implicit supply relationships. They demonstrated that a sectoral-level analysis of the type being considered here may be effectively conducted by using a price-endogenous, mathematical programming model.

Several characteristics of programming models are useful in the analysis of the interaction between agricultural production and the environment. First, the structure of these types of models is well suited for imposing resource and policy constraints. The explicit representation of production activities permits the analyst to identify resource use and environmental emissions associated with production and to place constraints on their use. Second, the use of fixed-proportion production technology used in most programming models has had intrinsic appeal (Howitt, 1995). Third, the representation of production activities is consistent with the manner in which production systems are represented within biophysical simulation models. Fourth, it is relatively easy to introduce new or alternative production activities. Fifth, programming models can be constructed from limited historical data, permitting full use of available information. The availability of time series covering the economic and environmental variables of interest is minimal; usually, information is only available to generate one observation per production system. This is not to imply that the data requirements of programming models are trivial. The data requirements for such models are extensive, and the time and manpower needed can be overwhelming (McCarl and Spreen, 1980). Finally, programming models permit detailed analysis of the effects of policy changes across commodities, regions, and production systems.

Despite their appeal, the extension of programming models beyond farm or regional analysis to sector analysis has been limited by their inability to replicate observed patterns of production. This is often the result of the overspecialization problem (Howitt, 1995; McCarl and Spreen, 1980; Preckel et al., 2002). Overspecialization occurs in activity analysis models because the marginal rate of transformation among production activities is constant. This means that the rate at which the inputs can be switched from the production of one good to another does not change. Because the marginal rate of transformation among production activities remains the same regardless of the quantity of inputs already devoted to the production of a particular good, programming models will allocate all inputs to the production activity with the highest net return unless constrained by resource availability.

Before the development of currently available modeling constructs, activity models relied on fixed technologies that necessitated the use of arbitrary upper and lower bounds on the activities to avoid overspecialization. Unfortunately, flexibility constraints, particularly at the sector level, contained little technological or economic information. As a result, the model response was being controlled by constraints that did not reflect limitations imposed by technology or economic behavior. Many solutions to the overspecialization or the calibration problem have been suggested, ranging from greater spatial disaggregation to making commodity prices endogenous, to incorporating risk-averse behavior, to specifying multicommodity demand functions, to using linear combinations of historical distribution of production activities, to specifying cost functions for each production activity. Only the specification of cost functions has proven very satisfactory.

Positive mathematical programming (PMP), formally articulated by Howitt (1995), is the most popular approach used for representing these production activity cost functions. In the PMP methodology, crop-specific cost functions are used to eliminate the need for flexibility constraints. At the sector level, commodity supply elasticities can be used to derive the PMP functions so that supply response reflects the historical data. Cross-supply effects, other than those caused by allocation constraints placed on inputs such as land, labor, and water, can be implicitly included in the parameters of production or cost functions (Paris and Howitt, 1998).

REAP uses an approach developed for calibrating and specifying programming models. It permits the degree of spatial and production disaggregation required for environmental analysis but eliminates the need to use flexibility constraints. The approach extends the PMP formulation by nesting sets of nonlinear transformation functions under the PMP formulation. The use of transformation functions differ from flexibility constraints in that, unlike flexibility constraints, they represent constraints imposed by our assumptions about the production technology.

This approach builds on the foundations laid by both positive mathematical programming and computable general equilibrium (CGE) modeling. The approach is similar to the technique used by Dervis et al. (1982) to specify country-specific export demand functions in CGE models in that it uses a functional form—a constant elasticity of transformation function—that can be specified by using prices, quantities, average costs, and an assumed elasticity of substitution. The approach also borrows from PMP in that it uses shadow prices from calibration constraints to obtain the difference between average and marginal returns needed to specify transformation function parameters.

In REAP, we assume that producers determine the crop they desire to produce, the rotation they will use to produce it, and the tillage practice they will employ. In REAP, PMP functions are used to represent the positively sloping marginal cost curves for the land allocation decision at the crop level. The functions are specified so that the resulting supply functions are consistent with supply response elasticities derived from the FAPSIM model. We then nest two sets of transformation functions under the crop-level PMP functions. The first set of CET functions allocates cropland to various crop rotations. The second set of CET functions allocates rotation acreage to the available tillage practices. This formulation results in a smooth response of acreage planted to changes in relative returns among production enterprises, in accordance with our neoclassical economic behavioral expectation of profit maximization. By using this approach, we avoid the problems of overspecialization and corner solutions that result from using linear activity analysis formulation.

Figure 3 illustrates the overspecialization problem. The transformation curve, CET, represents the maximum amount of a corn soybean rotation (RCB) attainable given the amount of continuous corn rotation (RCCC). The shape of the CET curve determines the rate at which RCB acres can be transformed into RCCC acres. The shape is drawn as it is represented in REAP and indicates that the marginal rate of transformation between RCB and RCCC is declining. When the elasticity of transformation, σ, equals zero, the CET curve takes the familiar corner shape associated with fixed-resource transformation. This indicates that the amount of cropland that can be converted into RCCC and RCB is fixed. When $\sigma = \infty$, the transformation curve becomes a straight line, indicating that the activities are perfectly substitutable. This is the shape of the transformation curve in activity analysis and linear programming models.

The terms of trade, R_1 and R_2, show the rate at which RCB can be exchanged for RCCC given total expenditures and prices. The slope of the terms-of-trade line—or relative price ratio—is given by P_{rccc}/P_{rcb}. As P_{rccc} increases relative to P_{rcb}, the slope of the terms-of-trade line will increase, causing it to become steeper. This implies that as the relative price of RCB to RCCC falls, the amount of land devoted to RCB used will fall and the amount of land devoted to RCCC will increase.

In figure 3, equilibrium occurs at the point where the CET curve is tangent to the terms-of-trade line. This is also the point where the marginal rate of transformation equals the terms-of-trade. When the expenditure line is R_1, equilibrium occurs at Q^1_{RCB} and Q^1_{RCCC}. As RCB becomes relatively less profitable than RCCC at P_{rccc}, the revenue line shifts to R_2, the use of RCB decreases, and RCCC increases until a new equilibrium is established at Q^2_{RCB} and Q^2_{RCCC}.

When $\sigma = 0$, the amount of each production activity used will remain unchanged no matter how the terms of trade change. When $\sigma = \infty$, as it is in linear programming models, only one of the production activities will be used, since the expenditure line becomes tangent to the transformation curve only at a boundary point. This also implies that the amount of a production activity used will only change when the terms of trade change sufficiently to make it more profitable to use the other production activity. When this occurs, the original production activity will no longer be used, since production shifts completely to the new activity. This is what occurs when the terms-of-trade line shifts from R_1 to R_2. In figure 3, when the terms of trade are at R_1, all land is devoted to RCB. If the terms of trade change to R_2, indicating that returns to RCCC are now greater than returns to RCB, all the land is allocated to RCCC.

To prevent this type of overspecialization, some models rely on flexibility constraints to limit movement along the transformation curve. This is depicted in figure 4, where the dark grey shaded block depicts the upper bound placed on RCB use by the flexibility constraint. The heavy straight black line represents the linear transformation curve. However, when the terms of trade change from R_1 to R_2, all land will be shifted to RCCC, and RCB use will go to zero. It is possible to prevent this from happening by using a flexibility constraint to place an upper bound on RCCC use as well. This is shown by the light grey shaded box in figure 4. The problem is how to identify where to place those constraints. Even with an upper bound to restrict movement of land to RCCC, notice that any change will still occur as a corner solution. Because flexibility constraints have no economic or technological justification, you will still have constraints that contain no relevant information determining the solution. By using the CET function approach, we avoid this problem.

Environmental Modeling

Unique features of REAP are its explicit environmental modeling of agricultural activities and calibration to observed environmental data. Environmental effects of crop production activities are obtained from simulations of the production activities using the Environmental Policy Integrated Climate (EPIC) model. EPIC uses information on soils, weather, and management practices, including specific fertilizer rates, and produces information on crop yields, erosion, and chemical losses to the environment. EPIC has been continuously updated since the early 1980s by a team of researchers from the U.S. Department of Agriculture's Agricultural Research Service, Natural Resources Conservation Service (formerly the Soil Conservation Service), and Economic Research Service (ERS), as well as scientists at the Texas Agricultural Experiment Station. EPIC is a field-scale model that uses a daily time step to calculate the fate of various environmental parameters under different tillage, crop rotation, soil management, and weather scenarios. Although originally developed specifically to analyze the extent and costs of soil erosion, the model has been expanded over the years to simulate and provide information on hydrology, erosion, nutrient cycling, pesticide fate, soil temperature, and crop growth and yield. In addition to the effect of production practices on yields, EPIC is used to estimate the effect of production practices on yield, as well as to compute environmental indicators such as nitrogen loss and greenhouse gas emissions per acre for each REAP crop system.

Management practices and initial fertilizer application rates are consistent with agronomic practices for the 45 regions as reported in USDA's Cropping Practices Survey. Yield and environmental indicators are estimated by running each of the cropping systems represented in REAP through EPIC. The set of environmental indicators represented includes soil erosion (water and wind), losses of nitrogen and phosphorus to ground and surface water, nitrogen runoff damage to coastal waters, and erosion damage and losses of nitrogen to the atmosphere through volatilization and denitrification, carbon sequestered by soils, greenhouse gas emissions associated with machinery use and fertilizer production, and pesticides lost to ground and surface waters. Livestock waste and associated nutrient emissions are derived from formulas used in Kellogg et al. (2000). These formulas are adjusted to account for differences in timeframes represented by REAP production activities and production activities in the report.

Onsite phosphorus and nitrogen runoff estimated by EPIC are calibrated to in-stream measurements made by the U.S. Geological Survey (Smith et al., 1997). The transport coefficients for phosphorus and nitrogen are used to estimate the quantity of sheet and rill erosion and pesticides that also run off into surrounding water bodies. Pesticide leaching and runoff are measured by the active ingredient quantity and then normalized to reflect toxicity and half-life (Barnard et al., 1997).

Estimates of offsite damages are derived from sediment and nitrogen damage indexes developed by USDA (Claassen et al., 2001). Amenities included in the indexes are municipal water use, industrial uses, irrigation ditch maintenance, road ditch maintenance, water storage, flooding, and soil productivity, as well as fresh-water-based recreation, navigation, estuary-based boating, swimming, and recreation. These do not reflect all amenities affected by sediment and nitrogen runoff, so the offsite damage estimates should be viewed as a lower bound. Table 2 lists the environmental parameters REAP estimates in each model run.

Model Environment

The REAP model is written and maintained in GAMS modeling language (see, for example, GAMS Development Corporation, 2006) and employs a nonlinear solver.[2] GAMS permits the compact representation of programming model by using concise algebraic statements that are easily read by model users. The equations that compose REAP are written in terms of “defined parameters”. This means that REAP's equations are written in symbolic terms and the values of data objects represented by these symbols (defined parameters) determine the specific form of REAP that is used in a model run.

Whenever REAP is run, GAMS generates a model based on whatever data exist in various REAP data objects. For example, the form and existence of domestic demand functions for commodities depend on the values of several coefficients in a demand parameter table, called DEMSUP (table 3). DEMSUP contains price, quantity, and either demand or supply elasticities for all final commodities represented in REAP. The existence of a price-quantity-elasticity combination for a commodity in DEMSUP will allow REAP to generate a supply or demand curve for that commodity in the market for which the price-quantity-elasticity combination exists. If there is only a price-quantity combination with no elasticity, then the price for that commodity in that market is kept constant.

In this section, we describe the major components of REAP using verbal, algebraic, and actual REAP model tables, as well as lists, equations, and statements.[3] We presume that readers have some familiarity with GAMS code conventions. We use several typographic conventions to differentiate elements of REAP presented in this bulletin. GAMS keywords appear in uppercase: EQUATION, for example. All GAMS identifiers (names of SETS, PARAMETERS, VARIABLES, EQUATIONS, and so on) and labels (names of SET elements) used in REAP are in a block font. Portions exceeding one line are separate text blocks as shown in example 1.

Example 1—REAP code Fragment (%%%%% indicates that portions of the list have been left out. This is used when the bulk of the list can be mentally filled in.)

```
$STITLE REAP MODEL REGIONAL PRODUCTION ACTIVITY SUBSETS

 SET BC(B) CROP ENTERPRISES /
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[2] Note the solver(s) must be purchased separately from the GAMS modeling language. Nonlinear solvers such as CONOPT (ARKI Consulting and Development, 2006) or MINOS (Stanford Business Software, Inc., 2006) have successfully been used but their mention here should not be construed as a USDA recommendation over others that maybe suitable.

[3] This represents the basic formulation for REAP. The formulation can and has been adjusted to represent different types of government policies, such as income support programs coupled to production, environmental credit trading, and agrienvironmental compliance requirements. The formulation can also be easily adjusted to include the introduction of alternative production activities, such as the introduction of sustainable cropping systems, genetically modified crops and carbon sequestering activities. The means of accessing these modules and using them for analyses are described in Appendix B.

```
 CORN,    SORGHUM,  BARLEY,  OATS,    WHEAT,   RICE,    SOYBEANS
 SUNFLOWER,  COTTON,   SILAGE,  HAY,   SUGBEET,  SUGCANE
 MILKWEED,  MEADOWFM,  KENAF,   GUYAULE,  OTHERC
 RCCC,     RBBB,     RWWW,    RSSS,    RTTT,    RRRR,
 RLLL,     RHHH,     RGGG
 RCB,      RCBW,     RCBWO,   RCBWL,   RCBWH,   RCBWG,
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 /;
```

In the REAP program, we first define the sets, then declare the various data objects (parameters, tables, and scalars) and assign data. Explanatory text is used in the declaration of sets, parameters, variables, and equations. All information needed to understand REAP is in the GAMS list file. As a result, the GAMS program represents a portion of the model documentation. All equations and data transformations are written in algebraic form. This procedure not only permits data to be entered in the form in which they are in the originating sources, but also makes the transformation of these data and the derivation of model parameters transparent to model users. Many secondary components of REAP are not presented—for example, calculations that convert published data into the model components. Full details of these secondary components are in the REAP code files.

Indexes (GAMS SETS)

SETS in the GAMS programming language serve as the model's building blocks—in other words the indexes represent the heart of the model. The indexes define the dimensions of the model with respect to commodities produced, inputs and production systems represented, regional sources of supply, and end-use markets. The parameters, variables, and equations defining REAP are all indexed by elements of REAP sets. The number of sets used in defining parameters, variables, and equations, along with the number of elements in the sets, determine the dimensions of the model. For example, commodity balance equations are defined over the set P; if set P is defined to contain only the elements `CORN` and `SOYBEANS,` then REAP would generate two commodity balance equations—one for corn and one for soybeans. In addition, SETS facilitate model formulation by permitting parameter calculations, solution algorithms, and more efficient reporting of results.

In the GAMS language, set declaration consists of a SET name and description followed by a list of the set elements. The first text on each row is the ELEMENT; everything following the next space is a description field. Comment lines (beginning with an asterisk, *) add documentation and aids in reading the model. The description field of set elements (and other GAMS objects) is also used in formatting and reporting model output.

Production Activities

The code below lists a portion of SET B—the primary production enterprises in REAP. Two features of `B's` elements are presented in the description field: "DESCRIPTION" clarifies what the element is, beyond GAMS's 10 character limit on element names. `PIGFIN`, for example, is FEEDER PIG FINISHING. "UNIT ON WHICH NORMALIZED" indicates the unit level of the activity for which inputs and outputs will be specified. For example, the unit level of a CORN enterprise is 1 acre. Yield and inputs used to produce corn will be specified on a per-acre basis.

b regional production activity, $b = 1,\ldots,B$

```
SET B   REGIONAL ENTERPRISE PRODUCTION PROCESS (ACTIVITY) SUPERSET /
* ---------------------------------------------------------------------------------
*                                                                   UNIT ON WHICH
*  NAME      DESCRIPTION                                             NORMALIZED
* ---------- --------------------------------------------------- ------------------
*  ---- TRADITIONAL FIELD CROPS
  CORN       CORN                                                 ACRE  PLANTED
  SORGHUM    SORGHUM                                              ACRE  PLANTED
  BARLEY     BARLEY                                               ACRE  PLANTED
  OATS       OATS                                                 ACRE  PLANTED
  WHEAT      WHEAT                                                ACRE  PLANTED
  RICE       RICE                                                 ACRE  PLANTED
  SOYBEANS   SOYBEANS                                             ACRE  PLANTED
  COTTON     COTTON                                               ACRE  PLANTED
  SILAGE     SILAGE                                               ACRE  PLANTED
  HAY        HAY                                                  ACRE  PLANTED
*  ---- ROTATIONS
  RCCC       CONTINUOUS CORN                                      ACRE  PLANTED
  RSSS       CONTINUOUS SORGHUM                                   ACRE  PLANTED
  RLLL       CONTINUOUS BARLEY                                    ACRE  PLANTED
  ROOO       CONTINUOUS OATS                                      ACRE  PLANTED
  RWWW       CONTINUOUS WHEAT                                     ACRE  PLANTED
  RTTT       CONTINUOUS COTTON                                    ACRE  PLANTED
  RRRR       CONTINUOUS RICE                                      ACRE  PLANTED
  RBBB       CONTINUOUS SOYBEANS                                  ACRE  PLANTED
  RHHH       CONTINUOUS HAY                                       ACRE  PLANTED
  RGGG       CONTINUOUS SILAGE                                    ACRE  PLANTED
  RCB        CORN SOYBEANS                                        ACRE  PLANTED
  RCBW       CORN SOYBEANS WHEAT                                  ACRE  PLANTED
  RCBWO      CORN SOYBEANS WHEAT OATS                             ACRE  PLANTED
...
...

*  ---- PRIMARY LIVESTOCK ENTERPRISES
  DAIRY       DAIRY                                               DAIRY COW
  FAROFIN     FARROW TO FINISH  HOGS                              HOG SLAUGHTER 10 CWT
  FEEDRPIG    FEEDER PIG PRODUCTION                               PIG PRODUCTION 10 CWT
  PIGFIN      FEEDER PIG FINISHING                                HOG SLAUGHTER  10 CWT
  BFCOWEN     BEEF COW ENTERPRISE                                 BEEF COW
*             (COW-CALF, 17 WESTERN STATES)
  BFCOWCF     BEEF COW-CALF HERD                                  BEEF COW
*             (COW-CALF, 31 EASTERN STATES)
  FEEDLOT     FARMER CATTLE FEEDING                               FED SLAUGHTER  CWT
  CFEEDLOT    COMMERCIAL FEEDLOT                                  FED SLAUGHTER  CWT
  STOCKER     STOCKER (BEEF CALF TO YEARLING)                     BEEF YEARLING  CWT
  OTHRLVSTK   OTHER LIVESTOCK  (SHEEP AND HORSES)                 GCAU
  EGGS        EGG PRODUCTION                                      DOZEN EGGS
  BROILERS    BROILER PRODUCTION (CARCASS)                        LBS BROILER CARCASS
  TURKEY      TURKEY PRODUCTION (CARCASS)                         LBS TURKEY CARCASS
  OTHERL      LIVESTOCK NOT OTHERWISE SPECIFIED                   DEPENDENT ON REPORT

  TOTAL       TOTAL USED FOR REPORTING PURPOSES                     DEPENDENT ON REPORT
  OTHER       ENTERPRISES NOT OTHERWISE SPECIFIED                   DEPENDENT ON REPORT
* -----------------------------------------------------------------------------------------

 ALIAS(B,BA);  ALIAS (B,BA1),(B,BA2);;
```

Subheadings such as "Traditional Field Crops" and "Primary Livestock Enterprises" divide set B elements into similar groups. Enterprise set B includes primary field crops such as CORN and SOYBEANS, livestock such as DAIRY, and several OTHER and control TOTAL categories that are used for summary reporting.

Following the definition of set B, the ALIAS command is used to create sets BA, BA1, and BA2, which contain all the same elements as set B. The ALIAS command gives another name to a previously declared set. Alias sets are used in a GAMS statement or equation when subsequent code involves interactions of elements within the same set.

Set B is further subdivided into subsets of production activities for crops and livestock. Set BC encompasses crop production activities, while BL includes livestock production activities.

Set bc(b) crop production activity, $bc \subset b$

```
SET BC(B) CROP ENTERPRISES /

  CORN,     SORGHUM,  BARLEY,   OATS,     WHEAT,    RICE,     SOYBEANS
  COTTON,   SILAGE,   HAY
  RCCC,     RBBB,     RWWW,     RSSS,     RTTT,     RRRR,     ROOO
  RLLL,     RHHH,     RGGG
  RCB,      RCBW,     RCBWO,    RCBWL,    RCBWH,    RCBWG,    RCBWX,   RCBH
   ....
  /;
```

Set bl(b) livestock production activity, $bl \subset p$

```
SET BL(B)  REGIONAL LIVESTOCK PRODUCTION PROCESSES /
       DAIRY
       FAROFIN,   FEEDRPIG,  PIGFIN
       BFCOWEN,   BFCOWCF
       FEEDLOT,   CFEEDLOT
       STOCKER,   OTHRLVSTK
       EGGS,      BROILERS,  TURKEY
       /;
```

Processing Activities

Set C describes processing activities, which are specified at the national level. Numerous processing activities in REAP perform widely different functions; their common characteristic is that they are specified only at the national level. This implies, for instance, that all finished hogs are sent to a central processing plant for processing, and then the resulting meat is sent out to domestic and export markets; the processing sector does not distinguish its inputs or outputs on the basis of the regions in which those inputs were produced.

Set c national processing activity, $c = 1,\ldots,C$

```
SET C  NATIONAL LEVEL PROCESSING PROCESSES (ACTIVITIES) /
* ------------------------------------------------------------------------------------
*                                                                     UNIT ON WHICH
*    NAME               DESCRIPTION                                     NORMALIZED
* ---------- --------------------------------------------------- ----------------------
*               LIVE ANIMALS TO MEAT (RETAIL WEIGHT)
  HOGTOPORK  SLAUGHTER HOGS                                       CWT    PORK
  SOWTOPORK  SLAUGHTER CULL SOWS                                  CWT    PORK
  FSLATOFBEF SLAUGHTER FED BEEF FROM FARMER CATTLE FEEDLOTS       CWT    FED BEEF
  FSCFTOFB   SLAUGHTER FED BEEF FROM COMMERCIAL FEEDLOT           CWT    FED BEEF
```

```
  DCOWNFBF   SLAUGHTER CULLED DAIRY COW                              CWT    NONFED BEEF
...
...

*              DAIRY PRODUCTS

  FLUIDMLK   FLUID MILK PROCESSING                                CWT WHOLE FARM MILK
  MFGMILK    MANFACUTURED (MFG) MILK PROCESSING                   CWT WHOLE FARM MILK
  BUTTER     BUTTER AND NONFAT DRY MILK PROCESSING                CWT MANUFACTURING MILK
  AMCHEESE   AMERICAN CHEESE PROCESSING                           CWT MANUFACTURING MILK
  OTCHEESE   OTHER   CHEESE PROCESSING                            CWT MANUFACTURING MILK
  ICECREAM   ICE CREAM PROCESSING                                 CWT MANUFACTURING MILK
  EVDRYMLK  " EVAPORATED, DRY, AND CONDENSED MILK"                CWT MANUFACTURING MILK

*              OILSEED CRUSH AND HIGH PROTEIN FEED ACTIVITIES

  SOYCRUSH1  SOYBEAN CRUSHING                                        BU     SOYBEANS

...

...
  BNMLTOHIPR SOYBEAN MEAL PROCESSING FOR HIPROTEIN FEED              CWT    BEANMEAL
  OOSMTOHIPR OTHER OIL SEED MEAL PROCESSING FOR HIPROTEIN FEED       CWT    BEANMEAL
  ANPRTOHIPR ANIMAL PROTEIN TANKAGE FOR HIPROFEED CONVERSION         CWT    BEANMEAL

*              FEED MIX AND PROTEIN SUPPLEMENT PRODUCTION

  GRAIN1     GRAIN FEED MIX 1 FOR CATTLE FEED                        CWT    GRAIN

*            (GRAIN1A TO GRAIN3 REPRESENT ALTERNATE COMBINATIONS
*             OF FEED GRAINS TO CREATE CATTLE PROTEIN AND ENERGY)
  GRAIN1A    GRAIN FEED MIX 1A FOR CATTLE FEED                       CWT    GRAIN
  GRAIN1B    GRAIN FEED MIX 1B FOR CATTLE FEED                       CWT    GRAIN
...
...

  CATPRO1    LOW PROTEIN BEEF CATTLE FEED PROD  (32% PROTEIN)        CWT    PROTSUP
*            (CATPRO2 TO CATPRO4 REPRESENT ALTERNATE COMBINATIONS
*            OF FEED GRAINS AND SOYBEAN MEAL TO CREATE CATTLE FEED)
  CATPRO2    LOW PROTEIN BEEF CATTLE FEED PROD  (32% PROTEIN)        CWT    PROTSUP
...
...

  DAIRYSUP1  DAIRY PROTEIN SUPPLEMENT PRODUCTION (16% PROTEIN)       CWT    PROTSUP

*            (DAIRYSUP2 TO DAIRYSUP6 REPRESENT ALTERNATE
*            COMBINATIONS OF FEED GRAINS AND SOYBEAN MEAL TO
*            CREATE DAIRY PROTEIN AND ENERGY.)
  DAIRYSUP2 DAIRY PROTEIN SUPPLEMENT PRODUCTION (16% PROTEIN)       CWT    PROTSUP
  DAIRYSUP3 DAIRY PROTEIN SUPPLEMENT PRODUCTION (16% PROTEIN)       CWT    PROTSUP
...
...
 LOPROSWN1  LOW PROTEIN SWINE FEED (19%-20% PROTEIN)               CWT    PROTSUP
*            (LOPROSWN2 REPRESENTS AN ALTERNATE COMBINATION OF
*            FEED GRAINS AND MEAL TO CREATE SWINE PROTEIN AND ENERGY)
  LOPROSWN2 LOW PROTEIN SWINE FEED (19%-20% PROTEIN)               CWT    PROTSUP

*              FEED PROTEIN AND ENERGY RELATED ACTIVITIES


  HIPROCAT   CONVERSION OF BEANMEAL TO CATTLE PROTEIN AND ENERGY     CWT    BEANMEAL
  HIPROSWI   CONVERSION OF BEANMEAL TO SWINE PROTEIN AND ENERGY      CWT    BEANMEAL
  HIPRODAI   CONVERSION OF BEANMEAL TO DAIRY PROTEIN AND ENERGY      CWT    BEANMEAL

  CORNSWI    CORN CONVERSION TO PROTEIN AND ENERGY                   CWT    CORN
  SORGSWI    SORGHUM  CONVERSION TO SWINE PROTEIN AND ENERGY         CWT    CORN
```

```
  CNSGSWI    CORN AND SORGHUM CONVERSION TO SWINE PROTEIN AND ENERGY CWT    CORN
...
...
*              ETHANOL PROCESSING ACTIVITIES

  ETHWMLCUR  CORN WETMILLING FOR ETHANOL (CURRENT STATE OF THE ART)   BU     CORN
  ETHWML95   CORN WETMILLING FOR ETHANOL (1995 STATE OF THE ART TECH) BU     CORN
  ETHWML20   CORN WETMILLING FOR ETHANOL (2000 STATE OF THE ART TECH) BU     CORN

  ETHDMLCUR  CORN DRYMILLING FOR ETHANOL (CURRENT STATE OF THE ART)   BU     CORN
  ETHDML95   CORN DRYMILLING FOR ETHANOL (1995 STATE OF THE ART TECH) BU     CORN
  ETHDML20   CORN DRYMILLING FOR ETHANOL (2000 STATE OF THE ART TECH) BU     CORN
...
...
* ------------------------------------------------------------------------------------
```

“Live animals to meat” represents slaughter and processing activities that convert live animals to retail cut weight. Dairy-processing activities convert whole farm and manufacturing milk into retail products. Oilseed crush activities convert soybeans into soybean meal and soybean oil. High-protein feed activities convert various protein sources to high-protein livestock feed. Feed mix and protein supplement activities convert various individual feeds such as CORN and BEANMEAL into animal feed rations. Feed protein and energy activities convert livestock feed rations into protein and energy components in which animal nutrition requirements are satisfied. Ethanol-processing activities convert corn to ethanol and various coproducts.

Regional Indexes

Set U encompasses all geographic regions that can be used in REAP: Farm Production Regions, Land Resource Regions; and 2-, 4- and 8-digit U.S. Geological Service hydrological units (HUCS). REAP production activities are specified at either the Farm Production Region (mainly livestock) or Land Resource Region level (crops). Summary results are typically reported at the Farm Production Region level. HUCS are used primarily for tracking results at the watershed level after a solution has been obtained. As such, HUCS do not play a role in how the model is specified. HUCS could be used to specify the model at the watershed level if the supporting information on production activities to do so were available. Currently, results from model regions are distributed to the HUCS based on the share of cropland of each HUCS in the model region. The Land Resource Regions can be further divided into highly erodible land (HEL) and nonhighly erodible land (NHEL) if desired.

u   all regions

```
SET U   "REGIONS AND US TOTAL SUPERSET" /
* -------------------------------------------------------
*         ELEMENT  REGION NAME
*         ------- ------------
*   FARM PRODUCTION REGIONS

      NT      NORTHEAST
      LA      LAKE STATES
      CB      CORN BELT
      NP      NORTHERN PLAINS
      AP      APPALACHIA
      SE      SOUTHEAST
      DL      DELTA STATES
      SP      SOUTHERN PLAINS
      MN      MOUNTAIN STATES
      PA      PACIFIC STATES

      US      UNITED STATES
```

```
*   LAND RESOURCE REGIONS
      NTL     NORTHEAST LAKE STATES FRUIT TRUCK AND DAIRY
      NTN     NORTHEAST EAST AND CENTRAL FARMING AND FOREST

      NTR     NORTHEAST NORTHEAST FORAGE AND FOREST
      NTS     NORTHEAST NORTH ATLANTIC SLOPE DIVERSIFIED FARMING
      NTT     NORTHEAST ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP
      LAF     LAKE STATES NORTH GREAT PLAINS SPRING WHEAT
      LAK     LAKE STATES NORTH LAKE STATES FOREST AND RANGE
      LAL     LAKE STATES LAKE STATES FRUIT TRUCK AND DAIRY
      LAM     LAKE STATES CENTRAL FEED GRAINS AND LIVESTOCK
      CBL     CORN BELT LAKE STATES FRUIT TRUCK AND DAIRY
      CBM     CORN BELT CENTRAL FEED GRAINS AND LIVESTOCK
      CBN     CORN BELT EAST AND CENTRAL FARMING AND FOREST
      CBO     CORN BELT MISSISSIPPI DELTA COTTON AND FEED GRAINS
      CBR     CORN BELT NORTHEAST FORAGE AND FOREST
      NPF     NORTHERN PLAINS NORTH GREAT PLAINS SPRING WHEAT
      NPG     NORTHERN PLAINS WEST GREAT PLAINS RANGE AND IRRIGATED
      NPH     NORTHERN PLAINS WEST GREAT PLAINS WINTER WHEAT AND RANGE
      NPM     NORTHERN PLAINS CENTRAL FEED GRAINS AND LIVESTOCK
      APN     APPALACHIA EAST AND CENTRAL FARMING AND FOREST
      APO     APPALACHIA MISSISSIPPI DELTA COTTON AND FEED GRAINS
      APP     APPALACHIA S ATL AND GULF SLOPE CASH CROPS FORES AND LVST
      APS     APPALACHIA NORTH ATLANTIC SLOPE DIVERSIFIED FARMING
      APT     APPALACHIA ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP
      STN     SOUTHEAST EAST AND CENTRAL FARMING AND FOREST
      STP     SOUTHEAST S ATL AND GULF SLOPE CASH CROPS FORES AND LVST
      STT     SOUTHEAST ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP
      DLN     DELTA STATES EAST AND CENTRAL FARMING AND FOREST
      DLO     DELTA STATES MISSISSIPPI DELTA COTTON AND FEED GRAINS
      DLP     DELTA STATES S ATL AND GULF SLOPE CASH CROPS FORES AND LVST
      DLT     DELTA STATES ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP
      SPH     SOUTHERN PLAINS WEST GREAT PLAINS WINTER WHEAT AND RANGE
      SPI     SOUTHERN PLAINS SW PLATEAUS AND PLAINS RANGE AND COTTON
      SPJ     SOUTHERN PLAINS SW PRAIRIES AND COTTON
      SPM     SOUTHERN PLAINS CENTRAL FEED GRAINS AND LIVESTOCK
      SPN     SOUTHERN PLAINS EAST AND CENTRAL FARMING AND FOREST
      SPP     SOUTHERN PLAINS S ATL AND GULF SLOPE CASH CROPS FOREST AND LVST
      SPT     SOUTHERN PLAINS ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP
      MNB     MOUNTAIN NW WHEAT AND RANGE
      MND     MOUNTAIN WESTERN RANGE AND IRRIGATED
      MNE     MOUNTAIN ROCKY MOUNTAIN RANGE AND FOREST
      MNF     MOUNTAIN NORTH GREAT PLAINS SPRING WHEAT
      MNG     MOUNTAIN WEST GREAT PLAINS RANGE AND IRRIGATED
      MNH     MOUNTAIN WEST GREAT PLAINS WINTER WHEAT AND RANGE
      PAA     PACIFIC NW FOREST, FORAGE AND SPEC CROPS
      PAB     PACIFIC NW WHEAT AND RANGE
      PAC     PACIFIC CAL SUBTROP FRUIT TRUCK AND SPECIALTY CROPS
      PAD     PACIFIC WESTERN RANGE AND IRRIGATED
      PAE     PACIFIC ROCKY MOUNTAIN RANGE AND FOREST

*   LAND RESOURCE REGIONS HIGHLY ERODIBLE LAND

      NTLH    NORTHEAST LAKE STATES FRUIT TRUCK AND DAIRY HEL
      NTNH    NORTHEAST EAST AND CENTRAL FARMING AND FOREST HEL
      NTRH    NORTHEAST NORTHEAST FORAGE AND FOREST HEL
      NTSH    NORTHEAST NORTH ATLANTIC SLOPE DIVERSIFIED FARMING HEL
      NTTH    NORTHEAST ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP HEL
      LAFH    LAKE STATES NORTH GREAT PLAINS SPRING WHEAT HEL
      LAKH    LAKE STATES NORTH LAKE STATES FOREST AND RANGE HEL
      LALH    LAKE STATES LAKE STATES FRUIT TRUCK AND DAIRY HEL
```

```
      LAMH    LAKE STATES CENTRAL FEED GRAINS AND LIVESTOCK HEL
      CBLH    CORN BELT LAKE STATES FRUIT TRUCK AND DAIRY HEL
      CBMH    CORN BELT CENTRAL FEED GRAINS AND LIVESTOCK HEL
      CBNH    CORN BELT EAST AND CENTRAL FARMING AND FOREST HEL
      CBOH    CORN BELT MISSISSIPPI DELTA COTTON AND FEED GRAINS HEL
      %%%%%%

 *   LAND RESOURCE REGIONS NON-HIGHLY ERODIBLE LAND

      NTLN    NORTHEAST LAKE STATES FRUIT TRUCK AND DAIRY NON-HEL
      NTNN    NORTHEAST EAST AND CENTRAL FARMING AND FOREST NON-HEL
      NTRN    NORTHEAST NORTHEAST FORAGE AND FOREST NON-HEL
      NTSN    NORTHEAST NORTH ATLANTIC SLOPE DIVERSIFIED FARMING NON-HEL
      NTTN    NORTHEAST ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP NON-HEL
      LAFN    LAKE STATES NORTH GREAT PLAINS SPRING WHEAT NON-HEL
      LAKN    LAKE STATES NORTH LAKE STATES FOREST AND RANGE NON-HEL
      LALN    LAKE STATES LAKE STATES FRUIT TRUCK AND DAIRY NON-HEL
      LAMN    LAKE STATES CENTRAL FEED GRAINS AND LIVESTOCK NON-HEL
      CBLN    CORN BELT LAKE STATES FRUIT TRUCK AND DAIRY NON-HEL
      CBMN    CORN BELT CENTRAL FEED GRAINS AND LIVESTOCK NON-HEL
      CBNN    CORN BELT EAST AND CENTRAL FARMING AND FOREST NON-HEL
      CBON    CORN BELT MISSISSIPPI DELTA COTTON AND FEED GRAINS NON-HEL
      CBRN    CORN BELT NORTHEAST FORAGE AND FOREST NON-HEL
      NPFN    NORTHERN PLAINS NORTH GREAT PLAINS SPRING WHEAT NON-HEL
      NPGN    NORTHERN PLAINS WEST GREAT PLAINS RANGE AND IRRIGATED NON-HEL
      NPHN    NORTHERN PLAINS WEST GREAT PLAINS WINTER WHEAT AND RANGE NON-HEL
      %%%
```

Major region schemes used in REAP are defined as subsets of `U`. Set `R` contains only the 10 USDA Farm Production Regions, while `RL` contains only the Land Resource Regions (LRRs). The LRRs are defined by the intersection of the USDA's 10 Farm Production Regions with the USDA's 26 LRRs. Thus, `RL` breaks each Farm Production Region into subregions defined by the portion of each Land Resource Region that it contains.

r farm production region $r \subset u$, $r = 1,\ldots,\mathrm{R}$

```
SET R(U)  FARM PRODUCTION REGIONS /
         NT,LA,CB,NP,AP,SE,DL,SP,MN,PA
           /
```

rl land resource region region, $rl = 1,\ldots,\mathrm{RL}$

```
SET RL(U)  LAND RESOURCE REGIONS /
      NTL     NORTHEAST LAKE STATES FRUIT TRUCK AND DAIRY
      NTN     NORTHEAST EAST AND CENTRAL FARMING AND FOREST
      NTR     NORTHEAST NORTHEAST FORAGE AND FOREST
      NTS     NORTHEAST NORTH ATLANTIC SLOPE DIVERSIFIED FARMING
      NTT     NORTHEAST ATLANTIC AND GULF COAST LOWLAND FOREST AND CROP
      LAF     LAKE STATES NORTH GREAT PLAINS SPRING WHEAT
      LAK     LAKE STATES NORTH LAKE STATES FOREST AND RANGE
      LAL     LAKE STATES LAKE STATES FRUIT TRUCK AND DAIRY
      LAM     LAKE STATES CENTRAL FEED GRAINS AND LIVESTOCK
      CBL     CORN BELT LAKE STATES FRUIT TRUCK AND DAIRY
      CBM     CORN BELT CENTRAL FEED GRAINS AND LIVESTOCK
      CBN     CORN BELT EAST AND CENTRAL FARMING AND FOREST
      CBO     CORN BELT MISSISSIPPI DELTA COTTON AND FEED GRAINS
      CBR     CORN BELT NORTHEAST FORAGE AND FOREST
...
...
        /
;
```

Set `RL` is defined above without differentiating between highly erodible and nonhighly erodible land. It is possible to define set `RL` so that it differentiates between highly erodible and nonhighly erodible land or so that it includes all three land types. The definition used depends on the type of analysis being run. For ease of exposition, we use `RL` as defined above in the rest of this section.

Mappings are multidimensional GAMS sets that relate elements of one set to elements of another set. Set `ER2RR`, for example, relates REAP Farm Production Regions to the Land Resource Regions. Mapping sets in REAP are generally named mnemonically to suggest linking the first set to, or "2," the second. Set `ER2RR`, which maps Land Resource Regions into Farm Production Regions, is shown below.

```
SET ER2RR(U,UR) FARM PRODUCTION REGION TO FARM RESOURCE PRODUCTION REGION MAP /

   (NTL, NTN, NTR, NTS, NTT)              .NT
   (LAF, LAK, LAL, LAM)                   .LA
   (CBL, CBM, CBN, CBO, CBR)              .CB
   (NPF, NPG, NPH, NPM)                   .NP
   (APN, APO, APP, APS, APT)              .AP
   (STN, STP, STT)                        .SE
   (DLN, DLO, DLP, DLT)                   .DL
   (SPD, SPH, SPI, SPJ, SPM, SPN, SPP, SPT).SP
   (MNB, MND, MNE, MNF, MNG, MNH)         .MN
   (PAA, PAB, PAC, PAD, PAE)              .PA
   /;
```

This mapping allows you to define operations to be applied over only those members of `U` that map to a specific region `UR`. Other regional mappings relating HUCS to each other and to Farm Resource Regions are in the REAP listing files. There are also mappings that separate Mississippi Basin HUCS from non-Mississippi Basin HUCS.

Government Program Indexes

Set `G` depicts government program attributes of REAP production enterprises. For example, `NP` portrays "nonparticipant" or "normal" activities, depending on the context where it appears.

Set g government program attribute category, $g = 1,\ldots,G$

```
SET G     GOVERNMENT PROGRAM ATTIBUTE CATEGORY /
           NP NONPARTICIPANT OR NORMAL
           P1 PARTICIPANT LEVEL 1
           /
```

A production activity for a crop such as `CORN`—for which a government program exists—can be either "participating in government programs" (`P1`) or "nonparticipating" (`NP`). An enterprise such as `FEEDLOT` for which no government program exists, has only one relevant category: "normal" (`NP`). Since the changes in the commodity programs that took place with the 1996 Farm Bill, the differentiation of crop production activities by their participation or nonparticipation in farm programs has not been used.

Production Types

Two sets, `Y` and `H`, are reserved (but not currently used) to differentiate alternative production regimes and methods of production. All variables and parameters, where these sets appear in the declaration, are defined with default values. Set `Y` refers to regimes with `PRD`, representing predominant systems, and `AL1`, refers to alternative sustainable practices that have been defined for cropping systems. The default value for production regimes is `PRD`. `AL1` systems are available for use in scenario analysis, but availability of those regimes would need to be switched on. Alternative systems denoted "`AL2`" have not yet been defined; this set element was created as a placeholder to create flexibility for inclusion of additional systems in the future.

Set y system of production, y = 1,…,Y

```
SET Y     SYSTEM OF PRODUCTION
           PRD     PREDOMINANT
           AL1     ALTERNATE 1
           AL2     ALTERNATE 2
           /
```

Set `H` denotes the use of irrigation for production activities. Crop enterprises might be either `D` (dry) or `I` (irrigated) if irrigation is modeled for a crop. Its default value is `A`.

Set h method of production, h = 1,…,H

```
SET H     METHOD OF PRODUCTION /
           D DRYLAND
           I IRRIGATED
           A ALL OR NORMAL
           /
```

Element `A` applies to those production activities in REAP not differentiated by irrigation method. Element `A` also applies to all livestock enterprises. Although REAP permits the specification of separate dry/irrigated crop production activities, in its current formulation it does not do so. Thus, `H` is set at `A` for "all crop production activities." This does not mean that the crop production activities specified with an `A` represent an average of irrigated and dryland practices. Usually, the production activity represented with an `A` will be either irrigated or dryland, depending on whether dryland or irrigated production for this crop predominates in a Farm Resource Production Region. The exception to this is for production of cotton in the Southern Plains, where the division between irrigated and dryland acreage is split fairly evenly. In this case the production activities used in the model represent a weighted average of irrigated and dryland production activities.

Set `T` covers tillage practice alternatives. All crop production activities are defined with one of the five tillage practices represented. `ATL` is used as the default setting for all livestock production activities, and those crop production activities, with no tillage-specific information.

Set t tillage practice, *t* = 1,…,T

```
SET T     STRATA OF PRODUCTION /
           CNV     CONVENTIONAL WITHOUT MOLDBOARD
           MLD     CONVENTIONAL WITH MOLDBOARD
           MCH     MULCH TILLAGE
           NTL     NO TILL
           RDG     RIDGE TILLAGE
           ATL     ALL TILLAGE TYPES
           /
```

Set `FT` specifies the fertilizer application rates available for a crop production activity. The element 1 represents the initial or base fertilizer application rate, while the remaining elements represent reduced application rates. Currently, REAP includes only the option of reducing nitrogen fertilizer application rates to 60 percent of the base rate.

Set ft fertilizer application rate, ft = 1,…,FT

```
SET ft      FT FERTLIZER APPLICATION RATE LEVELS /
1       BASE APPLICATION RATE (100 PERCENT)
9       NINETY PERCENT OF BASE APPLICATION RATE
8       EIGHTY PERCENT OF BASE APPLICATION RATE
7       SEVENTY PERCENT OF BASE APPLICATION RATE
```

```
6      SIXTY PERCENT OF BASE APPLICATION RATE
```

Market Types

Set M includes all product supply and use market categories modeled in REAP.

m supply and use market category, m = 1,…,M

```
SET M   PRODUCT SUPPLY AND USE MARKET CATEGORIES /
* -------------------------------------------
* CATEGORY    DESCRIPTION
* -------------------------------------------
*   SUPPLY CATEGORIES

   STB       TOTAL BEGINNING STOCKS (COMPOSED OF SGB & SCB)
     SGB     BEGINNING GOVERNMENT STOCKS (RHS VARIABLE)
     SCB     BEGINNING COMMERCIAL STOCKS (RHS VARIABLE)
   PRDN      DOMESTIC PRODUCTION (EXPLICIT SUPPLY)
   IMP       IMPORTS (EXPLICIT SUPPLY)
   RESS      RESIDUAL SUPPLY (USED IN CALIBRATION)

*   USE CATEGORIES

   DOM       DOMESTIC CONSUMPTION (EXPLICIT DEMAND THAT EXCLUDES PRPC)
   PRPC      PRODUCTION & PROCESSING USE (IMPLICIT DERIVED DEMAND)
   EXP       EXPORTS (EXPLICIT DEMAND) EXCLUDING EEP
   EEP       EXPORTS UNDER EXPORT ENHANCEMENT PROGRAM (EEP) (EXPLICIT DEMAND)
   STE       TOTAL ENDING STOCKS (COMPOSED OF SGE & SCE)
     SGE     ENDING GOVERNMENT STOCKS
     SCE     ENDING COMMERCIAL STOCKS (EXPLICIT DEMAND)
   RESD      RESIDUAL USE (USED IN CALIBRATION)

*   OTHER GOVERNMENT STOCK ACTION CATEGORIES
   SGA       GOVERNMENT STOCK ACCUMULATIONS (INCREASE OVER PERIOD)
   SGO       GOVERNMENT STOCK CARRYOVER FROM PREVIOUS PERIOD
   SGR       GOVERNMENT STOCK RELEASE TO THE COMMERCIAL MARKET (DECREASE OVER PERIOD)
   SGV       GOVERNMENT NET STOCK REMOVALS FROM THE COMMERCIAL MARKET (PURCHASES)
   SGD       GOVERNMENT STOCK DOMESTIC DONATIONS (FOOD DISTRIBUTION PROGRAMS)
   SGX       GOVERNMENT STOCK EXPORT   DONATIONS (CCC EXPORTS)
   /
```

Beginning stocks, STB, are comprised of government and commercial stocks, SGB and SCB. PRDN refers to production, and IMP refers to imports. A residual supply category, RESD, is used in model calibration to account for cases where baseline total supply and use fail to balance precisely. Domestic use of products includes final domestic demand, DOM, intermediate input or production and processing use, PRPC, and ending stocks, STE (comprised of commercial and government ending stocks, SCE and SGE). Export use includes both commercial and export enhancement program exports, EXP and EEP. Certain other stock categories account for government stock transactions for selected commodities. These include stock accumulation, carryover, release to commercial markets, and net stock removals from commercial markets (SGA, SGO, SGR, and SGV), as well as government stock domestic and foreign donations (SGD and SGX).

Inputs and Outputs

Set IO contains the all the items that appear in REAP production activities as either inputs or outputs. These are commodities, production inputs, and miscellaneous coefficients that describe production activities.

io   input or output of a production activity, *io* = 1,…, IO

```
SET IO  PRODUCTION INPUT-OUTPUT ITEMS /
* --------------------------------------------------------------------------------------
*                                                            PRODUCTION       SOLUTION
* COMMODITY           DESCRIPTION                          ACTIVITY UNITS   REPORT UNITS
* ----------- -------------------------------------------- -------------- --------------
*              PRIMARY (FARM PRODUCED) COMMODITIES, CROPS

  CORN        CORN                                                 BU      MILLION BU
  SORGHUM     SORGHUM                                              BU      MILLION BU
  BARLEY      BARLEY                                               BU      MILLION BU
  OATS        OATS                                                 BU      MILLION BU
  WHEAT       WHEAT                                                BU      MILLION BU
  RICE        RICE                                                 CWT     MILLION CWT
  SOYBEANS    SOYBEANS                                             BU      MILLION BU
  COTTON      COTTON                                               BALE    MILLION BALES

  PCORN       GOVT PROGRAM CORN                                    BU      MILLION BU
  PSORGHUM    GOVT PROGRAM SORGHUM                                 BU      MILLION BU
  PBARLEY     GOVT PROGRAM BARLEY                                  BU      MILLION BU
  POATS       GOVT PROGRAM OATS                                    BU      MILLION BU
  PWHEAT      GOVT PROGRAM WHEAT                                   BU      MILLION BU
  PRICE       GOVT PROGRAM RICE                                    CWT     MILLION CWT
  PSOYBEANS   GOVT PROGRAM SOYBEANS                                BU      MILLION BU
  PCOTTON     GOVT PROGRAM COTTON                                  BALE    MILLION BALES

  SILAGE      SILAGE                                               TON     MILLION TONS
  HAY         HAY                                                  TON     MILLION TONS

  LCORN       LONG TERM CORN                                       BU      MILLION BU
  LSORGHUM    LONG TERM SORGHUM                                    BU      MILLION BU
  LBARLEY     LONG TERM BARLEY                                     BU      MILLION BU
  LOATS       LONG TERM OATS                                       BU      MILLION BU
  LWHEAT      LONG TERM WHEAT                                      BU      MILLION BU
  LRICE       LONG TERM RICE                                       CWT     MILLION CWT
  LSOYBEANS   LONG TERM SOYBEANS                                   BU      MILLION BU
  LCOTTON     LONG TERM COTTON                                     BALE    MILLION BALES
  LSILAGE     LONG TERM SILAGE                                     TON     MILLION TONS
  LHAY        LONG TERM HAY                                        TON     MILLION TONS


*              ACREAGE SHARE INDICATORS (FOR ROTATION BUDGETS)

  SCORN       SHARE OF ACTIVITY DEVOTED TO CORN                      PROP    NA
  SSORGHUM    SHARE OF ACTIVITY DEVOTED TO SORGHUM                   PROP    NA
  SBARLEY     SHARE OF ACTIVITY DEVOTED TO BARLEY                    PROP    NA
  SOATS       SHARE OF ACTIVITY DEVOTED TO OATS                      PROP    NA
  SWHEAT      SHARE OF ACTIVITY DEVOTED TO WHEAT                     PROP    NA
  SRICE       SHARE OF ACTIVITY DEVOTED TO RICE                      PROP    NA
  SSOYBEANS   SHARE OF ACTIVITY DEVOTED TO SOYBEANS                  PROP    NA
  SCOTTON     SHARE OF ACTIVITY DEVOTED TO COTTON                    PROP    NA

  SSILAGE     SHARE OF ACTIVITY DEVOTED TO SILAGE                    PROP    NA
  SHAY        SHARE OF ACTIVITY DEVOTED TO HAY                       PROP    NA

*              PRIMARY (FARM PRODUCED) COMMODITIES, LIVESTOCK PRODUCTS

  CLDARYCF    CULL DAIRY CALVES FOR VEAL                           HEAD    MILLION HEAD
  CLDARYCW    CULL DAIRY COWS FOR SLAUGHTER                        HEAD    MILLION HEAD
  MILK        WHOLE FARM MILK                                      CWT     MILLION CWT

  FEEDERPIG   FEEDER PIGS                                          CWT LW  MILLION CWT
  CULLSOW     CULL SOWS FOR SLAUGHTER                              CWT LW  MILLION CWT
```

```
  HOGSLAUGH   SLAUGHTER HOGS                                       CWT LW  MILLION CWT

  LIVCALF     BEEF FEEDER CALVES                                   CWT LW  MILLION CWT
  BFYRLINGS   BEEF FEEDER YEARLINGS                                CWT LW  MILLION CWT
  CALFSLA     CULL BEEF CALVES FOR SLAUGHTER                       CWT LW  MILLION CWT
  CLBFCOW     CULL BEEF COWS FOR SLAUGHTER                         CWT LW  MILLION CWT
  CLBULLSTAG  CULL BULLS & STAGS FOR SLAUGHTER                     CWT LW  MILLION CWT
  NONFDSL     NONFED BEEF FOR SLAUGHTER                            CWT LW  MILLION CWT
  FEDSLA      FED BEEF FOR SLAUGHTER                               CWT LW  MILLION CWT
  FEDSLACF    FED SLAUGHTER COMM FEEDLOT                           CWT LW  MILLION CWT
  OTHRLVSTK   OTHER LIVESTOCK                                      GCAU    MILLION GCAU

*              SECONDARY (PROCESSED AND/OR CONVERSION) PRODUCTS

  BEANMEAL    SOYBEAN MEAL                                         CWT     MILLION CWT
  BEANOIL     SOYBEAN OIL                                          CWT     MILLION CWT
  OOSMEAL     OTHER OILSEED MEAL                                   CWT     MILLION CWT
  ANPROTEIN   ANIMAL PROTEIN (TANKAGE) BEANMEAL EQUIVALENT         CWT     MILLION CWT
  HIPROFEED   HIGH PROTEIN FEED BEANMEAL EQUIVALENT                CWT     MILLION CWT

*              ANIMAL PRODUCTS

  FEDBEEF     FED BEEF    (RETAIL WEIGHT)                          CWT     MILLION CWT
  NONFDBEEF   NONFED BEEF (RETAIL WEIGHT)                          CWT     MILLION CWT
  VEAL        VEAL        (RETAIL WEIGHT)                          CWT     MILLION CWT
  PORK        PORK        (RETAIL WEIGHT)                          CWT     MILLION CWT
  FLUIDMLK    FLUID MILK-CREAM (MILK EQUIVALENT)                   LBS     MILLION LBS
  MFGMILK     MANUFACTURING MILK                                   CWT     MILLION CWT
  BUTTER      BUTTER (PRODUCT WEIGHT)                              LBS     MILLION LBS
  AMCHEESE    AMERICAN CHEESE (PRODUCT WEIGHT)                     LBS     MILLION LBS
  OTCHEESE    OTHER CHEESE (PRODUCT WEIGHT)                        LBS     MILLION LBS
  ICECREAM    ICE CREAM (PRODUCT WEIGHT)                           LBS     MILLION LBS
  NFDMILK     NONFAT DRY MILK (PRODUCT WEIGHT)                     LBS     MILLION LBS
  EVDRYMLK    EVAPORATED, DRY, AND CONDENSED MILK (PRD. WEIGHT)    LBS     MILLION LBS
  MILKFAT     ALTERNATIVE ACCOUNTING METHOD FOR DAIRY PRODUCTS     LBS     MILLION LBS

  EGGS        EGG PRODUCTION                                       DOZEN   MILLION DOZ
  BROILERS    BROILER PRODUCTION (CARCASS WEIGHT)                  LB      MILLION LBS
  TURKEY      TURKEY PRODUCTION (CARCASS WEIGHT)                   LB      MILLION LBS

  PBUTTER     BUTTER PURCHASED BY GOVT                             LBS     MILLION LBS
  PAMCHEESE   AMERICAN CHEESE PURCHASED BY GOVT                    LBS     MILLION LBS
  PNFDMILK    NONFAT DRY MILK  PURCHASED BY GOVT                   LBS     MILLION LBS
*              ETHANOL AND SWEETENER PRODUCTS AND COPRODUCTS

  STARCH      CORN STARCH                                          CWT     MILLION CWT
  CORNOIL     CORN OIL                                             CWT     MILLION CWT
  GLUTMEAL    GLUTEN MEAL (60% PROTEIN)                            CWT     MILLION CWT
  GLUTFEED    GLUTEN FEED (21% PROTEIN)                            CWT     MILLION CWT

  DDG         DISTILLERS DRIED GRAINS                              CWT     MILLION CWT

  ETHWML      ETHANOL FROM WET-MILLING                             GAL     MILLION GAL
  ETHDML      ETHANOL FROM DRY-MILLING                             GAL     MILLION GAL
  ETHANOL     ETHANOL                                              GAL     MILLION GAL

*              PROTEIN, ENERGY ANIMAL NUTRITION COMPONENTS

  CATPROT     CATTLE CRUDE PROTEIN AVAILABLE                       LB      MILLION LBS
  SWIPROT     SWINE  CRUDE PROTEIN AVAILABLE                       LB      MILLION LBS
  DAIPROT     DAIRY  CRUDE PROTEIN AVAILABLE                       LB      MILLION LBS
  CATENER     CATTLE METABOLIZABLE ENERGY AVAILABLE                MCAL    MILLION MCAL
  SWIENER     SWINE  METABOLIZABLE ENERGY AVAILABLE                MCAL    MILLION MCAL
  DAIENER     DAIRY  METABOLIZABLE ENERGY AVAILABLE                MCAL    MILLION MCAL

  SWILINO     SWINE  LINOLEIC ACID AVAILABLE                       LB      MILLION LBS
```

```
  SWILYSI     SWINE  LYSINE AVAILABLE                              LB      MILLION LBS

  EGGPROT     EGG PROD CRUDE PROTEIN AVAILABLE                     LB      MILLION LBS
  EGGENER     EGG PROD METABOLIZABLE ENERGY AVAILABLE              MCAL    MILLION LBS
  BROPROT     BROILER PROD CRUDE PROTEIN AVAILABLE                 LB      MILLION LBS
  BROENER     BROILER PROD METABOLIZABLE ENERGY AVAILABLE          MCAL    MILLION LBS
  TRKPROT     TURKEY PROD CRUDE PROTEIN AVAILABLE                  LB      MILLION LBS
  TRKENER     TURKEY PROD METABOLIZABLE ENERGY AVAILABLE           MCAL    MILLION LBS

*               LIVESTOCK MANURE
  MANAU       MANURE EXCRETED                                      TON     MILLION TONS
  prenit      NITROGEN IN EXCRETED MANURE ALL LIVESTOCK OPERATIONS LB      MILLION LBS
  MANNIT      NITROGEN AVAILABLE IN AFTER HANDLING                 LB      MILLION LBS
  prephs      PHOSPHOROUS IN EXCRETED                              LB      MILLION LBS
  MANPHS      PHOSPHOROUS AVAILABLE AFTER HANDLING                 LB      MILLION LBS
* ---------------------------------------------------------------------------------------

$STITLE REAP MODEL'S INPUTS AND OUTPUTS: INPUTS

* ---------------------------------------------------------------------------------------
*                                                            PRODUCTION     SOLUTION
*      INPUT            DESCRIPTION                          ACTIVITY UNITS REPORT UITS
* ---------------- ------------------------------------------ -------------- -------------
* ---------------------------------------------------------------------------------------

*                                INPUTS

  CROPLAND    LAND (CROP)                                      ACRE        MILLION ACRES
  PASTURE     LAND (PASTURE)                                   ACRE        MILLION ACRES
  AUM         LAND (ANIMAL UNIT MONTHS)                        AUM         MILLION AUMS
  WATER       IRRIGATION WATER (GROUND)                        ACRE FT     MILLION ACFT
  NITROGEN    NITROGEN FERTILIZER                              US$         MILLION US$
  PHOSPHAT    POTASSIUM FERTILIZER                             US$         MILLION US$
  POTASH      POTASH FERTILIZER                                US$         MILLION US$
  LIME        LIME                                             US$         MILLION US$
  OVARCOST    OTHER VARIABLE COSTS                             US$         MILLION US$
  PUBGRAZG    PUBLIC GRAZING LAND                              AUMS        MILLION AUMS
  CUSTOM      CUSTOM FARMING OPERATIONS                        US$         MILLION US$
  CHEMICAL    CHEMICALS                                        US$         MILLION US$
  SEEDCOST    SEED COST                                        US$         MILLION US$
  OPERCAP     INTEREST ON OPERATING CAPITAL                    US$         MILLION US$
  REPAIRS     MACHINERY & EQUIPMENT REPAIR                     US$         MILLION US$
  VET+MED     VETERINARY & MEDICAL COST                        US$         MILLION US$
  MKT+STO     MARKETING AND STORAGE                            US$         MILLION US$
  INS+FEES    INSURANCE AND FEES                               US$         MILLION US$
  OWNRSHIP    CASH OWNERSHIP COSTS                             US$         MILLION US$
  OWNNONC     NONCASH OWNERSHIP COSTS                          US$         MILLION US$
  MANAGEMT    MANAGEMENT COSTS                                 US$         MILLION US$
  ESTMGMT     OTHER EST. MANAGEMENT COSTS                      US$         MILLION US$
  OVERHEAD    GENERAL FARM OVERHEAD                            US$         MILLION US$
  VARCNCSH    VARIABLE NONCASH COSTS                           US$         MILLION US$
  PURWATER    IRRIGATION WATER PURCHASED                       US$         MILLION US$
  TOTIRAPP    IRRIGATION WATER APPLICATION                     ACRE FT     MILLION ACFT
  ENERGY      ENERGY COSTS                                     US$         MILLION US$
  IRENERGY    IRRIGATION PUMPING COSTS                         US$         MILLION US$
  LANDTAX     LAND TAXES                                       US$         MILLION US$
  LANDRENT    LAND RENT                                        US$         MILLION US$
  CONSVCOP    CONSERVING USE PROD. COST                        US$         MILLION US$
  DIVPMT      ACREAGE DIVRSN PMTS (NEG COST)                   US$         MILLION US$
  LABOR       LABOR (FAMILY AND HIRED)                         US$         MILLION US$
  IRRLABOR    IRRIGATION LABOR (FAM & HRD)                     US$         MILLION US$
  MISCCOST    MISCELLANEOUS PRODUCTION COSTS                   US$         MILLION US$
```

```
  PROCCOST    PROCESSING COSTS                                 US$         MILLION US$
  INGRED      INGREDIENTS OTHER THAN CORN                      US$         MILLION US$
  MANAG      "MANAGEMENT, ADMINISTRATION, INSURANCE AND TAXES  US$         MILLION US$"
  OPERAT      LABOR AND MAINTENANCE                            US$         MILLION US$
  KIA         INCREMENTAL ADDITIONS TO WET MILLING             US$         MILLION US$
  KAD         ADAPTION OF ABANDONED CAPACITY                   US$         MILLION US$
  KNP         BUILDING NEW PLANT                               US$         MILLION US$

*                                       LVSK COP UPDATE REVISION TO THIS FILE 2/11-92)

  AI          ARTIFICIAL INSEMINATION                          US$         MILLION US$
  BY-PRODZ    BY-PRODUCTS (Z)                                  US$         MILLION US$
  DHIA        DAIRY HERD IMPROVEMENT ASSOCIATION FEES          US$         MILLION US$
  DAIRASSE    DAIRY ASSESSMENT                                 US$         MILLION US$
  DAIRYSUP    DAIRY SUPPLIES                                   US$         MILLION US$
  FUEL+ELE    FUEL LUBE AND ELECTRICITY                        US$         MILLION US$
  HAUL        LIVESTOCK HAULING                                US$         MILLION US$
  MILKHAUL    MILK HAULING AND MARKETING                       US$         MILLION US$
  TAX+INSU    TAXES AND INSURANCE                              US$         MILLION US$
  BEDDING     BEDDING                                          US$         MILLION US$
  FEEDMIX     CUSTOM FEED MIXING                               US$         MILLION US$
  MANURE      MANURE CREDIT                                    US$         MILLION US$
  HAYLAGEZ    HAYLAGE ($)                                      US$         MILLION US$
  MANAGEM     HIRED MANAGEMENT                                 US$         MILLION US$
  MISCELLA    MISCELLANEOUS                                    US$         MILLION US$
  PUBGRAZE    PUBLIC GRAZING                                   US$         MILLION US$
  MINERALZ    SALT AND MINERALS ($)                            US$         MILLION US$
  CROPRESI    CROP RESIDUE                                     US$         MILLION US$
  INTEREST    INTEREST                                         US$         MILLION US$

*ECONOMIC COST   ITEM DESCRIPTION

  CAPIREPL    CAPITAL REPLACEMENT COST                         US$         MILLION US$
  OPERCAPC    OPERATING CAPITAL COST                           US$         MILLION US$
  OTHECAP     OTHER NONLAND CAPITAL COST                       US$         MILLION US$
  LANDCOST    LAND OPPORTUNITY COST                            US$         MILLION US$
  LABUNPDZ    COST OF UNPAID LABOR                             US$         MILLION US$
  TECONCOS    TOTAL ECONOMIC COST                              US$         MILLION US$
  RESIDUAL    RESIDUAL RETURN TO MANAGEMENT AND RISK           US$         MILLION US$

*BUDGETED ENDOGENOUS  DESCRIPTION

  CONCZ       BUDGETED COST OF CONCENTRATES                    US$         MILLION US$
  HAYZ        BUDGETED COST OF HAY ($)                         US$         MILLION US$
  SILAGEZ     BUDGETED COST OF SILAGE ($)                      US$         MILLION US$
  GRAINZ      BUDGETED COST OF GRAIN ($)                       US$         MILLION US$
  PROTSUPZ    BUDGTD COST OF PROT SUPPLEMENT                   US$         MILLION US$

*QUANTITIES           DESCRIPTION

  GRAIN       GRAIN (COP BUDGET UNITS)                         CWT         MILLION CWT
  GRAINCORN   GRAIN CORN COMPONENT IN CORN EQ UNITS            CWT         MILLION CWT
  GRAINSBM    GRAIN BEANMEAL COMPONENT IN CORN EQ UNITS        CWT         MILLION CWT
  CONC        CONCENTRATES (DAIRY)                             CWT         MILLION CWT
  PROTSUP     PROTEIN SUPPLEMENT                               CWT         MILLION CWT
  LABUNPDH    HOURS OF UNPAID LABOR                            HR          MILLION HRS

*           REAP MODEL'S INPUTS AND OUTPUTS: ENVIRONMENTAL SET IO ELEMENTS

  EMENERGY    EMBODIED ENERGY                                  UNITS       MILLION UNITS
  SOILDEP     SOIL DEPRECIATION ALLOWANCE                      US$         MILLION US$
  EROSION     SOIL LOSS FROM WATER EROSION                     TONS        MILLION TONS
  ERSNCOST    OFF-SITE SOIL EROSION COST                       US$         MILLION US$
  WINDERSN    SOIL LOSS FROM WIND EROSION                      TONS        MILLION TONS
```

```
  NUSE        NITROGEN FERTILIZER USE                          LBS         MILLION LBS
  NSOLN       NITROGEN LOSS IN SOLUTION (SURFACE RUNOFF)       LBS         MILLION LBS
  NSEDMNT     NITROGEN LOSS WITH SEDIMENTS                     LBS         MILLION LBS
  NLEACH      NITROGEN LEACHING POTENTIAL                      LBS         MILLION LBS
  NDENITE     NITROGEN LOSS BY DENITRIFICATION                 LBS         MILLION LBS
  NVOL        NITROGEN VOLATALIZATION                          LBS         MILLION LBS
  NLOSS       TOTAL NITROGEN LOSS TO THE ENVIRONMENT           LBS         MILLION LBS
  NFLUX       NITROGEN FLUX                                    TONS        MILLION TONS
  NFLUXVAL    NITROGEN FLUX VALUE                              US$         MILLION US$
  NCRED       NITROGEN CREDIT                                  LBS         MILLION LBS
  XN          EXCESS NITROGEN BALANCE                          LBS         MILLION LBS
  PSOLN       PHOSPHORUS LOSS IN SOLUTION (SURFACE RUNOFF)     LBS         MILLION LBS
  PSEDMNT     PHOSPHORUS LOSS WITH SEDIMENTS                   LBS         MILLION LBS
  PLEACH      PHOSPHORUS LEACHED                               LBS         MILLION LBS
  PLOSS       TOTAL PHOSPHORUS LOSS TO THE ENVIRONMENT         LBS         MILLION LBS
  CFLUX       CARBON FLUX                                      TONS        MILLION TONS
  CFLUXVAL    CARBON FLUX VALUE                                US$         MILLION US$

*      EXTENDED ENVIRONMENTAL INDICATORS

  IRGA         IRRIGATION WATER APPLIED
* LIME        LIME ADDED TO SOIL
  MUST

  PRCP         PRECIPITATION

  SRUNOFF
  SSFN

*      NITROGEN AND PHOSPHOROUS BALANCE DETAIL

  N-NVOL       NITROGEN LOSS BY VOLITILIZATION      LBS         MILLION LBS
  N-BTN NITORGEN BEGINNING TOTAL IN SOIL     LBS         MILLION LBS
  N-NDENITE  NITROGEN LOSS BY DENITRIFICATION       LBS         MILLION LBS
  N-FNH3       NITROGEN FERTILIZER ANHYDROUS AMMONIA LBS         MILLION LBS
  N-FNO3       NITROGEN FERTLIZER  NITRATE   LBS         MILLION LBS
  N-FTN NITROGEN TOTAL FERTILIZER USE LBS         MILLION LBS
  N-FX  NITROGEN FIXED LBS         MILLION LBS
  N-NBAL       NITROGEN BALANCE      LBS         MILLION LBS
  N-NLEACH     NITROGEN LEACHING POTENTIAL   LBS         MILLION LBS
  N-RN  NITROGEN CONTAIEND IN RAINFALL       LBS         MILLION LBS
  N-SSFN       NITORGEN LOSS IN SUBSURFACE FLOW     LBS         MILLION LBS
  N-TFO NITROGEN FERTLIZER ORGANIC    LBS         MILLION LBS
  N-YLN NITROGEN CONTAINED IN CROP YIELD      LBS         MILLION LBS
  N-NSOLN      NITROGEN LOSS IN SOLUTION (SURFACE RUNOFF    LBS         MILLION LBS
  N-NSEDMT     NITROGEN LOSS WITH SEDIMENT   LBS         MILLION LBS
  P-BTP PHOSPHOROUS BEGINNING TOTAL IN SOIL  LBS         MILLION LBS
  P-FTP PHOSPHOROUS TOTAL FERTILIZER APPLIED LBS         MILLION LBS
  P-PBAL       PHOSPHOROUS BALANCE   LBS         MILLION LBS
  P-PLAB       PHOSPHOROUS LABILE    LBS         MILLION LBS
  P-PLEACH     PHOSPHOROUS LEACHING POTENTIAL       LBS         MILLION LBS
  P-PSOLN      PHOSPHORUS LOSS IN SOLUTION (SURFACE RUNNOFF)       LBS         MILLION LBS
  P-YLP PHOSPHOROUS CONTAIED IN CROP YIELD   LBS         MILLION LBS
  P-PSEDMT     PHOSPHOROUS LOSS WITH SEDIMENTS      LBS         MILLION LBS

*      PESTICIDE APPLICATION COMPONENTS
  PAPL  PESTICIDE APPLIED      LBS         MILLION LBS
  PDGF  PESTICIDE APPLIED FOLIAR      LBS         MILLION LBS
  PDGS  PESTICIDE APPLIED SOIL LBS         MILLION LBS
  PLCH  PESTICIDE LEACH POTENTIAL     LBS         MILLION LBS
  PSED  PESTICIDE LOSS WITH SEDIMENT  LBS         MILLION LBS
  PSRO  PESTICIDE LOSS WITH RUNOFF    LBS         MILLION LBS
  PSSF  PESTICIDE LOSS IN SUBSURFACE FLOW    LBS         MILLION LBS
```

```
  PTAI  PESTICIDE APPLIED ACTIVE INGEDIENT   LBS         MILLION LBS
  PIAI  PESTICIDE APPLIED INSECTICIDE ACTIVE INGREDIENT     LBS         MILLION LBS
  PHAI  PESTICIDE APPLIED HERBICIDE ACTIVE INGREDIENT       LBS         MILLION LBS
  PFAI  PESTICIDE APPLIED FUNGICIDE ACTIVE INGREDIENT       LBS         MILLION LBS
  POAI  PESTICIDE APPLIED OTHER ACTIVE INGREDIENT   LBS         MILLION LBS

*      PESTICIDE APPLICATION BY CROP AND PESTICIDE TYPE         LBS         MILLION LBS

* TOTAL        INSECTICIDE  HERBICIDE    FUNGICIDE    OTHER
  PTCORN,      PICORN     , PHCORN     , PFCORN     , POCORN
  PTSORGHUM  , PISORGHUM  , PHSORGHUM  , PFSORGHUM  , POSORGHUM
  PTBARLEY   , PIBARLEY   , PHBARLEY   , PFBARLEY   , POBARLEY
  PTOATS     , PIOATS     , PHOATS     , PFOATS     , POOATS
  PTWHEAT    , PIWHEAT    , PHWHEAT    , PFWHEAT    , POWHEAT
  PTRICE     , PIRICE     , PHRICE     , PFRICE     , PORICE
  PTSOYBEANS , PISOYBEANS , PHSOYBEANS , PFSOYBEANS , POSOYBEANS
  PTCOTTON   , PICOTTON   , PHCOTTON   , PFCOTTON   , POCOTTON
  PTHAY      , PIHAY      , PHHAY      , PFHAY      , POHAY
  PTSILAGE   , PISILAGE   , PHSILAGE   , PFSILAGE   , POSILAGE
```

Output Subsets

Final products, or outputs of production or processing, are defined as a subset `P` of set `IO`. Set `P` is further disaggregated into crops, livestock, and processed product subsets: `PC` (crop products), `PL` (livestock products), and `PX` (processed products).

p commodity, $p \subset io$, $p = 1,\ldots,P$

```
SET P(IO) COMMODITIES-OUTPUTS /

       CORN,      SORGHUM,   BARLEY,    OATS
       WHEAT,     RICE,      SOYBEANS,  COTTON
       PCORN,     PSORGHUM,  PBARLEY,   POATS
       PWHEAT,    PRICE,     PSOYBEANS, PCOTTON

       SILAGE,    HAY

       CLDARYCF,  CLDARYCW,  MILK
       FEEDERPIG, CULLSOW,   HOGSLAUGH
       LIVCALF,   BFYRLINGS, CALFSLA,   CLBFCOW,   CLBULLSTAG
       NONFDSL,   FEDSLA,    FEDSLACF,  OTHRLVSTK
       BEANMEAL,  BEANOIL,   OOSMEAL,   ANPROTEIN, HIPROFEED
       STARCH,    CORNOIL,   GLUTMEAL,  GLUTFEED
       CATPROT,   SWIPROT,   DAIPROT
       CATENER,   SWIENER,   DAIENER
       SWILINO,   SWILYSI
       EGGPROT,   EGGENER,   BROPROT
       BROENER,   TRKPROT,   TRKENER

       DDG,
       ETHSOA, ETHWML, ETHDML, ETHANOL
*
```

pc crop commodity, $pc \subset p$

```
SET PC(IO) CROP PRODUCTS /

          CORN,      SORGHUM,   BARLEY,    OATS
          WHEAT,     RICE,      SOYBEANS,  COTTON,
          SILAGE,    HAY
          /
```

pl livestock commodity, $pl \subset p$

```
SET PL(IO)  LIVESTOCK PRODUCTS /

          CLDARYCF,  CLDARYCW,  MILK
          CULLSOW,   FEEDERPIG, HOGSLAUGH
          LIVCALF,   BFYRLINGS, CALFSLA,   CLBFCOW,   CLBULLSTAG
          NONFDSL,   FEDSLA,    FEDSLACF
          OTHRLVSTK
```

px processed commodity, $px \subset p$

```
PX(IO)  PROCESSED PRODUCTS /

          BEANMEAL,  BEANOIL,   OOSMEAL,   ANPROTEIN, HIPROFEED
          STARCH,    CORNOIL,  GLUTMEAL,   GLUTFEED
          DDG,
          ETHSOA, ETHWML, ETHDML, ETHANOL

*

          CATPROT,   SWIPROT,   DAIPROT
          CATENER,   SWIENER,   DAIENER
          SWILINO,   SWILYSI
          EGGPROT,   EGGENER,   BROPROT
          BROENER,   TRKPROT,   TRKENER

          FEDBEEF,   NONFDBEEF, VEAL,      PORK
          FLUIDMLK,  MFGMILK,   BUTTER,    AMCHEESE,  OTCHEESE,  ICECREAM
          NFDMILK,   EVDRYMLK,  EGGS,      BROILERS,  TURKEY
```

Input Subsets

Inputs are defined as a subset I of set IO. Set I is further disaggregated into national and regional input subsets: IN and IR. National inputs are specified with a single fixed price in any area of the U.S. Regional inputs specify a relationship between price and quantity used by Farm Production Region:

```
I(IO)    INPUTS EXCLUSIVE OF MODEL-ENDOGENOUS PRODUCTS /

          CROPLAND,  PASTURE,   AUM,       WATER
          NITROGEN,  PHOSPHAT,  POTASH
          LIME,      OVARCOST,  PUBGRAZG,  CUSTOM,    CHEMICAL,  SEEDCOST
          OPERCAP,   REPAIRS,   VET+MED,   MKT+STO,   INS+FEES,  OWNRSHIP
          IRENERGY
          MANAGEMT,  ESTMGMT,   OVERHEAD,  VARCNCSH,  PURWATER,  TOTIRAPP
          ENERGY,    LANDTAX,   LANDRENT,  CONSVCOP,  DIVPMT,    LABOR
          MISCCOST,  PROCCOST

*                                                   LVSK ADDITION CASH COSTS
          AI,        BY-PRODZ,  DHIA,      DAIRASSE,  DAIRYSUP,  FUEL+ELE
          HAUL,      MILKHAUL,  TAX+INSU,  BEDDING,   FEEDMIX,   MANURE
          HAYLAGEZ,  MANAGEM,   MISCELLA,  PUBGRAZE,  MINERALZ,  CROPRESI
          INTEREST

*                                                   LVSK ADDITION ECONOMIC COSTS
          CAPIREPL,  OPERCAPC,  OTHECAP,   LANDCOST,  LABUNPDZ
          TECONCOS,  RESIDUAL
          /

IR(IO)  REGIONAL INPUTS /
          CROPLAND,  PASTURE,   AUM,       WATER,     TOTAL
          /

IN(IO)  NATIONAL INPUTS /
```

```
          NITROGEN,  PHOSPHAT,  POTASH
          LIME,      OVARCOST,  PUBGRAZG,  CUSTOM,    CHEMICAL,  SEEDCOST
          OPERCAP,   REPAIRS,   VET+MED,   MKT+STO,   INS+FEES,  OWNRSHIP
          IRENERGY
          MANAGEMT,  ESTMGMT,   OVERHEAD,  VARCNCSH,  PURWATER,  TOTIRAPP
          ENERGY,    LANDTAX,   LANDRENT,  CONSVCOP,  DIVPMT,    LABOR
          MISCCOST,  PROCCOST,

*                                                    ETHANOL REVISION
          INGRED, MANAG, OPERAT, KIA, KAD, KNP

*                                                    LVSK ADDITION CASH COSTS
          AI,        BY-PRODZ,  DHIA,      DAIRASSE,  DAIRYSUP,  FUEL+ELE
          HAUL,      MILKHAUL,  TAX+INSU,  BEDDING,   FEEDMIX,   MANURE
          HAYLAGEZ,  MANAGEM,   MISCELLA,  PUBGRAZE,  MINERALZ,  CROPRESI
          INTEREST

*                                                    LVSK ADDITION ECONOMIC COSTS
          CAPIREPL,  OPERCAPC,  OTHECAP,   LANDCOST,  LABUNPDZ
          TECONCOS,  RESIDUAL
          /
```

Exogenous Variables (GAMS Parameters)

Since REAP's formulation is parameter-driven, it is necessary to be familiar with its key data parameters; i.e., exogenous variables. In GAMS, data are stored in objects called "PARAMETERS." SCALARS are PARAMETERS with a single dimension. TABLES are PARAMETERS with 2 to 10 dimensions. GAMS parameters with several dimensions are shown in this bulletin and in GAMS, input or output code as two-dimensional tables. Indexes for additional dimensions (that is, beyond two) appear either in the table row stub or column heading, depending on what most clearly illustrates the data in question. Here, we present only the minimum information necessary to understand the REAP equations. We list and discuss definitions and at least part of the contents for the most important REAP PARAMETERS. Where the PARAMETER contains a large amount of data, we present only a fragment or two of the data. REAP model PARAMETERS that contain raw input data or are used in intermediate calculations are not presented or discussed here (but are present in the REAP source and listings).

Production Activity Data

REAP crop and livestock production activity coefficients reside in table `PP`. Production activity coefficients represent the quantity of outputs produced or inputs used per unit of each production activity. The production activity data to produce the coefficients come from the ERS Farm Costs and Returns Survey data, the USDA baseline, the agricultural census, and other sources.

`PP` is indexed over seven dimensions: input-output item, enterprise, government program category, method of production (not active), system of production (not active), tillage type, and region. The rows of the `PP` crops fragment refer to input-output items, and columns refer to the other indexes.

Example 2—PP(IO,B,G,H,Y,T,RL,R) Crop Fragment

```
PARAMETER PP(IO,B,G,H,Y,T,RL,R) ENTERPRISE TECHNICAL COEFFICIENTS

                     RCCC         RCB         RCB        RCBW        RCBW
                      NP          NP          NP          NP          NP
                       A           A           A           A           A
                     PRD         PRD         PRD         PRD         PRD
                     CNV         CNV         MCH         CNV         NLL
                     CBM         CBM         CBM         LAL         APP
                      CB          CB          CB          LA          AP

 CORN            132.582     136.690     136.470     129.979      89.953
 WHEAT                                                43.092      51.948
 SOYBEANS                     47.318      47.171      51.219      19.759
 LCORN           132.960     137.099     137.189     131.408      90.014
 LWHEAT                                               42.957      51.967
 LSOYBEANS                    47.649      47.459      51.227      19.766
 SCORN             1.000       0.500       0.500       0.333       0.500
 SWHEAT                                                0.333       0.500
 SSOYBEANS                     0.500       0.500       0.333       0.500
 CROPLAND          1.000       1.000       1.000       1.000       1.000
 NITROGEN         41.480      20.360      19.980      17.560      31.940
 PHOSPHAT         13.620      13.670      13.670      13.590       9.490
 POTASH            8.740       5.110       5.110       2.200       8.940
 LIME              1.040       0.060       0.060                   0.090
 CHEMICAL         16.110      10.670      15.680       9.300      17.770
 SEEDCOST         22.900      18.110      18.110      19.700      24.010
 OPERCAP           2.200       1.520       1.570       1.480       2.000
 REPAIRS           8.680       7.720       7.150       8.950       9.440
 INS+FEES         19.750      18.920      18.920      17.590      11.970
 OWNRSHIP         14.200      12.980      12.170      13.020      16.540
 OVERHEAD         12.440      14.560      14.560      19.370      19.980
 ENERGY            5.580       4.790       4.270       6.270       4.860
 LANDRENT         90.350      90.350      90.350      57.290      46.390
 LABOR             5.180       4.460       4.000       5.510       5.660
 EMENERGY         47.330      25.585      25.957      21.966      39.317
 SOILDEP          -0.304      -0.507      -0.587      -0.339      -0.042
 EROSION           3.925       4.587       3.325       2.411       0.529
 WINDERSN          0.081       0.049       0.025       0.016
 NSOLN                                                 3.000
 NSEDMNT          12.202      14.487      11.198       3.766       0.457
 NLEACH           11.000      11.000      10.000       6.000      13.000
 NDENITE          52.328      53.500      52.647      29.389      10.441
 NLOSS            75.529      78.988      73.845      42.155      23.898
 PSOLN             1.000       1.000       1.000       3.000
 PSEDMNT           1.744       2.043       1.552       0.534       0.064
 PLEACH            1.872       1.833       1.830       1.518       1.586
 PLOSS             4.616       4.876       4.382       5.052       1.650
 CFLUX            -3.448      -3.314      -3.024      -2.380       2.060
 SUSTOTAL          1.000       1.000       1.000       0.999       1.500
 SUSFLEX           1.000       1.000       1.000       0.999       1.000
```

In example 2 above, the label for column 1 refers to a continuous corn, nonprogram, normal, predominant production system, using conventional tillage in the Land Resource Region M portion of the Corn Belt Farm Production Region (CBM). The other four columns present activities that differ from the first by crop, rotation, tillage practice, and region. The column lists the input-output coefficients for each activity. The first index of PP is IO, input-output items that appear as row stubs in the listing. Set IO includes the subsets P (products), IN (national inputs), IR (regional inputs), and environmental indicators.

In the crops `PP` fragment, corn yield per planted acre is 132.582 bushels in the Corn Belt region. The share coefficient `SCORN` is 1.000, indicating that corn's share of this production activity is 100 percent. This happens for all continuous crop enterprises or production activities. If this were a multiplecrop rotation, then the value of `SCORN` would be less than 1. If it were a two-crop rotation as represented in the second column, then `SCORN` would be 0.500, indicating the proportion of corn yield in the `PP` table for this activity that would be attributed to this rotation. The `NITROGEN` coefficient indicates that nitrogen fertilizer used costs $41.480 per acre. The `EROSION` coefficient indicates that soil loss from water erosion averages 3.925 tons per acre on an annual basis. Likewise, the `NLOSS` coefficient indicates that nitrogen loss to water and the atmosphere for this system averages 75.529 pounds per acre annually.

Dairy, feeder pig, and beef cow enterprises are abstracted in the `PP` fragment in example 3. Although the dimensions of the `PP` table are the same for livestock production activities as for the crop production activities, several of the production strata sets are not relevant and are set to the same value for all livestock production activities. These include sets `G, H, Y, and T`.

Example 3—`PP(IO,B,G,H,Y,T,R,R)` Livestock Fragment

```
TABLE PP(IO,B,G,H,Y,T,R,R)  ENTERPRISE TECHNICAL COEFFICIENTS

                 DAIRY    FEEDRPIG     BFCOWEN
                    NP          NP          NP
                     A           A           A
                   PRD         PRD         PRD
                   ALT         ALT         ALT
                    NT          CB          CB
                    NT          CB          CB

 SILAGE         -7.250                  -0.380
 HAY            -2.626                  -1.090
 CLDARYCF        0.328
 CLDARYCW        0.189
 MILK          216.495
 FEEDERPIG                   7.970
 CULLSOW                     2.030
 LIVCALF                                 1.866
 BFYRLINGS                               2.063
 CLBFCOW                                 0.624
 CATPROT                              -117.789
 SWIPROT                  -855.389
 DAIPROT      -950.019
 CATENER                              -521.485
 SWIENER                 -7675.991
 DAIENER     -9869.950
 SWILINO                   -89.487
 SWILYSI                   -41.152
 PASTURE         0.414
 REPAIRS        59.160      49.800      21.790
 VET+MED        36.780      17.000       7.400
 MKT+STO                    17.900       5.780
 OVERHEAD      157.520      70.900      56.410
 LABOR         160.130      26.100      13.850
 AI             26.710
 BY-PRODZ       11.450
 DHIA           11.520
 DAIRYSUP       31.520
 FUEL+ELE       40.920      76.900      15.420
 HAUL            1.800       2.600       1.790
 MILKHAUL      121.680
 TAX+INSU       60.810      19.000      26.860
```

```
 BEDDING                     4.700
 FEEDMIX                    10.700       0.630
 MANURE                     -1.900
 PUBGRAZE                                0.950
 MINERALZ                                2.050
 CROPRESI                                0.220
 INTEREST      147.420      59.900      41.170
 CAPIREPL      270.960     120.100      61.280
 OPERCAPC       12.860      12.100       7.110
 OTHECAP       119.480      35.500      33.170
 LANDCOST       40.510       4.700      84.380
 LABUNPDZ      114.600     195.900      79.860
 TECONCOS     2056.650    1060.400     525.830
 RESIDUAL      214.810    -444.600    -141.040
 CONCZ         562.430
 HAYZ          109.190                  26.920
 SILAGEZ        99.190                   6.250
 GRAINZ                    186.300       8.770
 PROTSUPZ                  211.500      29.540
 GRAIN                     -43.980      -1.860
 CONC          -72.721
 PROTSUP                   -12.060      -2.280
```

In example 3, the label for column 1 refers to dairy production activity, nonprogram, normal, predominant system in the Northeast Farm Production Region. The other two columns present activities for hogs and beef. Since the livestock production activities are disaggregated only to the Farm Production Region, the Land Resource Region index is set to be the same as used for the Farm Production Region. Set `T` is set at `ALT` since tillage systems do not apply to livestock production activities. The column lists the input-output coefficients for each activity and uses the same signing conventions as used for crops. The first index of `PP` is `IO`, input-output items, which appear as row stubs in the listing.

In the livestock `PP` fragment in example 3, milk production per cow in the Northeast is 216.495 cwt. per cow per year. Fuel and electricity use total $40.92 per cow, while each cow requires 950.019 pounds of protein and 9,869.950 million calories of energy from feed per year.

Processing Activity Data

Processing activity coefficients reside in the table `PPC`. Four general types of processing activities are represented: livestock slaughter, dairy product conversion, feed ration mixing, and corn and oilseed crushing. Coefficients for these activities come from various Situation and Outlook reports, National Academy of Science publications or are derived from the baseline data or agriculture census data. References for these sources can be found in the model code.

Example 4—Processing activity livestock slaughter fragment

```
PARAMETER PPC(P,C)  PROCESSING ACTIVITIES (CONT.)

             HOGTOPORK   FSLATOFBEF    FSCFTOFB    DCOWNFBF    BCOWNFBF  NFSLATONFB  CLBLTONFBF

CLDARYCW                                             -0.200
CULLSOW
HOGSLAUGH       -1.432
CLBFCOW                                                          -2.406
CLBULLSTAG                                                                               -2.406
NONFDSL                                                                      -2.406
FEDSLA                       -2.247
FEDSLACF                                 -2.288
FEDBEEF                       1.000       1.000
```

```
NONFDBEEF                                             1.000       1.000       1.000       1.000
PORK             1.000
```

In example 4, the column headings list the types of slaughter activities, and the row labels give the inputs and outputs. Examples 5 to 7 follow a similar format, with column headings listing the processing activities and the row labels giving the inputs and outputs.

Example 5 shows dairy-processing activities found in parameter `PPC`. Fluid milk (`FLUIDMLK`) is converted directly to fluid milk. In contrast, manufactured milk (`MFGMILK`) is converted to butter (`BUTTER`), American cheese (`AMCHEESE`), other cheese (`OTCHEESE`), ice cream (`ICECREAM`), and evaporated dry milk (`EVDRYMLK`).

Example 5—Processing activity milk processing fragment

```
PARAMETER PPC(P,C)  PROCESSING ACTIVITIES (CONT.)

         +    FLUIDMLK     MFGMILK      BUTTER    AMCHEESE    OTCHEESE    ICECREAM    EVDRYMLK

FLUIDMLK       102.000
MFGMILK                      1.000      -1.000      -1.000      -1.000      -1.000      -1.000
BUTTER                                   4.805
NFDMILK                                  3.105
AMCHEESE                                            10.825
OTCHEESE                                                        18.253
ICECREAM                                                                     8.430
EVDRYMLK                                                                                25.288
MILK            -1.000      -1.000
```

Example 6 shows the feed ration processing activities for fed cattle. The rations use crops as input and produce protein (`CATPROT`) and energy (`CATENER`). Similar types of rations are specified for dairy, hogs, and poultry.

Example 6—Processing activity feed mix fragment

```
PARAMETER PPC(P,C)  PROCESSING ACTIVITIES (CONT.)

         +  GRAIN1      GRAIN2      GRAIN3     GRAIN1A     GRAIN1B     GRAIN1C     GRAIN1D

CORN           -1.231      -1.364      -1.366      -1.231      -1.364      -1.366      -1.350
SORGHUM        -0.234      -0.163      -0.225      -0.399      -0.326      -0.321
BARLEY         -0.096      -0.060      -0.069      -0.128      -0.099      -0.092      -0.024
OATS           -0.262      -0.183      -0.203      -0.087      -0.031      -0.030      -0.004
WHEAT          -0.082      -0.095      -0.018                                          -0.200
CATPROT        9.519       9.438       9.222       9.150       9.075       9.017       8.580
CATENER        126.559     127.519     127.141     126.907     127.965     127.330     115.105
```

Example 7 shows the processing activities for soybeans and ethanol. The soybean-processing activity (`SOYCRUSH1`) converts soybeans into bean meal (`BEANMEAL`) and oil (`BEANOIL`). The ethanol-processing activities take corn and convert it into ethanol and its byproducts—corn starch (`STARCH`), corn gluten meal (`GLUTMEAL`), corn gluten feed (`GLUTFEED`), and distiller's dried grains (`DDG`). Ethanol-processing activities include wet milling (`ETHWMLCUR, ETHWML95`) and dry milling (`ETHDMLCUR, ETHDML95`).

Example 7—Processing Activity corn-soybean crushing

```
PARAMETER PPC(P,C)  PROCESSING ACTIVITIES (CONT.)

         +   SOYCRUSH1    ETHWMLCUR    ETHWML95   ETHDMLCUR    ETHDML95      ETHSOA

SOYBEANS        -1.000
CORN                         -1.000      -1.000      -1.000      -1.000
ETHSOA                        2.500       2.500       2.600       2.600      -1.000
BEANMEAL         0.477
```

```
BEANOIL          0.113        0.020       0.020
STARCH                        0.315       0.315
GLUTMEAL                      0.026       0.026
GLUTFEED                      0.135       0.135
DDG                                                   0.175       0.175
ETHANOL                                                                       1.000
```

Processing and Production Activity Costs

w_c cost of processing activity c

SCR(C,*) PROCESSING ACTIVITY COST-RETURNS SUMMARY TABLE

Input costs are not explicitly represented for most of the model's processing activities. Processing activity cost (example 8) is determined as value added in production or net return to production. Net return for production is determined as the difference between revenue at base prices received for all outputs from the processing activity minus the value of intermediate inputs at base prices used by the processing activity. In a few instances, primarily ethanol processing, the processing costs are explicitly represented in the production activity. These costs are included in the calculation of net returns (value added) for these processing activities. The formula for calculating processing cost is shown here.

```
SCR(C,      "COST")          = SUM(IN, PPC(IN,C)* INPUTN(IN,"PBASE"))
                              -SUM(P,  PPC(P,C) * DEMSUP(P,"DOM","PBASE")
                         $(PPC(P,C) LT 0));
*                            ETHANOL CALCULATION
 SCR("ETHWMLCUR ","COST")    = SCR("ETHWMLCUR ","COST") - PPC("KIA","ETHWMLCUR ");
 SCR("ETHWML95  ","COST")    = SCR("ETHWML95  ","COST") - PPC("KAD","ETHWML95  ");
 SCR("ETHWML20  ","COST")    = SCR("ETHWML20  ","COST") - PPC("KNP","ETHWML20  ");
*                                                ETHANOL REVISION END
 SCR(C,   "REVENUE")         = SUM(P,  PPC(P,C) * DEMSUP(P,"DOM","PBASE")
                              $(PPC(P,C) GT 0));
 SCR(C, "NETRETURN")         = SCR(C,"REVENUE") - SCR(C,"COST");
```

Example 8 – Processing activity net return fragment

```
SCR(C,      " NETRETURN ")  PROCESSING ACTIVITY COST-RETURNS SUMMARY TABLE

--------------------------------------------------
Processing activity   Net Return
               ($/unit)
--------------------------------------------------
HOGTOPORK             217.621
SOWTOPORK             204.828
FSLATOFBEF            187.379
FSCFTOFB              184.170
DCOWNFBF              161.051
BCOWNFBF              141.291
NFSLATONFB            141.291
CLBLTONFBF            141.291
DCLFVEAL              415.507
FLUIDMLK               -0.481
MFGMILK                -2.158
BUTTER                 -3.422
AMCHEESE                2.375
OTCHEESE               16.158
ICECREAM               -0.311
EVDRYMLK                3.327
SOYCRUSH1               1.338
ETHWMLCUR               0.925
ETHWML95                0.845
```

```
ETHDMLCUR               0.962
ETHDMLROUTINE
```

$w^{vc}_{b,g,h,t,,rl,r}$ variable cost of production activity ***b,g,h,t*** in region ***rl,r***

Production activity costs are reported in `PCR(B,G,H,Y,T,U,UR, “VCOST”)`. Costs are calculated for each production activity at base period prices. The calculations for production activity costs can be found in file A1A0C.GMS in the root model directory. Cropping activity `VCOST` is determined by multiplying the inputs from the crop production budgets in `PP` by the input prices in parameter `INPUTN` and summing up over the inputs contained in set `INVC`. Since the input items contained in the production activity budgets represent expenditures and are already expressed in terms of dollar value, the prices in `INPUTN` are set at one. `VCOST` is adjusted by adding a credit equal to the rental rate for cropland in the base period. This credit is added to ensure that net returns for production activities are positive, a requirement for CET parameters to be calculated. Differences among regions in cropland costs will still affect any changes in cropland use from the base since any expansion or reduction in cropland use will cause crop price to change.

Crops:

```
PCR(B,G,   H,Y,T,U,UR,     "VCOST")    $ XCROPP(B,G,H,Y,T,U,UR)
*                                            ADD CREDIT FOR REGIONAL LAND PRICES FOR ENVIRONMENTAL VERSION
                                 =- (PP("CROPLAND",B,G,   H,Y,T,U,UR) * INPUTR(UR,"CROPLAND","PBASE")
                                  $ ((INPUTR(UR,"CROPLAND","PBASE") GT 0) AND (INPUTR(UR,"CROPLAND","PFXP") GE 0)))
                                  + SUM(INVC, PP(INVC,B,G,   H,Y,T,U,UR) * INPUTN(INVC,"PBASE"));
```

Livestock:

```
PCR(B,G,   H,Y,T,U,UR,      "VCOST")    $ XLVSTP(B,G,H,Y,T,U,UR)
                             = SUM(INVC, PP(INVC,B,G,H,Y,T,U,UR) * INPUTN(INVC,"PBASE"));
```

Similar calculations are done for livestock production activities. Examples of the results of the calculations are shown in example 9 below.

Example 9–`PCR(B,G,H,Y,T,U,UR, ‘VCOST’)` cost of production fragment

```
--------------------------------------------------------------------------------------
                    CB.CB     CBLN.CB     CBMN.CB     CBNN.CB     CBON.CB     CBRN.CB
--------------------------------------------------------------------------------------
RCCC  .NP.CNV                 167.854     167.934     169.187     167.854     168.015
RCCC  .NP.MLD                 161.600     161.680     162.261                 162.331
RCCC  .NP.MCH                 163.688     163.748     163.768                 163.798
RCCC  .NP.NLL                 151.929     151.989     152.520                 152.570
RTTT  .NP.CNV                                                     283.074
RBBB  .NP.CNV                             113.542                 113.482
RBBB  .NP.NLL                             145.134
RHHH  .NP.MLD                  92.001      95.709      93.584                  92.001
RGGG  .NP.CNV                             165.180
RGGG  .NP.MCH                             162.021
RCB   .NP.CNV                 137.960     137.970     137.970                 138.561
RCB   .NP.MLD                 151.580     151.590     152.782                 152.191
RCB   .NP.MCH                 146.925     146.935     146.925                 147.526
RCB   .NP.NLL                 142.277     142.287     142.878                 142.878
RCBW  .NP.CNV                 114.043     114.043                 114.043
RCBW  .NP.MLD                 125.153     125.153
RCBW  .NP.MCH                 129.446     129.446
RCBW  .NP.NLL                 122.435     122.435
RCBWH .NP.CNV                 115.718     115.738     117.371
```

%%%%%%

$w^{n}_{b,g,t,ft,rl,r}$ nitrogen fertilizer cost for production activity ***b,g,t,ft*** in region **rl,r**

```
PCRNIT(B,G,H,Y,T,FT,U,UR,"NCOST") NITROGEN FERTILIZER COSTS PER UNIT ACTIVITY
```

Nitrogen fertilizer costs (example 10) for rotations and tillage practice pairings are the same across all Land Resource Regions within a Farm Production Region. This is because fertilizer use by rotation and tillage practice was derived at the Farm Production Region level.

Example 10—Nitrogen fertilizer costs fragment

```
PCRNIT(B,G,H,Y,T,FT,U,UR,"NCOST") NITROGEN FERTILIZER COSTS PER UNIT ACTIVITY
                         CBLN.CB     CBMN.CB     CBNN.CB     CBON.CB     CBRN.CB
RCCC .NP.A.PRD.CNV.1      41.480      41.480      41.480      41.480      41.480
RCCC .NP.A.PRD.CNV.9      37.332      37.332      37.332      37.332      37.332
RCCC .NP.A.PRD.CNV.8      33.184      33.184      33.184      33.184      33.184
RCCC .NP.A.PRD.CNV.7      29.036      29.036      29.036      29.036      29.036
RCCC .NP.A.PRD.CNV.6      24.888      24.888      24.888      24.888      24.888
RCCC .NP.A.PRD.MLD.1      42.500      42.500      42.500                  42.500
RCCC .NP.A.PRD.MLD.9      38.250      38.250      38.250                  38.250
RCCC .NP.A.PRD.MLD.8      34.000      34.000      34.000                  34.000
RCCC .NP.A.PRD.MLD.7      29.750      29.750      29.750                  29.750
RCCC .NP.A.PRD.MLD.6      25.500      25.500      25.500                  25.500
RCCC .NP.A.PRD.MCH.1      42.750      42.750      42.750                  42.750
RCCC .NP.A.PRD.MCH.9      38.475      38.475      38.475                  38.475
RCCC .NP.A.PRD.MCH.8      34.200      34.200      34.200                  34.200
RCCC .NP.A.PRD.MCH.7      29.925      29.925      29.925                  29.925
RCCC .NP.A.PRD.MCH.6      25.650      25.650      25.650                  25.650
RCCC .NP.A.PRD.NLL.1      34.350      34.350      34.350                  34.350
RCCC .NP.A.PRD.NLL.9      30.915      30.915      30.915                  30.915
RCCC .NP.A.PRD.NLL.8      27.480      27.480      27.480                  27.480
RCCC .NP.A.PRD.NLL.7      24.045      24.045      24.045                  24.045
RCCC .NP.A.PRD.NLL.6      20.610      20.610      20.610                  20.610
```

$w^{\sigma}_{b,g,t,ft,rl,r}$ risk premium charged for nitrogen fertilizer use in production activity ***b,g,t,ft*** in region ***rl,r***

```
PCRNIT(B,G,H,Y,T,FT,U,UR,"RSKADJ") NITROGEN RISK ADJUSTMENT PER UNIT ACTIVITY
```

The risk premium (example 11) represents the amount producers would need to receive to make them indifferent between using the reduced rate of fertilizer application and the base rate of fertilization. The risk premium represents producers' perceptions about having sufficient fertilizer available for meeting crop needs in order to achieve yield targets. The risk premium associated with reduced nitrogen fertilizer use varies across rotation/tillage management pairings even for pairings in the same Farm Production Region. This is because the yield response curve for nitrogen fertilizer varies across all regions.

Example 11—Nitrogen fertilizer risk premium fragment

```
PCRNIT(B,G,H,Y,T,FT,U,UR,"RSKADJ") RISK ADJUSTMENT COST PER UNIT ACTIVITY

                         CBLN.CB     CBMN.CB     CBNN.CB     CBON.CB     CBRN.CB
RCCC .NP.A.PRD.CNV.9       2.863       6.470       8.695                   4.609
RCCC .NP.A.PRD.CNV.8       5.216      11.790      15.844                   8.398
RCCC .NP.A.PRD.CNV.7      12.204      27.583      37.069                  19.648
RCCC .NP.A.PRD.CNV.6      30.016      67.844      91.175                  48.327
RCCC .NP.A.PRD.MLD.9       6.434       8.110       9.946                   7.563
RCCC .NP.A.PRD.MLD.8      11.724      14.778      18.123                  13.780
RCCC .NP.A.PRD.MLD.7      27.430      34.576      42.402                  32.241
RCCC .NP.A.PRD.MLD.6      67.467      85.043     104.291                  79.299
RCCC .NP.A.PRD.MCH.9       4.064       7.652      10.597                   6.923
RCCC .NP.A.PRD.MCH.8       7.405      13.943      19.309                  12.614
RCCC .NP.A.PRD.MCH.7      17.324      32.621      45.176                  29.513
RCCC .NP.A.PRD.MCH.6      42.610      80.236     111.114                  72.590
```

$w^{\mathrm{crp}}_{ir,r}$ CRP rental rate for regional input *ir* in region *r*

```
ACRESDY("TOTAL","HST","CRPR","A","2005",R) CROP PLANTINGS AND ACREAGE BASE
```

CRP rental rates (example 12) are fixed in the formulation of the model because rental rates are set by the government, based on prevailing local market rental rates.

Example 12—CRP rental rate

```
ACRESDY("TOTAL","HST","CRPR","A","2005",R) CROP PLANTINGS AND ACREAGE BASE

NT      72.826
LA      71.833
CB      90.115
NP      46.411
AP      60.787
SE      44.317
DL      40.497
SP      35.082
MN      35.358
PA      43.843
```

Demand and Supply Function Data

Commodity demand and supply relationships are incorporated explicitly and implicitly in REAP. The parameters for the explicitly defined demand and supply equations are derived from supply and demand elasticities and base year prices and quantities. This information is contained in the `DEMSUP` parameter (see table 3). The prices and quantities contained in `DEMSUP` are updated automatically to the baseline year selected for the analysis. The absence of an elasticity indicates that no explicit supply or demand curve is specified for that particular commodity in that particular market—i.e., the price remains constant. The absence of a price indicates that the value or price of the commodity in that market is determined implicitly. A positive sign on elasticity indicates that it is a supply, elasticity, and a negative sign indicates it is a demand elasticity. MIN and MAX indicate lower and upper bounds on quantity to be imposed in that market. Sources of demand and supply elasticities in `DEMSUP` are also in the REAP calibration run listing or in the A1A0A.gms file.

The formulas used to derive the commodity demand and supply function parameters are provided here.

$\beta_{m,p}$ slope for commodity $\boldsymbol{p}$ demand or supply equation in market $\boldsymbol{m}$

```
BETA(P,M)             DEMAND AND SUPPLY FUNCTION SLOPES BY MARKET
```

$$\beta_{m,p} = (P_{m,p}/Z_{m,p}) * (1/e_{m,p}) \quad \text{such } e_{m,p} \neq 0 \ \forall \ p = 1,\ldots,P;\ m = 1,\ldots,M;$$

```
BETA(P,M)  = (DEMSUP(P,M,"PBASE") / DEMSUP(P,M,"QBASE")
/ DEMSUP(P,M,"ELAS")) $ DEMSUP(P,M,"ELAS");
```

$\alpha_{m,p}$ intercept on commodity $\boldsymbol{p}$ demand or supply equation in market $\boldsymbol{m}$

```
ALPHA(P,M)            DEMAND AND SUPPLY FUNCTION INTERCEPTS BY MARKET
```

$$\alpha_{m,p} = P_{m,p} - \beta_{m,p} * Z_{m,p}$$

```
ALPHA(P,M) = (DEMSUP(P,M,"PBASE") - BETA(P,M) * DEMSUP(P,M,"QBASE"))
```

where $P_{m,p}$ and $Z_{m,p}$ represent base year price and quantity, respectively, for commodity $\boldsymbol{p}$ in market $\boldsymbol{m}$ and $e_{p,m}$ equals the price elasticity for commodity $\boldsymbol{p}$ in market $\boldsymbol{m}$.

The parameters on the input supply equations are also derived from supply and demand elasticities and base year prices and quantities. This information is contained in the `INPUTR` parameter (table 4). The prices reported in this table are not updated automatically but on a periodic basis. Quantity information is not from an outside data source but is derived from baseline information on crop and livestock production. This information is updated automatically to the baseline year. The formulas used to derive the input supply functions are provided here.

$\beta_{ir,r}$ slope for regional input ***ir*** supply equation in farm production region ***r***

```
BETAI(R,IR)           INPUT SUPPLY FUNCTION SLOPES
```

$\beta_{ir,r} = (w_{r,ir}/VI_{r,ir}) * (1/e_{r,ir})$ such that $e_{r,ir} > 0 \; \forall \; r = 1,\ldots,R; \; ir = 1,\ldots,IR;$

```
BETAI(R,IR)  = (INPUTR(R,IR,"PBASE")  / INPUTR(R,IR,"QBASE")
/ INPUTR(R,IR, "ELAS")) $ INPUTR(R,IR, "ELAS");
```

$\alpha_{ir,r}$ intercept on regional input *ir* supply equation in farm production region *r*

```
ALPHAI(R,IR)          INPUT SUPPLY FUNCTION INTERCEPTS
```

$\alpha_{r,ir} = w_{r,ir} - \beta_{ir,r} * VI_{r,ir}$

```
ALPHAI(R,IR) = (INPUTR(R,IR,"PBASE")-BETAI( R,IR) * INPUTR(R,IR,"QBASE"))$ INPUTR(R,IR,"QBASE");
```

where $w_{r,ir}$ and $VI_{r,ir}$ represent base year price and quantity, respectively, for variable input *ir* in region *r*, and $e_{r,ir}$ equals the price elasticity of supply for variable input *ir* in region *r*.

The parameters on CRP land supply equations are also derived from cropland supply elasticities. The derivations, however, depend on base year CRP rental rates and CRP enrollment acreage. Information about CRP rental rates and enrollment is contained in `ACRESDY` (see example 12).

$\beta^{crp}_{ir,r}$ slope for regional CRP input ***ir*** supply equation in farm production region ***r***

```
BETAC( IR,YR,UR)          PMP CRP FUNCTION SLOPES BY PROCESS AND REGION
```

$\alpha^{crp}_{ir,r}$ intercept on regional CRP input ***ir*** supply equation in farm production region ***r***

```
ALPHAC(IR,YR,UR)          PMP CRP FUNCTION INTERCEPTS BY PROCESS AND REGION
```

CRP supply parameters are set at zero since CRP acreage is fixed in the base version of the model. CRP can be made endogenous by specifying values for these parameters and setting the CRP rental rate parameter to zero. National CRP enrollment is updated by the baseline data. CRP rental rates and distributions of enrollment acreage are updated periodically.

CET Parameters

The parameters for the CET allocation functions are derived from an elasticity of transformation and information on the value of the production activities. The transformation elasticities are given, while the value of the production activities is determined from shadow prices obtained by solving REAP, with constraints imposed on allocation of production activities associated with the level of CET function being derived. The elasticities of transformation are fixed for both the rotation CET function and the tillage CET function.

$\sigma_{b,rl}$ Elasticity of transformation.

```
SIGMA            CET FUNCTION ROTATION ACREAGE ELASTICITY OF SUBSTITUTION
SIGMAT           CET FUNCTION TILLAGE ACREAGE ELASTICITY OF SUBSTITUTION

SIGMAT(BA,U)        $RACD(BA,U)
                 = -10;

SIGMA(B,U)          = -2  $SUM(BA, BSBROT(B,BA,U));
```

$\rho_{b,rl}$ CET substitution parameter for crop or rotation ***b*** acres in farm resource region ***rl***

```
RHOT             CET FUNCTION TILLAGE SUBSTITUTION PARAMETER
RHO              CET FUNCTION ROTATION SUBSTITUTION PARAMETER
```

$\rho_{b,rl} = (1-\sigma_{b,rl})/\sigma_{b,rl}$ where $\sigma_{b,rl}$ is the elasticity of transformation among rotations used to produce crop ***b*** or among tillage practices used by rotation *b* in farm resource production region ***rl***.

```
RHOT(BA,U)                    $SIGMAT(BA,U)
= (1-SIGMAT(BA,U))/SIGMAT(BA,U);

RHO(BA,U)                     $SIGMA(BA,U)
                        o      = (1-SIGMA(BA,U))/SIGMA(BA,U);
```

$\delta_{b,t,rl}$ CET allocation parameter for *t* tillage acres planted to rotation ***b*** acres in farm resource production region ***rl***

```
DELTAT            CET FUNCTION TILLAGE DISTRIBUTION PARAMETER
```

$$\delta_{b,t,rl} = \frac{NR_{b,t,rl} * (\sum_{g}\sum_{h}\sum_{y}\sum_{r} X_{b,g,h,y,t,rl,r})^{1+\rho_{b,rl}}}{\sum_{ta} NR_{b,ta,rl} * \sum_{g}\sum_{h}\sum_{y}\sum_{r} X_{b,g,h,y,ta,rl,r})^{1+\rho_{b,rl}}}, \quad b=1,\ldots,B;\ t,ta=1,\ldots,T;\ rl=1,\ldots,RL$$

```
DELTAT(BA,T2,U)$(XACTD(BA,T2,U) > 0)

               = (MPRICET(BA,T2,U)
                  * SUM(XCROPP(BA,G,H,Y,T2,U,UR), XACT.L(XCROPP))**(1+RHOT(BA,U)))
                / SUM(T2A, MPRICET(BA,T2A,U)
                  * SUM(XCROPP(BA,G,H,Y,T2A,U,UR), XACT.L(XCROPP))**(1+RHOT(BA,U)));
```

where $NR_{b,t,rl}$ equals net return per acre to rotation ***b*** under tillage practice *t* in region ***rl***. $NR_{b,rl}$ is derived from the shadow value of constraints placed on the allocation of production activities in each ***rl*** region. In the model code, `$(XACTD(BA,T2,U) > 0)` is used to ensure that `DELTAT` is calculated only for systems with positive acreages. `(MPRICET(BA,T2,U)` represents the marginal price on production practices constrained to their base levels (`XACT.L(B,G,H,Y,T,RL,R`).

$\delta_{b,rl}$ CET allocation parameter for crop ***b*** acres in farm resource region ***rl***

```
DELTA             CET FUNCTION ROTATION DISTRIBUTION PARAMETER
```

$$\delta_{b,rl} = \frac{NR_{b,rl} * (\sum_{b} X_{b,rl})^{1+\rho_{b,rl}}}{\sum_{ba} NR_{ba,rl} *(\sum_{ba} X_{ba,rl})^{1+\rho_{ba,rl}}}, \quad b,ba=1,\ldots,B;\quad rl=1,\ldots,RL$$

```
MPRICER(BA,U)                     = CETT.M(BA,U);
MPRICEPX(B,BA,U)                  = BSBROT(B,BA,U)*CETT.M(BA,U);

BBASACS(B,BA,RL) $CAC(RL)

        ▪   = SUM(XCROPP(BA,G,H,Y,T2,RL,UR), XSB7(B,XCROPP) * XACT.L(XCROPP))
        ▪   / CAC(RL);

MPRICEP(B,RL)   = SUM(BA$RCROP4(BA,RL), MPRICEPX(B,BA,RL) * BBASACS(B,BA,RL));

LAMDA(BA,RL)    $RACD2(BA,RL)
        ▪   = SUM(B$BSBAS(B,BA,RL), BSBROT(B,BA,RL) * MPRICEP(B,RL) *
ACLRRL(B,RL,"CK4")**(1+RHO(B,RL)) * RAC.L(BA,RL)**(-RHO(B,RL) - 1) );

LAMINV(BA,U)  $LAMDA(BA,U)
        ▪   = LAMDA(BA,U)**(-1);

DELTA(BA,U)   $SUM(B, LAMINV(B,U)* MPRICER(B,U))
        ▪   = (LAMINV(BA,U) * MPRICER(BA,U)) / SUM(B, LAMINV(B,U)* MPRICER(B,U));
```

where $NR_{b,rl}$ equals net return per acre to rotation ***b*** in region ***rl***. $NR_{b,rl}$ is derived from the shadow value of constraints placed on the allocation of rotation acreage in each ***rl*** region. In the model code, the dollar control variables (`$RACD2(BA,RL)`, `BSBAS(B,BA,RL)`, `$LAMDA(BA,U)` & `$SUM(B, LAMINV(B,U)* MPRICER(B,U)))`) are used to ensure that the calculations are performed only for those activities with nonzero values for the control variable. `MPRICEP(B,RL)` represents the average net returns to crop ***b*** planted in farm resource region ***rl*** , and `CETT.M(BA,U)` is the shadow price of the tillage function and represents net returns to those rotations.

$\alpha_{b,rl}$ CET scale parameter for crop or rotation ***b*** acres in farm resource region ***rl***

```
AT                CET FUNCTION TILLAGE SHIFT PARAMETER
A                 CET FUNCTION ROTATION SHIFT PARAMETER
```

Tillage and Rotation Strata

$$\alpha_{b,rl} = \sum_{g}\sum_{h}\sum_{y}\sum_{t}\sum_{r} X_{b,g,h,y,t,rl,r} /(\sum_{ta} \delta_{b,ta,rl} g \sum_{b}\sum_{h}\sum_{y}\sum_{r} X_{b,g,h,y,ta,rl,r}{}^{-\rho_{b,rl}})^{-1/\rho_{b,rl}}$$

```
AT(BA,U)       $RACD(BA,U)
       ▪   =  SUM(XCROPP(BA,G,H,Y,T2,U,UR), XACT.L(XCROPP))
       ▪   /(SUM(T2A, DELTAT(BA,T2A,U) * SUM(XCROPP(BA,G,H,Y,T2A,U,UR), XACT.L(XCROPP))
                 **(-RHOT(BA,U)))**(-1/RHOT(BA,U)));
```

$\alpha_{b,rl} = \sum_{b} X_{b,rl} /(\sum_{ba} \delta_{b,rl} s_{b,ba,rl} RAC_{ba,rl}{}^{-\rho_{b,rl}})^{-1/\rho_{b,rl}}$ where $s_{b,ba,rl}$ is the crop enterprise ***b*** share of one unit of rotation ***ba*** acres in region ***rl*** .

```
A(B,U)         $ACLRRL(B,U,"CK4") = ACLRRL(B,U,"CK4")
                /(SUM(BA, DELTA(BA,U) * BSBROT(B,BA,U) * RAC.L(BA,U)**(-RHO(B,U)))
                                   **(-1/RHO(B,U)));
```

The scale parameters for both the tillage and rotation CET functions are obtained directly from the relevant CET function once the substitution ($\rho_{b,rl}$) and allocation parameters ($\delta_{b,rl}$) have been obtained.

PMP Cost Parameters

The crop and livestock PMP functions used differ from each other by the level in the model at which they are specified. The crop PMP functions are part of a nested system of CET functions that determine the substitution behavior among crop rotations and tillage practices. The CET functions aggregate individual production activities that differ by crops produced, rotations used, and tillage practices employed into a crop production index `ACLRR` that is used in the PMP function for crops. The PMP function for livestock, in contrast, is specified for each livestock production activity represented in the model. The formulas for deriving the parameters for the PMP functions for crops and livestock are shown here.

$\beta_{b,rl}$ slope for crop production activity **b** supply equation in farm resource region **rl**

```
BETA3(B,U)        PMP AGGREGATE ACREAGE COST FUNCTION SLOPES LRR LEVEL CET FORMULATION
```

$\alpha_{b,rl}$ intercept on crop production activity *b* supply equation in farm resource region *rl*

```
ALPHA3(B,U)       PMP AGGREGATE ACREAGE COST FUNCTION INTERCEPTS LRR LEVEL CET FORMULATION

SCALAR ACCFAF     AGGR CROP AC COST FUNCTION ACREAGE FACTOR
```

$\beta_{b,rl} \quad = \sum_{p \in p2b}((\mathrm{P}_{\text{'dom',p}} / \mathrm{X}_{\mathrm{b,rl}}) \; * (1/e_p) *(\mathrm{X}_{b,rl} / \sum_{ba} \mathrm{X}_{ba,rl}) \; * \; \mathrm{YLD}_{p,rl})$ such that

$e_{p,,rl} > 0 \; \forall p, \; p \in pc, b \in bc, p = 1,\dots,P; b = 1,...,BC; rl = 1,\dots,RL;$

```
BETA3( B,RL)    $YCROP3(B,RL)
= PES(B,"BPLNTP")* ACCFAF * (SUM(RLA, ACLRR.L(B,RLA))
/ACLRR.L(B,RL))       {WGHT LRR RESP BY CROP LRR ACRES}
                 ·•    SUM(P$P2B(P,B), YLDTPCLR(P,"CK5",RL));
```

$\alpha_{b,rl} \quad = w_{b,rl} - \beta_{b,rl-} * \mathrm{X}_{b,rl} \;,\; b = 1,\dots,B; rl = 1,\dots,RL;$

```
ALPHA3(B,RL)    $YCROP3(B,RL)
=  CETR.M(B,RL) - BETA3(B,RL) * ACLRR.L(B,RL);
```

$\beta_{b,g,h,r}$ slope for livestock production activity ***b*** supply equation in farm production region ***r***

```
PARAMETERS   BETAP( B,G,H,UR)  PMP COST FUNCTION SLOPES BY PROCESS AND REGION
```

$\alpha_{b,g,h,rl}$ intercept on livestock production activity ***b*** supply equation in farm production region ***r***

```
        ▪   ALPHAP(B,G,H,UR)  PMP COST FUNCTION INTERCEPTS BY PROCESS AND REGION

PARAMETER    PMPLCL(B,*,U)      OPTIMAL AGGREGATE LIVESTOCK PRODUCTION LEVELS
        ▪   PMPLCM(B,*,U)     SHADOW PRICES ON OPTIMAL LVSK PRODUCTION LEVELS

SCALAR      ALCFAF             AGGREGATE LIVESTOCK PRODUCTION COST FUNCTION FLEXIBILITY FACTOR
```

$$\beta_{b,g,h,r} \quad = (\sum_{p\in p2b} P_{'dom',p} / \sum_{g}\sum_{h}\sum_{y}\sum_{t}\sum_{rl} X_{b,g,h,y,t,rl,r}) * (1/e_p)$$

$$\bullet \; (\sum_{ba\in xlvstp} \sum_{g}\sum_{h}\sum_{y}\sum_{t}\sum_{rl}\sum_{ra} X_{ba,g,h,y,t,rl,ra} \; / \; \sum_{b\in xlvstp} \sum_{g}\sum_{h}\sum_{y}\sum_{t}\sum_{rl} X_{b,g,h,y,t,rl,r})$$

$$o \quad * \quad \mathrm{YLD}_{p,rl} \;)$$

```
BETAP( B,"NP","A",R)   $(PMPLCL(B,"CAL",R) GT 0)                      {SLOPE WRT PRODVAL BY REGN}
        •   = SUM(P$PESL(B,P,"BPRDNP"), PESL(B,P,"BPRDNP")
        •   ALCFAF * (PMPLCL(B,"CAL","US") / PMPLCL(B,"CAL",R))
        •   *(SUM(XLVSTP(B,"NP",H,Y,T,U,R),   PP(P,XLVSTP))        <<SIMPLE AVG YIELD
        •   /SUM(XLVSTP(B,"NP",H,Y,T,U,R), 1$PP(P,XLVSTP))));
```

$\alpha_{b,g,h,rl} \quad = w_{b,rl} - \beta_{b,rl-} * \mathrm{X}_{b,rl} \;,\; b = 1,\dots,B; rl = 1,\dots,RL;$

```
ALPHAP(B,"NP","A",R)   $ (PMPLCL(B,"CAL",R) GT 0)
        •   = PMPLCM(B,"CAL",R) - BETAP(B,"NP","A",R) * PMPLCL(B,"CAL",R);
```

where $\mathrm{P}_{'dom',p}$ is the price of commodity ***p*** in the domestic market (*'dom'*), e_p equals the supply elasticity for commodity ***p*** $\in$***pl*** or ***pc*** (see tables 5 and 6), ***p2b*** maps ***p*** commodities to the ***b*** commodity production activities that the ***p*** commodities come from, $\mathrm{YLD}_{p,u}$ represents the yield of commodity ***p*** in region ***r*** or ***rl***, and $\boldsymbol{w}_{b,rl}$ represents the price or net returns per unit of production activities *b* in region *r* or *rl*. The parameters `ACCFAF` and `ALCFAF` are scaling factors for the slopes. These factors can be used to adjust the slope of the supply functions if desired.

Endogenous Variables (GAMS Variables)

The POSITIVE VARIABLE or VARIABLE statement declares endogenous variables used in the REAP formulation. Each block of variables is indexed over one or more sets. For example, DOMESUSE(P) establishes a block of domestic demand variables over the set `P` of products; `XACT(B,G,H,Y,T,RL,R)` establishes production activity variables over the index space of sets `B,G,H,Y,T,RL,R`--that is, enterprise, government program category, method of production (not used), system of production (not used), tillage type, Land Resource Region and Farm Production Region. Activities are designated production activities if indexed over enterprise, geographic area, program category, and so on, or processing activities if indexed only over enterprises (and therefore formulated as a national-level input/output process, rather than differentiated by region). Variables in REAP represent commodity supply and demand levels, production and processing activity levels, variable input levels, and government programs.

Commodity Demand and Supply Variables

Commodity demand and supply variables in REAP are represented both explicitly and implicitly. Explicit variables are `DOMESUSE(P)`, `EXPORTUSE(P)`, `EEPUSE(P)`, `STKUSEC(P)`, `STKUSEG(P)`, and `RESIDUSE(P)`. Other supply and demand variables are represented implicitly in the model's formulation but do not exist as a specific variable. For example, livestock feed use of corn is determined through the accumulation of enterprises producing various livestock types in various regions across the country by using various feed rations and nutrient combinations that react to conditions in livestock and feed markets. Although no explicit variable exists, the amount of corn used to feed livestock could be calculated from the levels of these other enterprises.

`DOMESUSE(P)` represents primarily seed and industrial uses for each commodity. (`EXPORTUSE(P)`, `EEPUSE(P)`) represent quantity of commodity exported, and (`STKUSEC(P)`, `STKUSEG(P)`) represent commercial and government acquired stocks, respectively. Residual supply or use (`RESIDUSE(P)`, `RESIDSUP(P)`) is specified during model calibration for commodities for which their baseline supply and use fails to balance precisely. Commodity use categories such as government stock accumulation, carryover, release, net removals, and domestic and foreign donations are used in presolution and postsolution calculations but are not endogenous model variables.

Commodities for which explicit supply and demand functions exist are shown in table 7. Commodity supply and demand variables are declared separately for each of the ***m*** markets represented in set `M`.

$Z_{p,m}$ Commodity supply or demand for commodity ***p*** in market ***m***

```
*    COMMODITY DEMAND AND SUPPLY
DOMESUSE(P)       DOMESTIC DEMAND
EXPORTUSE(P)      EXPORT DEMAND EXCLUDING EEP
EEPUSE(P)         EXPORT DEMAND -- EEP ONLY
IMPORTSUP(P)      IMPORT SUPPLY
PRDNSUP(P)        AGGREGATE PRODUCTION FUNCTION SUPPLY
STKUSEC(P)        COMMERCIAL STOCK DEMAND
STKUSEG(P)        GOVERNMENT STOCK DEMAND
RESIDUSE(P)       RESIDUAL DEMAND
RESIDSUP(P)       RESIDUAL SUPPLY
```

Variables `YACT(C)` represent processing activities in REAP. Example processing activities include `SOYCRUSH`, which converts soybeans into soybean meal and soybean oil, and `DAIRYSUP5`, which converts a specific mix of feed grains and soybean meal into the protein and energy nutrients available for dairy cattle. Processing activity variables are indexed only over `C`, indicating that they are only specified at the national level.

Y_c Quantity processing activity *c*

```
YACT(C)           PROCESSING ACTIVITY LEVELS
```

Regional Input Supply and Use Variables

REAP designates inputs as either regional or national. Inputs are modeled regionally if we can specify a reliable relationship between price and quantity used and model region. Examples are CROPLAND, PASTURE, AUM, and WATER.

National inputs are those specified with a single fixed price in any area of the United States in which they are used. Examples include LIME and CHEMICALS, which are specified in dollar units, and their prices are always in dollars. LIME and CHEMICALS are specified in dollars (instead of tons or another unit) in the ERS cost of production budget source data. Modeling input use in physical units (instead of value) and actual market prices is always preferred, but often not feasible. For example, LIME prices vary greatly even within one region, and there exist so many CHEMICAL types and compositions that one price would not be accurate. In these cases, the most accurate accounting of input cost for a production enterprise is cost per acre for the specified inputs.

National inputs require no model variable in REAP's formulation—their supply functions are implicit. By holding the prices of these inputs fixed, we are assuming that they have perfectly elastic supply curves. Because the cost per unit of using these inputs does not change, we do not explicitly represent them in the objective function. Rather, we calculate the total cost per unit for the production activity and include that in the objective function. Most input use takes place in the production and processing activities discussed below.

Two types of regional input variables are distinguished in REAP. Those variables with fixed prices (e.g., WATER) are tallied in INPUTRFSUP(R,IR). Input prices that vary with quantity supplied (e.g., CROPLAND, PASTURE, and AUM (animal unit months)) are tallied in two variables: the price-sensitive supply in INPUTRSUP(R,IR), and any optional quantity available in INPTRSUPFP(R,IR). The supply of each is represented with a kinked supply function. INPUTRSUP(R,IR) represents the portion of the regional input that is available at a fixed price, and INPTRSUPFP(R,IR) represents the portion beyond that, which is available at increasing prices.

CRPLND(R,IR,YR) represents the amount of cropland enrolled in the Conservation Reserve Program (CRP) in the base year (YR). This variable can be fixed or allowed to vary, with fixed default setting, meaning that the amount of land enrolled in CRP is not allowed to change in response to any scenario that may be run.

$VI_{ir,r}$ Variable supply of input *ir* in farm production region *r*

`INPUTRSUP( R,IR)  REGIONAL PRICE SENSITIVE INPUTS`

$FI_{ir,r}$ Fixed supply of input ***ir*** in region farm production region ***r***

`INPTRSUPFP(R,IR)  REGIONAL NON-PRICE SENSITIVE PRICE SENSITIVE INPUTS`

$CRAC_{ir,r}$[4] Acres of input ***ir*** in farm production region ***r*** placed in the Conservation Reserve Program (CRP)

`CRPLND(R,IR,YR)      CROP LAND ENROLLED IN THE CRP IN THE YEAR DESIGNATED`

---

[4] CRPLND indexed by 'YR' to indicate what year CRP is for

Production Activity Variables

Production activities combine inputs to produce a product. These variables are differentiated by enterprise, geographic area, program category, method, and other indexes. Crop and livestock production are tallied in variable XACT(B,G,H,Y,T,U,UR), which are indexed over enterprise or production activity, government program category, method of production (not used), system of production (not used), tillage practice, subregion, and region. In addition, SXACT(B, T,FT, U, UR) represents the proportion of acreage XACT that uses fertilizer application rate FT. SXACT ranges in value from 0 to 1, with the sum of SXACT over fertilizer application rates, FT, equal to 1.

$X_{b,g,h,y,,t,rl,r}$[5] Quantity of production activity *b* in government program ***g****, using method h, in system y* utilizing tillage practice *t* in land resource region ***rl*** in farm production region ***r***

```
XACT(B,G,H,Y,T,U,UR) PRODUCTION ACTIVITY LEVELS
```

$S_{b,t,ft,rl,r}$ Share of fertilizer rate ***ft*** used in crop rotation ***b*** using tillage practice *t* in land resource region ***rl*** in farm production region ***r***

```
SXACT(B,T,FT,U,UR)     ALTERNATE NITROGEN ENTERPRISES SHARE OF CROPPING SYSTEM ACRES
```

Cropland Allocation Variables

The cropland allocation variables are part of the nesting structure for the CET functions that allocate cropland to rotations and tillage practices. ACLRR(B,U) is defined over crop (corn, soybeans, wheat, etc.) and Land Resource Regions, representing the total amount of acres planted to a crop across all rotations that produce that crop. RAC(B,U) is defined over crop rotations and Land Resource Regions and represents the total amount of acres planted to a particular rotation across all tillage practices.

$RAC_{b,rl}$ Quantity of rotation acres $\boldsymbol{b} \in \boldsymbol{bc}$ used in land resource region ***rl***

```
RAC(B,U)    ROTATION ACREAGE LEVEL--ROT:LRR:NPR
```

$X_{b,rl}$ Quantity of crop acres $\boldsymbol{b} \in \boldsymbol{bc}$ used in land resource region ***rl***

```
ACLRR(B,U)         AGGREGATE CROP ACREAGE PLANTED LRR LEVEL CET FORM
```

Objective Function Variable

CPS is a scalar variable that represents the value of the programming problem's objective function. CPS measures the sum of consumer and producer surplus, minus or plus any social costs/payoffs associated with system behavior, such as environmental emissions.

---

[5] This variable includes both livestock and crop production activities that were separated out in the presentation of the model given in Chapter 2 the Model Environment section of this report.

CPS Objective function value (net social payoff)

```
CPS             CONSUMER & PRODUCER SURPLUS (DOL) ;
```

Equations

EQUATION definition statements define how a GAMS model is generated—that is, what rows and what columns are generated to pass to the solver for execution.

Objective Function

The objective function represents net social benefit, or consumer plus producer surplus (CPS). Net social benefit equals the sum of the areas under the crop demand functions plus government payments, such as Conservation Reserve Program (CRP) rental payments, minus the areas under the supply functions for the quasi-fixed regional inputs, crop-specific PMP cost functions, CRP land supply functions, and production costs. The objective function is written as:

$$
\begin{aligned}
\text{Max CPS} = {} & \sum_m \sum_p \alpha_{m,p} Z_{m,p} + \frac{1}{2} \sum_m \sum_p \beta_{m,p} Z^2_{m,p} - \sum_c w_c Y_c \\
& - \sum_r \sum_{ir} \alpha_{ir,r} VI_{ir,r} - \frac{1}{2} \sum_r \sum_i \beta_{ir,r} VI^2_{ir,r} - \sum_r \sum_{ir} w_{ir,r} FI_{ir,r} \\
& - \sum\nolimits_{xlvstp(b,g,h,y,t,r,r)} \alpha_{b,g,h,r} X_{xlvstp} - \sum\nolimits_{xlvstp(b,g,h,y,t,r,r)} \beta_{b,g,h,r} X^2_{xlvstp} \\
& - \sum_{b \in bc} \sum_{rl} \alpha_{b,rl} X_{b,rl} - \sum_{b \in bc} \sum_{rl} \beta_{b,rl} X^2_{b,rl} \\
& - \sum\nolimits_{xcropp(b,g,h,y,t,rl,r)} X_{xcropp} \left[\sum\nolimits_{ft} S_{b,t,ft,rl,r} \left(w^n_{b,g,h,y,t,ft,rl,r} + w^{\sigma}_{b,g,h,y,t,ft,rl,r} \right) \right] \\
& - \sum\nolimits_{xcropp(b,g,h,y,t,rl,r)} X_{xcropp} w^{vc}_{xcropp} - \sum\nolimits_{xlvstp(b,g,h,y,t,r,r)} X_{xlvstp} w^{vc}_{xlvstp} \\
& + \sum_{ir} \sum_r w^{\text{crp}}_{ir,r} CRAC_{ir,r} - \sum_{ir} \sum_r \alpha^{crp}_{ir,r} CRAC_{ir,r} - \frac{1}{2} \sum_{ir} \sum_r \beta^{crp}_{ir,r} CRAC^2_{ir,r}
\end{aligned}
$$

The first terms in the objective function, $\sum_m \sum_p \alpha_{m,p} Z_{m,p} + \frac{1}{2} \sum_m \sum_p \beta_{m,p} Z^2_{m,p}$, represent the sum of the area under market demand and supply curves. The parameters for these curves are derived from the demand or supply for each commodity *p* in each market *m* in the base year ($Z^0_{m,p}$), the commodity price in the base year (P^0_p), and the price elasticity of demand or supply ($\varepsilon_{m,p}$). The formula for deriving the slope parameter is $\beta_{m,p}$= ($P^0_p / Z^0_{m,p}$) * (1/ $\varepsilon_{m,p}$). The intercept is then obtained from the equation $\alpha_{m,p} = P^0_p - \beta_{m,p} * Z^0_{m,p}$.

The third term, $\sum_c w_c Y_c$, is the sum of production costs incurred by intermediate product processing activities. These are costs for labor and inputs separate from the cost of primary products used by the activities. For many of the processing activities, these costs are zero because the activities are assumed only to transform the initial product into another form. In other cases, such as ethanol production, costs of processing are explicitly represented.

The fourth and fifth terms, $\sum_{r}\sum_{ir}\alpha_{ir,r}VI_{ir,r} - \frac{1}{2}\sum_{r}\sum_{i}\beta_{ir,r}VI_{ir,r}^{2}$, represent the sum of areas under the quasi-fixed regional input supply curves. The parameters for these curves are derived from the supply of each input *ir* in each Farm Production Region *r* in the base year ($VI_{ir,r}^{0}$), the input price in each region in the base year ($w_{ir,r}^{0}$), and the price elasticity of supply ($\varepsilon_{ir,r}$). The slopes for these equations are then obtained from $\beta_{ir,r} = (w_{ir,r}^{0}/VI_{ir,r}^{0}) * (1/\varepsilon_{ir,r})$, and the intercepts are obtained from $\alpha_{ir,r} = w_{ir,r}^{0} - \beta_{ir,r} * VI_{ir,r}^{0}$.

The sixth and seventh terms, $\sum_{xlvstp(b,g,h,y,t,r,r)}\alpha_{b,g,h,r}X_{xlvstp} - \sum_{xlvstp(b,g,h,y,t,r,r)}\beta_{b,g,h,r}X_{xlvstp}^{2}$, represent the sum of areas under the PMP supply functions for livestock production activities. The parameters for the PMP functions are derived from the supply of each livestock commodity *pl* in each Farm Production Region *r* in the base year ($Q_{pl,r}^{0}$), the net return to the livestock production activity in the base year ($R_{bl,r}^{0}$), and the price elasticity of supply (ε_{pl}). Livestock production is represented only at the Farm Production Region (*r*) level. Net returns per production activity are obtained from shadow prices on calibration constraints.

The slopes for the livestock PMP functions are then obtained from $\beta_{b,g,h,r}$ = $(R_{bl,r}^{0}/X_{xlvstp}^{0})*(1/\varepsilon_{pl})*(X_{xlvstp}^{0}/\sum_{b\in xlvstp}X_{xlvstp}^{0})*\mathrm{YLD}_{p,r}$), where $\mathrm{YLD}_{p,r} = Q_{pl,r}^{0} / X_{xlvstp}^{0}$. The intercepts for the PMP functions are then obtained from $\alpha_{b,g,h,r} = R_{bl,r}^{0} - \beta_{b,g,h,r} * X_{xlvstp}^{0}$.

The eighth and ninth terms in the function, $\sum_{b\in bc}\sum_{rl}\alpha_{b,rl}X_{b,rl} - \sum_{b\in bc}\sum_{rl}\beta_{b,rl}X_{b,rl}^{2}$, are the sum of the areas under the PMP supply functions for crops. The parameters for these PMP functions are derived from the supply of crop acreage *bc* in each Land Resource Region *rl* in the base year ($X_{bc,rl}^{0}$), the net return to crop *bc* in the Land Resource Region *rl* in the base year ($R_{bc,rl}^{0}$), and the price elasticity of supply for crops (ε_{pc}). Crop production is represented at the Land Resource Region *rl* level and is therefore more disaggregated than the level at which livestock production is represented. Net returns per production activity are obtained from shadow prices on calibration constraints.

The slopes for the crop PMP functions are derived from $\beta_{b,r} = \sum_{p\in p2b}((P_{p}^{0}/X_{b,rl}^{0}) * (1/\varepsilon_{pc}) *(X_{bc,rl}^{0} / \sum_{ba}X_{bc,rl}^{0}) * \mathrm{YLD}_{p,rl})$, where $p \in p2b$ maps livestock product *p* to livestock production activity *b* and $\mathrm{YLD}_{p,rl}$ equals average yield for crop *p* in Land Resource Region *rl*. The intercept is then obtained from $\alpha_{b,rl} = R_{bc,rl}^{0} - \beta_{b,rl} * X_{bc,rl}^{0}$.

The 10th term, $\sum_{xcropp(b,g,h,y,t,rl,r)}X_{xcropp}[\sum_{ft}S_{b,t,ft,rl,r}\left(w_{b,g,h,y,t,ft,rl,r}^{n} + w_{b,g,h,y,t,ft,rl,r}^{\sigma}\right)]$, is the sum of the fertilizer costs for crop production activities, where $S_{b,t,ft,rl,r}$ is the convexity variable that indicates the proportion of a particular fertilizer application activity *ft* used by crop production activity $X_{xcropp(b,g,h,y,t,rl,r)}$. The expression contained within the parentheses represents the cost of each of the fertilizer activities *ft* associated with the crop production activity $X_{xcropp(b,g,h,y,t,rl,r)}$, where

$w^{n}_{b,g,h,y,t,ft,rl,r}$ represents fertilizer cost and $w^{\sigma}_{b,g,h,y,t,ft,rl,r}$ represents the risk premium associated with using a particular fertilizer application rate.

The 11th term in the objective function, $\sum_{xcropp(b,g,h,y,t,rl,r)} X_{xcropp} w^{vc}_{xcropp}$, is the sum of the production costs, excluding fertilizer, for the primary crop production activities, where w^{vc}_{xcropp} represents the sum of all the cost of the inputs, excluding quasi-fixed and fertilizer inputs used by the production activity. The implicit assumption underlying this specification is that the prices of these inputs are constant.

Similarly, the 12th term, $\sum_{xlvstp(b,g,h,y,t,r,r)} X_{xlvstp} w^{vc}_{xlvstp}$, represents the total costs of the primary livestock production activities.

The 13th term, $\sum_{ir}\sum_{r} w^{\text{crp}}_{ir,r} CRAC_{ir,r}$, is the sum of rental payments for CRP land, while the final two terms, $\sum_{ir}\sum_{r} \alpha^{crp}_{ir,r} CRAC_{ir,r} - \frac{1}{2}\sum_{ir}\sum_{r} \beta^{crp}_{ir,r} CRAC^{2}_{ir,r}$ represent the sum of the areas under the CRP supply functions. The parameters of the CRP supply functions are derived from the supply of each input *ir* placed in the CRP in each Farm Production Region *r* in the base year ($CRAC^{0}_{ir,r}$), the net return to CRP activities in each region in the base year ($R^{0}_{ir,r}$), and the price elasticity of input supply ($\varepsilon_{ir,r}$). Slopes and intercepts are obtained by using the similar formulas to the formulas used to derive them for the other supply functions. In GAMS code, the objective function is depicted as:

```
UOBJ.. CPS =E=  SUM(P,  ALPHA(P,"DOM")     *     DOMESUSE(P)
                  + 0.5 * BETA( P,"DOM")    * SQR(DOMESUSE(P)))
                + SUM(P$PRES(P), ALPHA(P,"RESD") * RESIDUSE(P))
                - SUM(P$PRES(P), ALPHA(P,"RESS") * RESIDSUP(P))
                + SUM(P,  ALPHA(P,"EXP")    *     EXPORTUSE(P)
                  + 0.5 * BETA( P,"EXP")    * SQR(EXPORTUSE(P)))
*                   NOTE: ALPHA(P,"EEP") WAS INCREASED ABOVE BY AVE BNS LVL
                + SUM(P,  ALPHA(P,"EEP")    *     EEPUSE(P)
                  + 0.5 * BETA( P,"EEP")    * SQR(EEPUSE(P)))
                + SUM(P,  ALPHA(P,"SCE")    *     STKUSEC(P)
                  + 0.5 * BETA( P,"SCE")    * SQR(STKUSEC(P)))
                + SUM(P,  ALPHA(P,"SGE")    *     STKUSEG(P)
                  + 0.5 * BETA( P,"SGE")    * SQR(STKUSEG(P)))
* <<            + SUM(P,  ALPHA(P,"SGA")    *     STKACCG(P))
                - SUM(P, (ALPHA(P,"IMP")    * IMPORTSUP(P)) $ (ALPHA(P,"IMP") GT 0)
                  + 0.5 * BETA( P,"IMP")    * SQR(MAX(0, (IMPORTSUP(P) - DIF(P,"IMP")))))
                - SUM(P, (ALPHA(P,"PRDN")   * PRDNSUP(P)) $ (ALPHA(P,"PRDN") GT 0)
                  + 0.5 * BETA( P,"PRDN")   * SQR(MAX(0, (PRDNSUP(P) - DIF(P,"PRDN")))))

                - SUM(C, YACT(C) * (PPC("PROCCOST",C) + SCR(C,"NET RETURN")))

                - SUM((R,IR),
                          INPTRSUPFP(R,IR)  * PMINI(R,IR) $ PMINI(R,IR))
                - SUM((R,IR), ALPHAI(R,IR)  *     INPUTRSUP(R,IR)
                  + 0.5 *     BETAI( R,IR)  * SQR(INPUTRSUP(R,IR)))
                - SUM((R,IR),
                          INPUTRFSUP(R,IR)  * INPUTR(R,IR,"PFXP"))

                - SUM((B,H,R),
                      ( ALPHAP(B,"NP",H,R)  *  SUM(XLVSTP(B,"NP",H,Y,T,U,R), XACT(XLVSTP))
                  + 0.5 * BETAP( B,"NP",H,R)* SQR(SUM(XLVSTP(B,"NP",H,Y,T,U,R), XACT(XLVSTP)))
                      ) $ (XI4(B,"NP",H,R) GT 0)
                     )$RTYPE
```

```
                - ( SUM(XCROPP(BC,G,H,Y,T2,RL,R),   XACT(XCROPP)
                        * SUM(FT, SXACT(BC,T2,FT,RL,R) *
                          ( PCRNIT(BC,G,H,Y,T2,FT,RL,R, "NCOST")
*                           +PCRNIT(BC,G,H,Y,T2,FT,RL,R, "GRNPMT")
                           +PCRNIT(BC,G,H,Y,T2,FT,RL,R, "RSKADJ")
                           )
                             )
                       )

                  )  $((ENVIR=1)$(VNITF=1))

                - ( SUM(XALL,   XACT(XALL)   * PCR(XALL,      "VCOST")) ) $(ENVIR=1)
                - ( SUM(XALL,   XACT(XALL)   * PCR(XALL,      "NICOST")) )$(STDCROP=1)

                - SUM(XALNDC, XACT(XALNDC) * PCR(XALNDC,"NET RETURN"))    $(ENVIR=1)
                - SUM(XALNDC, XACT(XALNDC) * PCR(XALNDC,"NET RETURN"))    $(STDCROP=1)

                - SUM(XALBLV, XACT(XALBLV) * PCR(XALBLV,"NET RETURN"))    $(ENVIR=1)
                - SUM(XALBLV, XACT(XALBLV) * PCR(XALBLV,"NET RETURN"))    $(STDCROP=1)

$BATINCLUDE MODULE.CTL ACPROG apACUOBJ.GMS
*
*$BATINCLUDE MODULE.CTL VNITF vnUOBJ.GMS

                - SUM(YCROP(B,H,R),
                              ALPHAX(B,H,R)     * PMPAC(B,H,R)
                  +  0.5 * SUM((BA)$YCROPX(B,H,R,BA),
                               PMPAC(B,H,R)     * BETAX(B,H,R,BA) * PMPAC(BA,H,R))
                     )$RTYPE

                - SUM(YCROP(B,H,R),
                            ( ALPHAA(YCROP)       *     PMPAC(YCROP)
                  +  0.5 *     BETAA(YCROP)       * SQR(PMPAC(YCROP)))
                     )$RTYPE

                - SUM(YCROP2(B,H,RL,R),
                            ( ALPHA2(YCROP2)       *     PMPAC2(YCROP2)
                  +  0.5 *     BETA2(YCROP2)       * SQR(PMPAC2(YCROP2)))
                     )$RTYPE

                 - SUM((B,RL)$SACPLRR(B,RL),
                            ( ALPHA3(B,RL)       *     ACLRR(B,RL))$ (ALPHA3(B,RL) GT 0)
                  +  0.5 *     BETA3(B,RL)       * SQR(MAX(0, (ACLRR(B,RL) - PMPDIF(B,RL))))
                     )$RTYPE

                - SUM(XCROPP(B,G,H,Y,T,U,R),
                            ( ALPHAZ(XCROPP)       *     XACT(XCROPP)
                  +  0.5 *     BETAZ(XCROPP)       * SQR(XACT(XCROPP)))
                     )$RTYPE

$BATINCLUDE MODULE.CTL ACPROG apPBUOBJ.GMS
$BATINCLUDE MODULE.CTL ACPROG apDPUOBJ.GMS

                + SUM(XCROPP(   B,G,H,Y,T,U,R), XACT(XCROPP) * PCR(XCROPP,"MKRETADJ"))
$BATINCLUDE MODULE.CTL ACPROG apMKUOBJ.GMS

*               - 0.5 * CAR * SUM(R$R10(R), SUM(BA$VENT(BA,R), SUM(B$VENT(B,R),
*                             XACT(B,R) * VCV(B,BA,R)) * XACT(BA,R)))

                + SUM((R,IR),
                      CRPLND(R,IR,"%1") * ACRESDY("TOTAL","HST","CRPR","A","%1",R)
                                                        $ACRESDY("TOTAL","HST","CRPR","A","%1",R)

                  +   (      ALPHAC(IR,"%1",R)   *     CRPLND(R,IR,"%1")
                  +    0.5 * BETAC( IR,"%1",R)   * SQR(CRPLND(R,IR,"%1"))
                      ) $   ACRESDY("TOTAL","HST","CRPR","A","%1",R)
                     )
```

```
               -  SUM(RL$GPPBASE(RL), (PFCPR(RL) + CRPPR(RL)) * GPPAC(RL))
               ;
```

CPS (consumer and producer surplus) is defined to be the sum of the areas under domestic, export, and commercial stock demand functions, minus the sum of areas under import, regional (variable and fixed price) input, national input, and other cost supply functions, plus the expected value of deficiency payments. The area under domestic demand functions, for example, is computed by the terms: SUM(P, ALPHA(P,"DOM")*DOMESUSE(P) + 0.5*BETA(P,"DOM")*SQR(DOMESUSE(P))). In simpler algebra, this is: (intercept * price + 0.5 * slope * (price*price)). Some of the expressions in `UOBJ` are complicated by the DIF and DIFI terms and formulation, which are necessary to exclude negative surplus values. The GAMS code used to represent the objective function differs from the algebraic formulation mainly in that it includes portions of code that permit alternative representations of the supply response for crop production and make supply of CRP land and the CRP rental rate exogenous (i.e., fixed). Control variables are used to determine which parts of the objective function are active. For example, the control variables `ENVIR`, `STDCROP`, and `VNITF` are used to control the supply response formulation for crops. When `STDCROP = 1` and `ENVIR = 0`, then crop production in REAP is represented with single production activities for each crop down to the Farm Production Region level. This formulation of the model uses the standard PMP functions to represent crop acreage response. When `STDCROP = 0` and `ENVIR = 1,` then crop production in REAP is represented with multiple rotations and tillage practices for a single crop down to the Land Resource Region. This formulation uses the nested set of CET functions in combination with the standard PMP crop function to represent crop acreage response. If `VNITF = 1,` then nitrogen fertilizer application rates are determined endogenously, whereas when `VNITF = 0,` then nitrogen fertilizer application rates per production activity are fixed. Permitting variable nitrogen fertilizer application rates per production activity is only available when ENVIR = 1.

Commodity Balance

The commodity balance constraints require that the supply of a commodity from all its sources is greater than or equal to the demand for it in all its uses. This ensures that no more of a commodity is consumed than is available for consumption. In equilibrium, this constraint will be binding, or the product will not be produced at all. Sources of `P` include the amount produced from all production activities `B` producing `P` across all government programs, `G`; production methods, `H`; system types, `Y`; tillage practices, `T;` in regions `RL,` and `R` or from all processing activities `C` or unspecified domestic source plus the amount supplied by imports and from beginning stocks. Uses of a commodity `P` include domestic use (seed and industrial uses), commercial and government stocks, and exports. This is represented algebraically by the constraint:

$$\sum\nolimits_{xcropp\,(b,g,h,y,t,rl,r)} s_{p,xcropp} \Big(\sum_{ft} pp^{n}_{p,b,g,h,y,t,ft,rl,r}\, S_{b,t,ft,rl,r}\Big) X_{xcropp}$$

$$+ \sum\nolimits_{xlvstp\,(b,g,h,y,t,r,r)} pp_{p,xlvstp}\, X_{xlvstp} + \sum_{c} ppc_{p,c} Y_c$$

$$+ \sum_{m\in S} Z_{m,p} - \sum_{m\notin S} Z_{m,p} \geq 0, \qquad p = 1,\ldots, P;$$

where $\sum\nolimits_{xcropp(b,g,h,y,t,rl,r)} s_{p,xcropp} \big(\sum_{ft} pp^{n}_{p,b,g,h,y,t,ft,rl,r} S_{b,t,ft,rl,r}\big) X_{xcropp}$ represents the amount of commodity *p* produced by all primary crop production activities, $\sum\nolimits_{xlvstp(b,g,h,y,t,r,r)} pp_{p,xlvstp} X_{xlvstp}$ represents the net amount of *p* produced by all livestock production activities, $\sum_{c} ppc_{p,c} Y_c$ represents the net amount of *p* produced (or used) by the processing activities, $\sum_{m\in S} Z_{m,p}$ is the amount of commodity *p* supplied from supply markets (import and beginning stock markets) m , and $\sum_{m \in D} Z_{m,p}$ represents the amount of commodity p used in demand markets (domestic, export, and ending stocks). In GAMS code, this is depicted as:

```
PRODBAL(P).. (SUM(XCROPP, XACT(XCROPP) * PP(P,XCROPP) * XSP7(P,XCROPP)) )$(VNITF=0)  {Fix Fert }
                + ( SUM(XCROPP(B,G,H,Y,T,RL,R),  XACT(XCROPP) * SUM(FT, SXACT(B,T,FT,RL,R)
                  * PNIT(P,B,G,H,Y,T,FT,RL,R))* XSP7(P,XCROPP))          $(VNITF=1)  {Var Fert }
                + SUM(XLVSTP,    XACT(XLVSTP) * PP(P,XLVSTP))                        {LVSTK}
*              + SUM(XFRUTP,    XACT(XFRUTP) * PP(P,XFRUTP))                         {FRUIT}
                + SUM(XOLU,      XACT(XOLU  ) * PP(P,XOLU  ))                        {OLUSE}
$BATINCLUDE MODULE.CTL ACPROG apPRDBAL.GMS
                + SUM(C,     YACT(C)     * PPC(P,C)) {PROCESSING}
                + IMPORTSUP(P)   $ PI(P)
                + PRDNSUP(P)     $ PF(P)
                - DOMESUSE(P)    $ PD(P)
                - EXPORTUSE(P)   $ PE(P)
                - EEPUSE(P)      $ PEEP(P)
                - STKUSEC(P)     $ PSCE(P)
                - STKUSEG(P)     $ PSGE(P)
                - RESIDUSE(P)    $ PRES(P)
                + RESIDSUP(P)    $ PRES(P)
            =G=
                - STKCOMB(P)
                - STKGOVB(P)
                + STKGOVD(P)
                + STKGOVX(P)
                + RESIDUAL(P)               <<ZERO IN CALIBRATE, FIXED IN VERIFY AND BEYOND RUNS
                ;
```

Fertilizer Application Convexity Constraints

The fertilizer application constraints permit the relationship between yield and fertilizer application rates per unit per production activities to be approximated by a small set of discreet fertilizer application activities. This set of convexity constraints allows fertilizer application rates per unit of a production activity to vary independently of the application rate used for other production activities. The set can be easily extended to cover other inputs if desired.

The constraint on fertilizer application rates is represented algebraically by:

$$\sum_{ft} S_{b,t,ft,rl,r} - 1 = 0, \qquad b = 1,\ldots,B;\ t = 1,\ldots,T;\ rl = 1,\ldots,RL;\ r = 1,\ldots,R;$$

where $0 \le S_{b,t,ft,rl,r} \bullet\le 1$, and $\sum_{ft} S_{b,t,ft,rl,r}$ represents the sum of the proportions of a fertilizer application rate used per cropping system b,t and must equal one. In GAMS code, this is written:

```
CNVXBAL(B,T2,RL,R)$CNVX(B,T2,RL,R)..
                  SUM(HCROPPFT(B,T2,FT,RL,R), SXACT(B,T2,FT,RL,R))
            =E=   1;
```

Input Supply Balance

The supplies of all inputs, except quasi-fixed inputs (cropland and pasture), are assumed to be perfectly elastic. This means that there is no need to explicitly represent supply balance for these inputs since it is assumed that there will always be sufficient supply to meet demand.

The supplies of quasi-fixed inputs are divided into two separate pools: livestock (pasture and AUMs) and crop (cropland). The supply of livestock land is specified by using a simple linear inverse supply function in each of the 10 Farm Production Regions. AUM is used in the Pacific, Mountain, and the Northern and Southern Plains regions to represent the carrying capacity of the land.

The pool of cropland in each Farm Production Region is further split into crop, rotation, and tillage-specific pools for each of the 45 Land Resource Regions by soil erosion category (HEL/NHEL). Cropland supply is represented with a simple inverse supply function for each Farm Production Region. Allocation of land to crops is represented with a system of simple linear, PMP calibrated, supply functions. In each Land Resource Region, the distribution of crop-specific land to rotations and tillage type is represented with a set of nested constant elasticity of transformation functions.

In essence, the structure of the model assumes that farmers engage in a multistage decision process whereby they first determine the amount of land to allocate to crops and livestock. In the next stage, farmers determine how much livestock land to allocate to each species and how much of the cropland to each crop. Then, for each crop, farmers decide how much land to allocate to each rotation, and they determine the tillage practice they will use for each rotation.

Regional Crop Rotation Acres Balance

The regional crop rotation acres balance ensures that land allocated to a particular crop rotation b is equal to the use of land by all the tillage practice activities t associated with that rotation in region rl. The balance is represented by the function:

$$\alpha_{b,rl}\left(\sum\nolimits_{xcropp(b,g,h,y,t,r,rl)}\delta_{b,t,rl}\left(X_{xcropp}\right)^{-\rho_{b,rl}}\right)^{-\left(\frac{1}{\rho_{b,rl}}\right)}-RAC_{b,rl}=0,\quad b=1,\ldots,B;\ rl=1,\ldots,RL;$$

where

$$\rho_{b,rl}=(1-\sigma_{b,rl})/\sigma_{b,rl}$$

$$\delta_{b,t,rl}=\frac{R^{0}_{xcropp}*(X^{0}_{xcropp})^{1+\rho_{b,rl}}}{\sum_{ta}R^{0}_{xcropp}*(X^{0}_{xcropp})^{1+\rho_{b,rl}}}$$

and

$$\alpha_{b,rl}=X^{0}_{xcropp}/(\sum_{ta}\delta_{b,ta,rl}*X^{0\ -\rho_{b,rl}}_{xcropp})^{-1/\rho_{b,rl}}$$

The function is nonlinear, implying that the marginal rate of transformation between land used in one tillage activity of a particular type of rotation and land used for other tillage practices used with the same rotation is declining. The parameters for these equations are derived from the quantity of each crop production activity in the base year X^{0}_{xcropp}, the net return to each production activity, R^{0}_{xcropp}, and an elasticity of transformation $\sigma_{b,rl}$ for each crop rotation b in each Land Resource Region rl. Net returns per crop production activity are obtained from shadow prices on calibration constraints. In GAMS code, this can be written as:

```
CETT(BA,RL)              $RCROP4(BA,RL)..
                          AT(BA,RL) * SUM(T2$DELTAT(BA,T2,RL), DELTAT(BA,T2,RL)
                          * SUM(XCROPP(BA,G,H,Y,T2,RL,UR)$ROTSHR(BA,T2,RL),
                                    XACT(BA,G,H,Y,T2,RL,UR))$(XACTD(BA,T2,RL) > 0)
                          **(-RHOT(BA,RL)) )**(-1/RHOT(BA,RL))
$BATINCLUDE MODULE.CTL ACPROG apCET1.GMS
                      =E= RAC(BA,RL);
```

Dollar control statements are used to make sure that these equations are generated only for those rotations with positive acreage in a region and include only those production activities with a positive amount of acreage.

Regional Crop Acreage Balance

The regional crop acreage balance constraint ensures that supply of land allocated to crop *b* in Land Resource Region *rl* is equal to the land used by the crop rotations *ba* to produce that crop. This balance is represented by the function:

$$\alpha_{b,rl}\left(\sum_{ba}\delta_{ba,rl}s_{b,ba,rl}RAC_{ba,rl}^{-\rho_{b,rl}}\right)^{-\left(\frac{1}{\rho_{b,rl}}\right)}-X_{b,rl}=0, \qquad b\in bc, b=1,...,B;\ rl=1,...,RL;$$

where

$$\delta_{ba,rl}=\frac{R_{ba,rl}^{0}*RAC_{ba,rl}^{0}{}^{1+\rho_{b,rl}}*(\sum_{b}\lambda_b X_{b,rl}^{-\rho_{b,rl}})^{(-1/\rho_{b,rl}-1)}*s_{b,ba,rl})^{-1}}{\sum_{ba}R_{ba,rl}^{0}*RAC_{ba,rl}^{0}{}^{1+\rho_{ba,rl}}*(\sum_{b}\lambda_b X_{b,rl}^{-\rho_{b,rl}})^{(-1/\rho_{b,rl}-1)}*s_{b,ba,rl})^{-1}},\quad b,ba=1,\ldots,B;\quad rl=1,\ldots,RL$$

$$\alpha_{b,rl}=\sum_{b}X_{b,rl}/(\sum_{ba}\delta_{b,rl}s_{b,ba,rl}RAC_{ba,rl}{}^{-\rho_{b,rl}})^{-1/\rho_{b,rl}}$$

$s_{b,ba,rl}$ is the crop enterprise ***b*** share of one unit of rotation ***ba*** acres in region ***rl***.

The function is nonlinear and implies that there is a declining rate of transformation between land used in one crop rotation and land used to produce the same crop as part of another rotation. The parameters for these equations are derived from the quantity of each rotation acre supplied in the base year $RAC_{ba,rl}^{0}$, the net return to each crop rotation activity, $R_{ba,rl}^{0}$, the weighted sum of crop b acreages, $(\sum_{b}\lambda_b X_{b,rl}^{-\rho_{b,rl}})^{(-1/\rho_{b,rl}-1)}$, and an elasticity of transformation $\sigma_{b,rl}^{r}$ for each crop *b* in each Land Resource Region *rl*. Net returns per crop rotation activity are obtained from shadow prices on the model's calibration constraints. The transformation elasticities used in the calculation of the parameters of these functions are derived by using an iterative procedure that selects the set of transformation elasticities that generate the same crop supply response as obtained from FAPSIM (Price, 2004). In GAMS code, this is written as:

```
CETR(B,RL)             $ACLRRL(B,RL,"CK4")..
                       A(B,RL)*SUM(BA$DELTA(BA,RL), DELTA(BA,RL) * BSBROT(B,BA,RL)
                       * RAC(BA,RL)**(-RHO(B,RL))
                                  )**(-1/RHO(B,RL))
                   =E= ACLRR(B,RL);
```

Again, the dollar control statements are used to restrict the equations generated and rotations represented in the equations to those for which positive crop and rotation acreage exists.

Regional Input Balance

The regional input balance equations ensure that no more of a quasi-fixed input *ir* is used in region *r* than can be supplied and list all sources of supply and all sources of use for any such input (production activity, government program category, method of production, system of production, strata of production, and region). This includes all cropland put into the Conservation Reserve Program.

$$\sum\nolimits_{xcropp(b,g,h,y,t,rl,r)} pp_{ir,xcropp} X_{xcropp} + \sum\nolimits_{xlvstp(b,g,h,y,t,r,r)} pp_{ir,xlvstp} X_{xlvstp}$$

$$+ CRAC_{ir,r} - VI_{ir,r} \leq 0; \qquad\qquad ir = 1,...,I;\ r = 1,...,R;$$

In GAMS code this is written as:

```
INPUTRBALF(R,IR)$(INPUTR(R,IR,"QBASE") OR INPUTR(R,IR,"PFXP"))
               ..  SUM(XCROPP(B,G,H,Y,T,U,R),    XACTS(XCROPP)   * PP(IR,XCROPP))  {PIP+NPR}
                  + SUM(XLVSTP(B,G,H,Y,T,U,R),    XACT(XLVSTP)    * PP(IR,XLVSTP))  {LIVESTK}
                  + SUM(XFRUTP(B,G,H,Y,T,U,R),    XACT(XFRUTP)    * PP(IR,XFRUTP))  {FRUT+VEG}
$BATINCLUDE MODULE.CTL ACPROG apINPBAL.GMS
                  +  CRPLND(R,IR,"%1")                                 {+ CRP}
                    $ (ACRESDY("TOTAL","HST","CRP","A","%1",R) GT 0)

            =L=   INPUTRSUP( R,IR)  $ MFI(  R,IR)                        {CONVERTED TO MFI QUAL}
                +(INPTRSUPFP(R,IR)  $ MFI(  R,IR)) $ PMINI(R,IR)         {CONVERTED TO MFI QUAL}
                + INPUTRFSUP(R,IR)  $ ((INPUTR(R,IR,"PFXP") GT 0) AND
                                       (INPUTR(R,IR,"ELAS") LE 0))
                  ;
```

In REAP, the nonlinear regional input supply curves are represented in two linear segments. The first portion—over which input price is constant—is represented by `INPTRSUPFP(R,IR).` After input use exceeds `INPTRSUPFP(R,IR),` input supply is represented with an upward sloping linear curve.

Nonnegativity Constraints

$Z_{m.p}$, Y_{c} , $VI_{ir,r}$, $FI_{ir,r}$, $X_{b,rl}$, $RAC_{b,rl}$, $X_{b,g,h,y,t,rl,\ r}$, $S_{b,t,ft,\ rl,\ r}$, $CRAC_{ir,,r} \geq 0$

Nonnegativity constraints in GAMS are implied when the POSITIVE VARIABLE command is used when the variables are declared.

Bounds and Starting Values

Variable bounds are specified by placing an .UP, .LO, or .FX after the primary variable name. For example, INPUTRUSE.UP(R, IR) is used to specify upper bounds placed upon regional input activity levels—this bounds regional input supply. Input supply functions may be bounded with limits on the physical availability of the resource. Input supply and commodity demand functions are generally bounded with arbitrary limits, not meant to restrict the model solution, but to improve optimizer efficiency by restricting the domain over which the optimizer must search.

```
 INPUTRUSE.UP(R,IR)$INPUTR(R,IR,"QBASE") = INPUTR(R,IR,"QBASE")*3;
 INPUTRUSE.UP(R,IR)$SFI(R,IR) = INPUTRUSE.UP(R,IR) / SFI(R,IR);

 DOMESUSE.UP(P)     = 2*DEMSUP(P,"DOM","QBASE")$DEMSUP(P,"DOM","QBASE");
 DOMESUSE.UP(P)$SF(P,"DOM") = DOMESUSE.UP(P) / SF(P,"DOM");
 EXPORTUSE.UP(P)    = 2*DEMSUP(P,"EXP","QBASE")$DEMSUP(P,"EXP","QBASE");
 EXPORTUSE.UP(P)$SF(P,"EXP") = EXPORTUSE.UP(P) / SF(P,"EXP");
 STOCKUSE.UP(P)     = 2*DEMSUP(P,"STKE","QBASE")$DEMSUP(P,"STKE","QBASE");
 STOCKUSE.UP(P)$SF(P,"STKE") = STOCKUSE.UP(P) / SF(P,"STKE");
```

Starting values are specified by placing .L after the primary variable name. XACT.L(B,R), for example, specifies initial values for primary commodity production activities. The base activity level values, PP("BASELEVL",B,R), are specified as initial values to give the optimizer a good starting point; the REAP optimization is begun from the initial values rather than, say, a previous saved basis.

The remaining starting values are specified as part of the PMP formulation. A calibration run is first performed with the PMP type activities locked onto the PMP base activity levels. The XACT.FX(B,R) specification is used to fix the PMP activities at the desired levels:

```
 XACT.L(B,R)        = PP("BASELEVL",B,R);
 XACT.FX(B,R)$PMP(B,R) = PMP(B,R);
```

Two additional sets of variables and equations are used in REAP to ensure that the CET functions for the tillage and rotation strata are always defined when evaluated by the solver. (This is needed because many other solvers evaluate exponents by transforming them into logarithms; consequently, if a value of zero is returned, the model will stop and give an error message indicating that an illegal operation was performed.)

```
EQUATIONS          CETTEVAL          CET TILLAGE PRACTIVE EVALUATION DOMAIN CONSTRAINT
POSITIVE VARIABLE  CETTEVALV(B,T,U)  CET TILLAGE PRACTICE DOMAIN VARIABLE

CETTEVAL(BA,T2,U)               $ROTSHR(BA,T2,U)..
                                     SUM(XCROPP(BA,G,H,Y ,T2,U,UR), XACT(XCROPP))
                                 =E= CETTEVALV(BA,T2,U);

CETTEVALV.L(BA,T2,U)             $XACTD(BA,T2,U)
                               = XACTD(BA,T2,U);
CETTEVALV.UP(BA,T2,U)            $XACTD(BA,T2,U)
                               = CETTEVALV.L(BA,T2,U) * 100;
CETTEVALV.LO(BA,T2,U)            $XACTD(BA,T2,U)
                                = CETTEVALV.L(BA,T2,U) * .01;

EQUATIONS          CETREVAL     CET ROTATION EVALUATION DOMAIN CONSTRAINT
POSITIVE VARIABLE  CETREVALV(BA,U)    CET ROTATION DOMAIN VARIABLE

CETREVAL(BA,RL)       $RAC.L(BA,RL)..
                        RAC(BA,RL) =E= CETREVALV(BA,RL);
CETREVALV.L(BA,RL)     $RAC.L(BA,RL)
                       = RAC.L(BA,RL);
CETREVALV.UP(BA,RL)    $CETREVALV.L(BA,RL)
                       = CETREVALV.L(BA,RL) * 10;
CETREVALV.LO(BA,RL)    $CETREVALV.L(BA,RL)
                       = CETREVALV.L(BA,RL) * .01;
```

Solving the Model

MODEL Statement Specification

The MODEL statement is used to define a GAMS model as some combination of the equations that have been declared. REAP1 is the first calibration run model, consisting of all equation blocks initially specified for the first calibration run: the objective function, the product balance equations, the regional variable-price input balance, the regional fixed-input balance, the supply response equations, and the government program equations (plus several optional dry/irrigation and acreage limit controls not used in current REAP formulations). REAPS8 is the final, validated REAP formulation, after calibration of all supply response and constant elasticity share functions. The BATINCLUDE statements shown below allow equations to be added to the model definition for REAPS8 if options for including those modules have been turned on. In the **MODEL** statement for REAPS8 the variable nitrogen application rate module has been turned on (VNITF = 1), causing the convexity constraint equations to be added to the model definition for REAPS8.

```
$STITLE REAP MODEL SPECIFICATION:  ROWS AND OBJECTIVE FUNCTION, CALIBRATION RUN
* ---------------------------------------------------------------------------

*                              DECLARE THE MODEL EQUATIONS
  EQUATIONS
     OBJECTIVE FUNCTION
             UOBJ       REAP OBJECTIVE FUNCTION

*    COMMODITY AND INPUT BALANCE
             PRODBAL    COMMODITY PRODUCT BALANCE EQUATION
             INPUTRBALF REGIONAL INPUT BALANCE EQUATION
             INPUTRFBAL REGIONAL FIX PRICE INPUT BALANCE EQUATION
             CETT       CONSTANT ELASTICITY OF TRANSFORMATION AMONG TILLAGE TYPES
             CETR       CONSTANT ELASTICITY OF TRANSFORMATION AMONG ROTATIONS
             CNVXBAL    VARIABLE N FERT APPLICATION CONVEXITY CONSTRAINTS
             GPPBASEAC  GOVERNMENT PROGRAM PAYMENT BASE SODBUSTER PROVISIONS

 MODELS
       REAP1 FLEXIBLE MODEL FORUMLATION /
                          UOBJ,      PRODBAL,   INPUTRBALF, INPUTRFBAL, GPCON
                          ACEQ2
                          /;

      REAP8 STRATA FIXED MODEL FORUMLATION /
                          UOBJ,      PRODBAL,   INPUTRBALF
                          CETR,      CETREVAL,  CETT,       CETTEVAL
BATINCLUDE D:\REAPGAMS\A1A0\CET\MODULE.CTL
BATINCLUDE D:\REAPGAMS\A1A0\CET\MODULE.CTL
BATINCLUDE D:\REAPGAMS\A1A0\NITR\VNMODEL1.GMS
  *<vnMODEL1.GMS>
  *bVNITF
                           CNVXBAL
  *eVNITF

                               /;
```

SOLVE Statement Specification

The SOLVE statement calls for solution of a particular model. The following SOLVE statement asks for solution of model REAPS8 by maximizing variable CPS:

```
SOLVE REAPS8 USING DNLP MAXIMIZING CPS.
```

The SOLVE statement essentially causes GAMS to generate the model in a form in which it can be passed to and solved by an optimizer or other solution procedure. Discontinuous nonlinear programming (DNLP) is the solution method specified. REAP requires DNLP because of the two expressions in the objective function that contain the MAX function, for example: (MAX(0,(IMPORTSUP(P)-DIF(P,"IMP")))). This formulation causes a discontinuity in the objective function, at which point the function gradients for these variables are be undefined.

Model Solution

Some useful solution and diagnostic information is printed into the LST output file for every model run, indicating first whether an optimal solution was found.

```
                S O L V E     S U M M A R Y
MODEL   REAP8               OBJECTIVE  CPS
      TYPE    DNLP                DIRECTION  MAXIMIZE
      SOLVER  MINOS5              FROM LINE  58062

  **** SOLVER STATUS     1 NORMAL COMPLETION
 **** MODEL STATUS      2 LOCALLY OPTIMAL
 **** OBJECTIVE VALUE           769542.4849

  RESOURCE USAGE, LIMIT       1656.960    10000.000
  ITERATION COUNT, LIMIT      3500        20000
  EVALUATION ERRORS              0           0

M I N O S    5.3    (NOV 1990)         VER: 225-386-02
      = = = = =

B. A. MURTAGH, UNIVERSITY OF NEW SOUTH WALES
        AND
      P. E. GILL,  W. MURRAY,  M. A. SAUNDERS AND M. H. WRIGHT
      SYSTEMS OPTIMIZATION LABORATORY, STANFORD UNIVERSITY.

  OPTIONS FILE
  ------------
       BEGIN GAMS/MINOS  OPTIONS
       * MINOS5.OP6 USED IN A0C2 DIRECTORY FOR VFY RUN AFTER CTF
        HESSIAN DIMENSION      1050
        SUPERBASICS LIMIT      1050
        COMPLETION          PARTIAL
        LOG FREQUENCY            20
        SOLUTION                 NO
        PRINT LEVEL               1
        ROW TOLERANCE          1.0E-7
        MINOR ITERATIONS       1000
        MAJOR ITERATIONS       40
        MAJOR DAMPING PARAMETER  .2
        MINOR DAMPING PARAMETER  .2
        PENALTY PARAMETER        .5
       END GAMS/MINOS OPTIONS

WORK SPACE ALLOCATED           --    7.52 MB

EXIT -- OPTIMAL SOLUTION FOUND

MAJOR ITNS, LIMIT            13      40
  FUNOBJ, FUNCON CALLS       5294    5302
  SUPERBASICS                 580
  INTERPRETER USAGE        346.59
  NORM RG / NORM PI     1.969E-07
```

```
  NO. OF ITERATIONS                3500     OBJECTIVE VALUE      7.6954248487E+05
  NO. OF MAJOR ITERATIONS            13     LINEAR OBJECTIVE    -4.9270982959E+04
  PENALTY PARAMETER            0.000000     NONLINEAR OBJECTIVE  8.1881346783E+05
  NO. OF CALLS TO FUNOBJ           5294     NO. OF CALLS TO FUNCON          5302
  NO. OF SUPERBASICS                580     NORM OF REDUCED GRADIENT    5.363E-04
  NO. OF BASIC NONLINEARS          1086     NORM RG / NORM PI           2.119E-07
  NO. OF DEGENERATE STEPS             0     PERCENTAGE                       0.00
  NORM OF X                   4.174E+02     NORM OF PI                  2.531E+03
  NORM OF X  (UNSCALED)       1.084E+03     NORM OF PI (UNSCALED)       2.724E+03
  CONSTRAINT VIOLATION        7.906E-12     NORMALIZED                  7.288E-15

STATUS         OPTIMAL SOLN          ITERATION 3500     SUPERBASICS  580

  SOLUTION FILE SAVED ON FILE  20
  MAJOR ITNS, LIMIT            13      40
  FUNOBJ, FUNCON CALLS       5294    5302
  SUPERBASICS                 580
  INTERPRETER USAGE        346.59
  NORM RG / NORM PI     1.969E-07
```

Output Reports

In the LST output file generated, GAMS will report the solution and marginal values for model variables and equations. In addition, two standard sets of reports are generated by REAP. The first report, called "A1A0RPT00.GMS," is found in the A1A0LIB directory (table 8). This bulletin is generated automatically every time REAP solves successfully and is found at the end of the GAMS listing. A1A0RPT00 calculates such things as changes in acreage planted, commodity supply and uses, commodity prices, farm income, and environmental indicators. The tables in A1A0RPT00 are in standard GAMS format and are used primarily in the evaluation of model results.

In addition, a second report of about 40 to 60 pages of model results can be generated for distribution. This summary report is generated by running ARPT20.GMS, that is located in the AREPORT directory (table 9). The report includes explanations of commodity, input, and environmental indicators, plus tables reporting supply and use, acreage, income, other economic indicators, and physical and economic environmental indicators. Detailed tables focusing on additional topics are often produced for specific scenario analysis. A fragment of the output generated by ARPT20 for a carbon sequestration analysis is shown in example 13. This fragment lists some of the tables that are generated by ARPT20. An example of the tables from this report is shown in table 9.

Example 13—ARPT20 fragment

```
        REAP REGIONAL AGRICULTURAL MODEL -- CARBON SEQUESTRATION  ALTERNATIVES             PAGE 2
    SCP1100S 2010 0201bsl AER SCP RUNS ALL C=0 P=100 D=0 FP=1 NDISC=1 A1A093V TCM15bV    03/04/02

                             CONTENTS

                   TABLE                                                     PAGE
                   ---------------------------------------------------      ----
                   PRIMARY COMMODITY AND PRODUCT LISTS                          2
                   SECONDARY (PROCESSED) PRODUCTS LISTS                         4
                   PRODUCTION INPUTS                                            5
                   ENVIRONMENTAL INDICATORS                                     6
                   ALTERNATIVE CROP ROTATIONS                                   7
                   TABLE 1:  GOVERNMENT PROGRAM ASSUMPTIONS                     8
                   TABLE 2:  CROP PRODUCT SUPPLY AND USE                        9
                   TABLE 3:  PROCESSED PRODUCT SUPPLY AND USE                  10
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                   TABLE 5:  TOTAL ACRES PLANTED BY REGION                     13
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```

Model Data

In the REAP model system, we link supply and use projections to regional land use production practices and their corresponding environmental loadings. To establish the linkage, we pooled information from several sources of data, including the baseline data, crop production enterprise database, the National Resources Inventory, and the Agricultural Resource Management Survey (ARMS). The data sources, their use, and the procedures used to integrate them into REAP are outlined below.

Baseline Data

The baseline data provides the market prices and quantities used in setting up the base solution. The baseline data provides projections of agricultural commodity production, prices, trade, and farm income over a 10-year time period. Commodities covered include corn, sorghum, barley, oats, wheat, rice, cotton, soybean and soybean products, milk, beef, pork, chicken, and turkey.   Projections contained in the baseline assume the continuation of current farm policies and specific conditions for the economy, weather, and global situation. For more detailed information on the baseline see the ERS Briefing Room (www.ers.usda.gov/Briefing/Baseline/).

The information from the baseline is brought into REAP through files generated by a relational database. We use the database to import the baseline spreadsheets; select the relevant price, supply and use, and policy variable data; and organize it so that it is consistent with REAP naming conventions and GAMS coding requirements. With the database, we generate two files to be called into REAP, one containing the baseline data for crops (buca*mmyy*.gms) and one containing the baseline data for livestock (buli*mmyy*.gms). Both files are located in the model library directory (A1A0LIB). *Mmyy* represents the month and year that the baseline data was published. Baseline files are updated to the most recent baseline data; periodically and current files exist intermittently for baseline data going back to 1992.[6]

REAP calls in the most recent baseline files available by default. The selection of the baseline files, however, is hard coded into the file BGSET.GMS. The baseline call needs to be updated when new baseline files become available. The file BGSET.GMS is in the base model directory.

To change the baseline files being used, all you need to do is to change the name of the baseline files being called in BGSET.GMS. Make sure the desired year exists in the library directory to avoid errors. An example of changing the baseline files used is demonstrated in example 14.

Example 14—Changing from 2001 baseline data to the 2003 baseline

In this example, we are changing the baseline files being used from those containing data from the 2001 baseline data to those containing data from the 2003 baseline data. In this example, the call for baseline files contained in bgset.gms changes from:

---

[6] One needs to be aware that current formulation of REAP, particularly with respect to its representation of farm programs, is not necessarily consistent with the historical baseline files. REAP can be changed fairly easily to accommodate farm programs as they existed in these historical files if so desired.

```
$STITLE SETUP REAP TO MATCH SELECTED BASELINE YEAR YB--calls USDA baseline file
* FILE: <BGSET.GMS>   THIS IS CALLED FROM REAP RUN SETUP FILE: E.G. A1A0A.GMS

* GET BASELINE LIVESTOCK DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BULI0201.GMS %1 %2 %3

* GET BASELINE CROP DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BUCA0201.GMS %1 %2 %3
```

to

```
$STITLE SETUP REAP TO MATCH SELECTED BASELINE YEAR YB--calls USDA baseline file
* FILE: <BGSET.GMS>   THIS IS CALLED FROM REAP RUN SETUP FILE: E.G. A1A0A.GMS
.
* GET BASELINE LIVESTOCK DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BULI0203.GMS %1 %2 %3
.
* GET BASELINE CROP DATA TABLES
$BATINCLUDE MODULE.CTL LIB1 BUCA0203.GMS %1 %2 %3
```

In addition, the first time a new baseline file is run, a new table specifying the parameter BSAC will be needed to be changed in the ACRGLY.TBL file in the ENVIR sub-directory. The new BSAC table is created the first time REAP is run with the new baseline file. A code at the bottom of the bucammyy.gms file that automatically aborts the model run when a new baseline file is detected and prints the new BSAC table to use in the listing file.

```
* FILE <BUCA0201.GMS>  <LIBRARY FILE> CALLED FROM BGSET.GMS
.
.
.
ABORT$(ABS(BLCROPT - BSACT) > 0.0001) "**** MUST UPDATE BSAC IN ACRGLY.TBL", BLCROPT, BSACT,
BLCROPA;
```

To update the BSAC table in the ACRGLY.TBL file, copy the BSAC table from the listing over the existing BSAC table in ACRGLY.TBL.

```
*FILE<ACRGLY.TBL> AUGMENTED BY CROPSHR, ROTSHR TABLES AND DERIVATIVES
* ENVIR FORMULATION
.
TABLE BSAC(B,YR) BASELINE ACRES PLANTED 0201 BASELINE
  +         2005        2006        2007        2008        2009        2010
CORN      80.000      80.000      80.500      80.500      81.000      81.000
SORGHUM    9.500       9.600       9.700       9.800       9.900      10.000
```

Becomes

```
TABLE BSAC(B,YR) BASELINE ACRES PLANTED 0203 BASELINE
   +        2007        2008        2009        2010        2011        2012
CORN      80.000      80.000      80.500      80.500      81.000      81.000
SORGHUM    9.500       9.600       9.700       9.800       9.900      10.000
```

If there have been no changes in government programs that would change policy variable names or the manner in which the programs affect producer decisions, then the changes needed to include the new baseline file is complete. However, when the farm programs represented in the baseline data change, then REAP will need to be reformulated to account for the new programs. Because government farm policy changed from 2001 to 2003, updating REAP to the 2003 baseline required some slight adjustments, primarily in naming conventions for government programs and in the way government program payments and expenditures are calculated in reports.

The major change to farm policy in the 2002 Farm Bill was in the manner in which decoupled income support payments were structured. Prior to the 2002 Farm Bill, decoupled income support payments were fixed in the 1996 Farm Act and called “Production Flexibility Contract (PFC) payments.” With the 2002 Farm Bill, we divide the uncoupled income support payments into two parts: a direct payment and counter-cyclical payment. The direct payment was setup similar to the PFC payment. All that was required to incorporate the direct payment into REAP was to add a label for it and substitute this label for PFC in the calculations of government program payments and expenditures. The counter-cyclical payment, however, depends on the difference between the target price and market price or loan rate (whichever is higher), and so required that some additional calculations be added to the code in addition to adding a label for it to the model. Even though the counter cyclical payment was tied to the market price, it was not tied to production since the payment was based on base acreage and program yields that are derived from historical production rather than current production. Actual production of crop was not required to receive the payment. Because both programs were decoupled from production, we assumed that they had no effect on production decisions and could be treated as exogenous variables in the model formulation.

The changes to the model formulation required when the 1996 Farm Bill was enacted, in contrast, were much more extensive. Prior to the 1996 Farm Bill income support payments were tied to both prices and production. The area planted to program crops was limited by base acreage constraints and annual acreage reduction programs. In addition, farmers had limited flexibility to plant oilseeds on a portion of their base acreage.

Crop Production Enterprises

The crop production enterprise database provides data needed to construct crop production activities for REAP and provides the field operation data used to run the EPIC simulations used to generate the environmental indicator coefficients for the cropping systems used in REAP. The database was developed by using information contained in ARMS and literature reviews for each of the 10 Farm Production Regions.

The database includes two types of cropping systems. “Predominant systems” are those systems currently in widespread use. Predominant system coefficients are based upon ARMS[7] estimates, with input costs updated to reflect current input prices and ERS Cost of Production estimates. “Alternative systems” are newer systems that may prove to be less intensive over time in terms of soil erosion and chemical use. There are 623 predominant systems that include rotations of up to 4 crops differentiated by up to 5 tillage practices. The alternative systems include innovative and experimental rotations. These rotations are designed to be less detrimental to the environment. The rotations include using legume crops as a

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[7] The information used in the current database came from the CPS, which is now part of ARMS. See the ERS Briefing Room.

substitute for nitrogen fertilizer and using crop rotation sequences to break up pest life cycles in place of chemical pesticides.

Predominant Systems

The 1992 National Resources Inventory (NRI) and the 1992 Cropping Practices Survey (CPS)[8] were used to define the 62 crop rotations commonly used throughout the United States and the tillage practices commonly associated with them. Rotations were defined based on the number of different REAP crops contained in the cropping history. Records in NRI were divided into regions by overlaying the 26 Land Resource Regions onto the 10 Farm Production Regions. The records were then subdivided again based on whether they were on HEL or NHEL soils. Acreage for each rotation was then recorded.

Tillage practices associated with the rotations and acreage devoted to them were derived from the CPS. Crop rotations as identified through the NRI were used to group the CPS records. ERS definitions pertaining to tillage practices were used to assign tillage practices and acreage associated with each rotation.

All information used to construct predominant systems was obtained from ARMS, primarily the Phase II field practices survey. The Phase II was previously known as the CPS. Because the information used to produce the production systems came from the CPS before its name was changed, we will refer to it as the CPS for the remainder of this section. To create the management files to run EPIC simulations for the predominant systems (and obtain the physical effects of these systems—yields and environmental effects) required obtaining all the management information needed to mimic the complete production cycle of any crop in a rotation. This included information on all field operations from pre-planting to post-harvesting (i.e., what occurred, when it occurred, with what type of equipment, and how frequently) and input levels (i.e., seeding rates, fertilization and liming rates, and pesticide applications) for each crop within a production activity sorted by rotation, tillage practice, and model region.

Data to create the crop production enterprise database for the production of corn, soybeans, wheat, cotton, and rice came from the 1992 CPS. The data used for sorghum came from the 1991 CPS. Information on field operations for silage, which was not included in the CPS, was obtained by assuming that silage was corn being harvested for silage. The exception to this was in the Southern Plains, where it was assumed that silage was sorghum being harvested for silage. Accordingly, we assumed that a silage system was managed identically to its "twin" corn or sorghum system, except that silage systems were harvested for silage at the appropriate time. Analogously, EPIC management files for barley and oats were assumed to be similar to wheat managed in a comparable wheat system, with minor modifications (e.g., to ensure that any herbicide applications derived from a wheat system to be used on a comparable barley system were not toxic to barley).

Finally, it was assumed that hay was grown according to established practices for alfalfa in that region. In most regions, it was assumed that alfalfa was established in the summer and fall after the preceding crop

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[8] Not to be confused with the objective function variable CPS.

had been harvested and grown for 4 years, with cuttings two or three times each year. Where alfalfa was not suited to the growing conditions of a particular region, clover or hairy vetch was substituted.

Machinery implement compliments used in each rotation-tillage system were based on the size (horsepower) of the tractor used. The CPS was used to determine the average size (horsepower) of the tractor used in each FPR. A representative implement complement (machinery and equipment) for each FPR was constructed by using the average tractor size in that FPR and information obtained from the publication *Minnesota Farm Machinery Economic Cost Estimates for 1992* (Fuller et al., 1992) and staff of the Rodale Institute Research Center.

Planting information for each crop in a rotation-tillage system was derived from information in the CPS on average seeding rates and planting dates. The type of tillage practice under consideration determined the type of planter for the particular crop. Fertilizer regimes for each crop in a rotation-tillage system were derived from the fertilizer information contained in the CPS. The mean number of fertilizer applications as reported in the CPS for a crop (rounding up or down to an integer, according to convention, but not rounding down to zero) was used to determine the number of fertilizer applications. The mean of CPS for total quantity of nitrogen (N), phosphate (P), and potash (K) were used to determine how many pounds per acre of elemental N, P, and K to apply to each system. Likewise, liming information from the CPS was used to determine lime applications. Also, the most frequently occurring month(s), in the CPS data, were used to set fertilization date(s).

The CPS did not provide necessary information about adjusting the amount of N, P, and K to apply to reflect credits due to manure applications. Yields of some crops in the base systems may have been affected by this omission. The CPS did not contain sufficient information to identify the type of fertilizer used. This is because fertilizer applications can be reported in the survey by type of fertilizer and quantity or by amount of elemental form (N, P, and K) applied or both. As a result, the quantity of each type of fertilizer applied was set so as to equal the quantity of elemental nutrient (N, P, and K) as reported in the CPS.

The appropriate pesticide schedule for a crop (again, by FPR, specific to each crop within a rotation-tillage system) was determined from the mean number of pesticide applications for a particular crop and quantity of active ingredients in the pesticide. To determine which pesticides to apply in the production system, the CPS data was used to determine the first two or three active ingredients in a product mix. The most frequently applied pesticides (active ingredients) for that rotation-tillage system were used as much as possible. Potential complications occurred whenever the number of pesticide applications was greater than one. It was difficult to associate specific pesticides with a particular pesticide application.

Take, for example, a rotation-tillage system where an average of two pesticide applications were reported for a particular crop. The first most frequently occurring pesticide is a herbicide, but this herbicide is a substitute for the second most commonly applied pesticide for the crop. It is conceivable that only one application of a herbicide was being applied for this type of system, but some producers used the first herbicide while others used the second herbicide rather than two applications of herbicide. Also, again suppose that for a rotation-tillage system, there were two pesticide applications reported, and this time, both a herbicide and an insecticide were used. It is difficult to detect from the CPS data whether producers sprayed their fields with a herbicide only once, sprayed their fields a second time with an insecticide, or sprayed their fields twice by using both a herbicide and an insecticide. The typical or representative pesticide application regime for a given system was based on the most frequent pesticide application and the average number of pesticide applications for that crop as observed in the CPS. Information from the CPS was used to determine the application rate of each pesticide (active ingredient) applied in the system and the month(s) of which the most frequent specific pesticide application(s).

Lastly, information from the CPS was used to determine how many field or tillage operations (other than planting, fertilizing, or spraying) occurred for a crop (again, by FPR, specific to each crop within a rotation-tillage system). The mean number of machinery operations reported in the tillage table in the CPS data for that crop (rounding up or down to an integer, according to convention) was used. Further, information in the CPS was used to determine the most frequently occurring time(s) of field (tillage) operations.

Harvest information from the CPS was not used in the analysis. In EPIC simulations, crops were allowed to reach physiological maturity before being killed. Further, crops harvested for grain were allowed to dry in the fields to a specific moisture content, avoiding storage and drying issues and costs.

Alternative Systems

Regional agronomists were asked to complete surveys for alternative systems as part of a study undertaken by the World Resources Institute.[9] The agronomists were asked to complete surveys only for those systems for which there was documented information on all aspects of the systems (i.e., management practices, input levels, and yields). These sources included records of field trials at experiment stations, records from onfarm producer trials, and results of studies published in university experiment station bulletins or peer-reviewed journals. All management information from the completed surveys was used to create the EPIC input files for simulating the biophysical effects (yields and environmental indicators) of the systems. These simulated effects were used in the analysis, but no actual effects were recorded on the survey instrument.

Despite the fact that this database is the most extensive single source of alternative production systems, the coverage is not uniformly comprehensive or representative of all alternatives in each FPR. The unevenness in coverage results from one or more of the following: (1) producers may not have been using many alternative systems in that region when the surveys were completed; (2) producers may have been using alternative systems in that region, but any scientifically gathered or published data for alternative systems in that region may have been limited; and (3) there may have been scientifically gathered or published data for the alternative systems in that region. In general, FPRs, with many alternative systems, have more comprehensive coverage of alternative systems than FPRs with fewer systems.

Crop Production Enterprise Budgets

REAP's production enterprise budgets contain economic items typical of the cost of production budgets (e.g., nitrogen cost, chemical cost, and energy cost) and physical measures of output and input use (e.g., yields, cropland, and irrigation water). They also contain a set of environmental coefficients[10] (e.g., erosion and nitrogen leaching) corresponding to the specific rotation and tillage cropping practices (e.g., soil erosion and nitrogen leaching).

Economic coefficients in the budgets were initially developed by using methods similar to those used in the USDA/Natural Resources Conservation Service's crop budget generator. Ten agronomists in different

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[9] See Faeth (1995) for details.

[10] Environmental indicators are typically reported in physical units. A few such as soil depreciation allowance, soil erosion off-site costs, carbon flux value, and nitrogen flux value are reported in monetary terms.

regions across the United States contributed to the effort. Scientists at RIRC developed a customized budget generator and data-processing procedures to combine the information into budgets and consolidate the budgets into databases suitable for managing the large volume of information.[11]

ERS analysts updated the initial set of crop budgets in several ways. Cost of production estimates are updated to USDA baseline projections of variable cost for the year in which a model scenario is based. The estimates are also updated to be consistent with recent ERS crop cost of production estimates.[12] In addition, the environmental coefficients for each cropping system derived by way of the EPIC biophysical model have been recalculated as part of several update and calibration processes discussed below (see Appendix B).

Livestock Budgets

Budgets for beef, dairy, and swine operations are obtained from cost of production estimates published by ERS.[13] Poultry, slaughtering, and feed ration generation activities are for the most part represented as value added activities with constant returns to scale. Poultry activities have been slightly modified to include energy costs. Energy cost for poultry was obtained from various ERS Situation and Outlook reports. Manure production and nutrient content of animal manure are based on estimates in Kellogg et al. (2000).

Data Reconciliation

We combine information from four databases to derive the base solution in REAP: land use and tillage practices, crop production enterprise, baseline data, and crop yield. The process of combining the information in these databases to obtain a base solution can be thought of as economic calibration and biophysical calibration. Economic calibration is the process of adjusting parameters on behavioral relationships and the production enterprise budgets so that the base solution replicates price, supply, and use as reported in the baseline data. Biophysical calibration is the process of adjusting various parameters in the EPIC model and environmental indicator coefficients in the crop enterprise budgets to be consistent with available information on crop yields, soil erosion, and assumptions about producer behavior, with respect to application of nitrogen fertilizer.

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[11] See Faeth (1995) for details.

[12] These costs are updated periodically by using ARMS data. Future costs of production will be econometrically estimated from farm surveys (see USDA, ERS, 2006).

[13] These costs are updated periodically using ARMS data. Future costs of production will be econometrically estimated from farm surveys (see USDA-ERS, 2006).

Economic Calibration

Economic calibration is to USDA's agricultural baseline for a historical or projected year, including agricultural commodity policies affecting prices and production of crops and livestock, and environmental policies affecting resource use, such as the Conservation Reserve Program (USDA, 2006). National acreage for 10 major field crops is specified by the baseline. Regional acreage allocation is calibrated to crop rotations (up to 4 years). REAP applies several routines to set up a base solution from which to work. The routines enable REAP to replicate production and price estimates as represented in the baseline data for any given year in a manner consistent with available information on the distribution of production activities across the United States. The routines are used to distribute crop and livestock production estimates contained in the USDA baseline to the model regions, adjust crop yields, and update costs of production estimates for production activities. Data sources used during this process include the baseline data, the National Resources Inventory (NRI), ARMS, and production and yield estimates from USDA's National Agricultural Statistics Service (NASS).

To account for data reporting inconsistencies across the REAP data sources, several reconciliation procedures were followed. These procedures are either designed to reconcile baseline projections with historical distribution of production activity or, for the environmental indicators such as soil erosion, reconcile simulation results with levels estimated directly from the NRI.

Information on production for livestock and crop production from NASS estimates are used to apportion the baseline data projections to model the Farm Production Regions. Each region's share of crop production as reported by NASS is applied to the national estimate provide in the baseline projection to allocate crop production among the 10 Farm Production Regions. The regional allocations are then used to specify parameters in cost functions so that REAP validates to the regional production estimates.

Crop Acreage Reconciliation

Crop acreage allocation is further extended by distributing crop acreage in each Farm Production Region obtained from the general procedure used to assign crop acreage to the Farm Resource Regions among the various crop production enterprise systems in each region. REAP uses three databases to reconcile distribution of crop acreage by rotation and tillage practice, with the national crop acreage estimate from the baseline data projections for any given year. The crop rotation and tillage information is combined with the baseline production data by using a matrix balancing routine to allocate crop acreage in each model region/practice strata as determined by share information from NRI and USDA CPS regional data. Responses in individual region, tillage practice, rotation, and other strata follow nested adjustment functions, which are part of the calibration, and sum to aggregate response. The matrix balancing routine used to achieve this reconciliation is in \REAPgams\a1a0\envir\acrgly.tbl. A fragment of code using this routine is shown in Example 15—Crop acreage matrix balancing routine

```
*   I------------------------------------------I
*   I  QUADRATIC CONSTRAINED MATRIX BALANCING  I
*   I------------------------------------------I

 PARAMETER XAC0(BA,U,UR)    BASE PRODUCTION SYSTEM ACREAGE BY MODEL REGION (FROM NRI)
           SRL0(B, U,UR)    BASE              CROP ACREAGE BY MODEL REGION (FROM NRI)
           SR0( B, U   )    BASE              CROP ACREAGE BY FARM  REGION (FROM NASS)
           DRL0(BA,U   )    BASE PRODUCTION SYSTEM ACREAGE BY FARM  REGION (FROM NRI)

           SXRL(B,BA,U,UR)  CROP ACREAGE SHARE PER UNIT OF PRODUCTION SYSTEM BY SYSTEM BY MODEL REGION
           ARI( B, U   )    WEIGHT ON CROP ACREAGE              BY FARM  REGION  DEVNS OF COMPUTED VS NASS
           ARIF             WEIGHT ADJUSTER ON ACREAGE          BY FARM  REGION  DEVNS OF COMPUTED VS NASS
           BRLJ(BA,  UR)    WEIGHT ON PRODUCTION SYSTEM ACREAGE BY FARM  REGION  DEVNS OF COMPUTED VS NRI
           GRLI(BA,U,UR)    WEIGHT ON PRODUCTION SYSTEM ACREAGE BY MODEL REGION  DEVNS OF COMPUTED VS NRI
```

```
           RSR(B,  *,UR)    REPORT OF CROP ACREAGE              BY FARM  REGION
           RDRL(BA,*,UR)    REPORT OF PRODUCTION SYSTEM ACREAGE BY FARM  REGION
           RXAC(BA,*,U,UR)  REPORT OF PRODUCTION SYSTEM ACREAGE BY MODEL REGION

*          DRL0(BA,U,UR)    ROTATION ACREAGE OBTAINED (FROM NRI)
*          BRLI(BA,U,UR)    WEIGHT PLACED ON MODEL REGION CROP ACREAGE DEVIATIONS FROM NRI ACREAGE
           ;

 OPTION XAC0:3:1:2, SRL0:3:1:2, SXRL:3:2:2, GRLI:3:1:2;
 OPTION RSR:3:2:1, RDRL:3:2:1, RXAC:3:2:2;

XAC0(BA,RL,R)      = SUM(T2, ROTAC(BA,T2,RL)$ER2RR(RL,R));
  DRL0(BA,R)         = SUM(RL, XAC0(BA,RL,R));
  SR0(B,R)           = ACRG92(B,R);
  SXRL(B,BA,RL,R)     $SUM(T2A, XSB7(B,BA,"NP","A","PRD",T2A,RL,R))
                     = SUM(T2, XSB7(B,BA,"NP","A","PRD",T2,RL,R))
                     / SUM(T2A, 1$XSB7(B,BA,"NP","A","PRD",T2A,RL,R)) ;

  ARIF               = 1;

*                                DEVIATION WEIGHT CALCULATIONS
*                                WEIGHTS: INVERSES IMPLIES CHI-SQUARE MINIMAND FOR CONSTRAINED MATRIX
PROBLEM
*                                               EQUAL TO 1 IMPLIES CONSTRAINED LEAST SQUARES
  ARI(B,R)            $SR0(B,R)
                     = 1 / SR0(B,R);
  BRLJ(BA,R)          $DRL0(BA,R)
                     = 1 / DRL0(BA,R);
  GRLI(BA,RL,R)       $XAC0(BA,RL,R)
                     = 1 / XAC0(BA,RL,R);

  DISPLAY XAC0, DRL0, SR0, SXRL, ARI, BRLJ, GRLI;

 POSITIVE VARIABLES
           XAC(BA,RL,R)      ACREAGE OF PRODUCTION SYSTEM BY MODEL PRODUCTION REGION
           SR(B,R)           ACREAGE OF CROP PLANTED IN FARM PRODUCTION REGION
           DRL(BA,R)         ACREAGE OF CROP SYSTEM ACREAGE BY FARM PRODUCTION REGION
           ;
 VARIABLE  DEVFN             QUADRATIC CONSTRAINED MATRIX DEVIATION FUNCTION
           ;

 EQUATIONS OBJCHIS           CHI-SQUARE OBJECTIVE FUNCTION
*          OBJCLSQ           CONSTRAINED LEAST-SQUARES OBJECTIVE FUNCTION
           SCROP(B,R)        CROP ACREAGE BALANCE BY FARM REGION
           NCROP(B)          NATIONAL BASELINE CROP ACREAGE BALANCE REQUIREMENT
           DSYSTEM(BA,R)     PRODUCTION SYSTEM BALANCE BY FARM REGION
           XACP(BA,RL,R)     PRODUCTION SYSTEM BY MODEL REGION POSITIVE CONSTRAINT
           {REQUIRE ALL SYSTEMS > 0
                                                                ACREAGE}

           ;

 OBJCHIS..    DEVFN =E=   SUM((B, R)$SR0(B,R),  ARIF * ARI(B, R) * SQR(SR( B, R) -  SR0(B, R)))
                        + SUM((BA,R)$DRL0(BA,R),      BRLJ(BA,R) * SQR(DRL(BA,R) - DRL0(BA,R)))
                        + SUM((BA,RL,R)$XAC0(BA,RL,R), GRLI(BA,RL,R) * SQR(XAC(BA,RL,R)- XAC0(BA,RL,R)));
SCROP(B,R)$SR0(B,R)..

                       SR(B,R)$SR0(B,R)     =E= SUM((BA,RL)$XAC0(BA,RL,R), XAC(BA,RL,R) * SXRL
( B,BA,RL,R));

 NCROP(B)$BSAC(B,"%1")..
                       BSAC(B,"%1")       =E= SUM(R$SR0(B,R), SR( B, R));

 DSYSTEM(BA,R)$DRL0(BA,R)..
                       DRL(BA,R)$DRL0(BA,R) =E= SUM(RL$XAC0(BA,RL,R), XAC(BA,RL,R));
```

```
 XACP(BA,RL,R)$XAC0(BA,RL,R)..
                XAC(BA,RL,R)$XAC0(BA,RL,R) =G= MIN(.05, .05 * XAC0(BA,RL,R));

MODEL QCM_CHIS2 RECONCILE CROP AND ROTATION SYSTEM ACREAGE BY FARM PRODUCTION REGION /
 OBJCHIS, SCROP, NCROP, DSYSTEM, XACP /;

 OPTION LIMROW            = 10;
 OPTION LIMCOL            = 10;

 SOLVE QCM_CHIS2 USING NLP MINIMIZING DEVFN;

 RSR(B,"RCHI-2",   R)     = SR.L(B,R);
 RDRL(BA,"RCHI-2",  R)    = DRL.L(BA,R);
 RXAC(BA,"RCHI-2",RL,R)   = XAC.L(BA,RL,R);

DISPLAY "QUADRATIC CONSTRAINED MATRIX ADJUSTMENTS", RSR, RDRL, RXAC;
```

Cost of Production Reconciliation

Crop and livestock production activity costs can be updated to the most recently available cost of production estimates obtained from the ARMS survey if desired. Costs can be updated by using a set of matrix balancing routines that adjust individual line item budget expenditures in the REAP budgets to ensure that average costs as reported for these items by crop and region by ERS match REAP estimates. The routines for updating are in \REAPgams\a1a0lib\bucaxx96.gms for crops and \REAPgams\a1a0lib\bulixx96.gms for livestock production activities.

Demand and Supply Response Calibration

Demand and supply parameters are calibrated to replicate demand and supply response embodied in FAPSIM supply and demand effect multipliers. The multipliers represent the supply and demand response obtained when a single commodity is subjected to a supply or demand shock over a 10-year period. All other prices and quantities are allowed to vary in response to the shock. The multipliers are similar to elasticities except that they rely on the total derivative, not the partial derivative. Most supply and demand elasticities reported in the literature are derived by using the partial derivative, where all other prices and quantities are held constant. Export demand and import supply parameters were derived from elasticities contained in the Partial Equilibrium Agricultural Trade Simulator (PEATSim) model (Abler, 2006).

On the supply side, several sets of parameters need to be calibrated, including the elasticities of transformation used in specifying the CET functions for crop rotations and tillage practices. These elasticities were calculated by using a search algorithm that loops through a range of possible values and calculates the change in production with respect to a price shock for each commodity for each set of elasticity values. The set of elasticity values that comes closest in replicating the FAPSIM supply multipliers are used in the model formulation. Currently, the transformation elasticities are set at -2. The results from the search algorithm indicate that crop supply response is sensitive to the magnitude of the transformation elasticity on the CET function used to control substitution among crop rotations. Crop supply response was largely unaffected by the magnitude of the transformation elasticity used on the CET functions that control substitution among the tillage practices.

Biophysical Calibration

Biophysical calibration is accomplished by running regional specification of soil type, weather conditions, crop systems, and management practices through EPIC biophysical simulations. A representative soil was selected for each region from the NRI and SOILS5 databases by using a multidimensional measure of similarity to regional average Universal Soil Loss Equation (USLE) variables capturing slope, hydrological, and erodability characteristics (Wischmeier and Smith, 1978). Representative weather conditions are estimated from distributional information (mean and variance) on temperature and rainfall from the National Oceanic and Atmospheric Administration (NOAA) combined with information on location of crop production. Average crop yields are estimated for the model regions from county yield data for the 10 crops.

Each crop system is specified as a sequence of crops, with dated field operations including planting, cultivation, fertilizer and pesticide application, and harvesting. Biophysical model biological parameters are validated in each production region so that simulated yields calibrate to regional yields and to ensure the yield-nitrogen response is consistent with observed nitrogen application rates and rational economic behavior on the part of producers.

Once the biophysical model has been calibrated, the environmental loading coefficients used by REAP for each combination of crop, rotation, tillage, drainage (tile drained or not), and region are derived. To more closely replicate the long-term effects of a particular set of practices, EPIC is first used to simulate the evolution of soil condition over 60 years of weather conditions for each set of practices. After that period of priming the soil, the soil condition is fixed, and the coefficients for nitrogen leaching, soil erosion, and so forth are calculated. These parameters represent the average annual results over a number of years; the specific number varies, depending on the number of crops in rotation and the number of years in the rotation, but is usually equal to 7 years' worth of results per crop.

Onsite phosphorus and nitrogen runoff estimated by using EPIC are calibrated to in-stream measurements made by the U.S. Geological Survey (Smith et al., 1997). The transport coefficients for phosphorus and nitrogen are used to estimate the quantity of sheet and rill erosion and pesticides that also run off into surrounding water bodies. Pesticide leaching and runoff are measured by the quantity of the active ingredient and then normalized to reflect toxicity and half-life (Barnard et al., 1997).

An interface called I_EPIC is used to manage the multiple EPIC runs necessary for calibration and generation of REAP environmental parameters. I_EPIC was developed and is maintained by Iowa State University. In order to increase the transparency of input, I_EPIC uses Microsoft Access databases as its input files rather than the more cryptic text-based input files used directly by EPIC. When input modifications are required, these databases can easily be opened and edited, then reloaded into I_EPIC. I_EPIC generates the text-based input files required by EPIC, and then translates EPIC's output into pre-formatted output tables in the same Microsoft Access database.

EPIC requires extremely detailed information about soil conditions, other site conditions (such as slope and weather), and sequence and timing of field operations in order to run. Creation of the data-rich input databases used by I_EPIC is therefore the most time-intensive step in the process of calibrating the model and generating the environmental effect parameters. As mentioned earlier, soil and weather information were originally compiled from external data sources, while field operations were compiled by USDA and WRI from existing data.

I_EPIC supports several versions of EPIC, including version 0509, which was used to generate the most recent set of environmental parameters used by REAP. More information on EPIC is at http://www.brc.tamus.edu/epic/. More information on I_EPIC is at http://www.public.iastate.edu/~elvis/i_epic_main.html.

Crop Yield Reconciliation

Crop production in REAP is calibrated to baseline data projections by adjusting crop yields in the crop production enterprise systems. This is accomplished by distributing projected crop production to the Farm Resource Region by using each region's share of crop production as derived from crop production information reported by NASS. The regional crop production results for each crop are then compared with each simulated yield for a Farm Resource Region to form a crop-specific index in each Farm Resource Region, which is then used to adjust yields in each production enterprise system so that simulated production matches projected production for each crop in each Farm Resource Region. This routine is in a1a0\bgcaxa.gms.

Environmental Indicator Reconciliation

The erosion estimates in the budgets are calibrated to meet erosion information obtained from the NRI by obtaining the soils erosion estimate by REAP model region from the 1992 NRI. The erosion coefficients in the REAP budgets are then used to calculate REAP estimates of cropland erosion in each region. An erosion index for adjusting REAP erosion coefficients are constructed by dividing the NRI estimates by the REAP soil erosion estimate for each model region. A similar routine is used to calibrate wind erosion. The code for this is in a1a0\envir\evactga.gms.

Box 1—History of Model's Development

The U.S. Mathematical Programming Regional Agricultural Sector Model (USMP) (now Regional Environment and Agriculture Programming Model (REAP), an agriculture sector analysis model, grew out of innovations in optimization, economic modeling, and computing in the 1970s and 1980s. Following Duloy and Norton's (1973 and 1975) application of separable programming, the Economic Research Service (ERS) began sector model efforts in 1981 to support analysis of 1981 and 1985 farm legislation. Robert House built the initial USMP sector model based on the Duloy and Norton model. In 1982, House reformulated USMP as a nonlinear system enabling direct solution of USMP's quadratic demand and Positive Math Programming (PMP) supply system, based on Howitt's (1995) PMP methodology.

From the mid-1980s to late 1980s, crop commodity programs and endogenous acreage program participation were added to the model. The addition of the Conservation Reserve Program followed, along with incorporation of and calibration to the USDA multiyear baselines. In these years, USMP contributed to ERS food and agricultural public and staff analyses, including the 1981 and 1985 Farm Bills.

Terry Hickenbotham collaborated on USMP enhancements and analyses in the 1980s, including GATT trade liberalization and analyses of the new triple base provisions of the 1990 Farm Bill. In 1991, W. Terry Disney joined the USMP effort. Disney rebuilt the livestock sector, and Mark Peters developed comprehensive feed grain and wet/dry milling components that supported 1990's ethanol analyses. A joint project with the World Resources Institute (WRI) and the Rodale Institute (including Paul Faeth and John Westra of WRI, and Kim Kroll and Jim Reynolds of the Rodale Institute) was initiated to add environmental indicators and alternative tillage and rotation cropping systems to the model, facilitating conservation and environmental policy analysis.

House and Peters enhanced these by integrating constant-elasticity crop supply to manage the numerous regional, tillage, fertilizer application, and multiyear rotation alternatives. House and Peters integrated calibrated estimates of crop yield and alternative nitrogen application rates and other physical indicators by using the EPIC crop biophysical model. Howard McDowell enhanced the environmental indicator measures and analysis and linked GIS information with USMP analyses.

After 2000, Keith Paustian and Mark Sperow of the Natural Resource Ecology Laboratory of Colorado State University helped to develop carbon sequestration implications of changes in U.S. crop and forestry land uses; Robert Johansson and Jonathan Kaplan of ERS helped to incorporate the environmental implications of animal production; Suzie Greenhalgh, Mindy Selman, and Elizabeth Marshall of WRI helped to develop watershed applications and biofuel components for the model.

In 2006, the model was renamed "REAP" to reflect the importance of the region-specific interaction between the environmental and economic components of the model, which are currently being revised by researchers at WRI (Elizabeth Marshall, Suzie Greenhalgh, and Mindy Selman), ERS (Scott Malcolm), and the Louisiana State University Agricultural Center (John Westra).

Figure 1
REAP Schematic

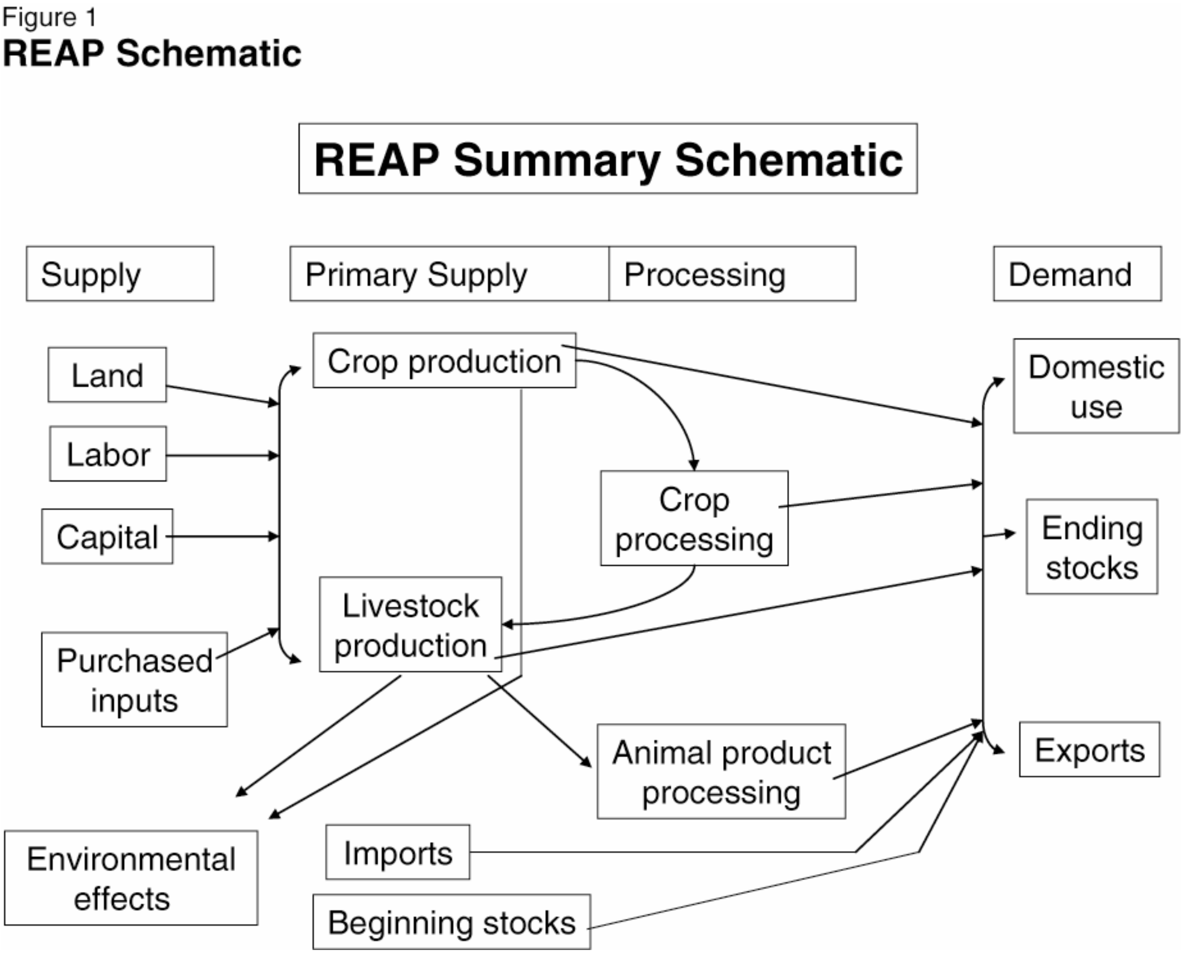
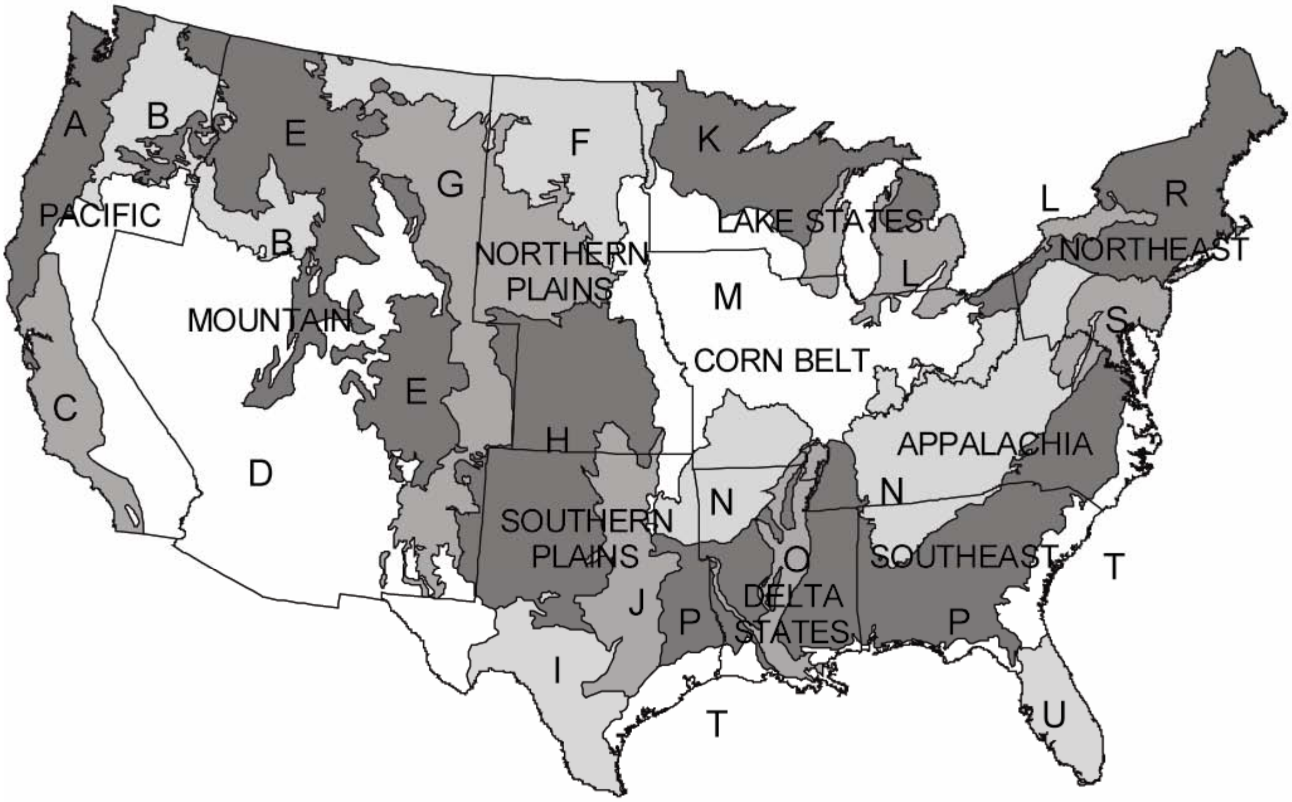


Figure 2

REAP Model Regions



Farm Production and Land Resource Regions

NT - Northeast
LA - Lake States
CB - Corn Belt
NP - Northern Plains
AP - Appalachia
SE - Southeast
DL - Delta States
SP - Southern Plains
MN - Mountain
PA - Pacific

A - NW Forest, Forage, and Spec. Crops
B - NW Wheat and Range
C - Cal. Subtop. Fruit, Truck, and Spec. Crops
D - Western Range and Irrigated
E - Rocky Mountain Range and Forest
F - N. Great Plains Spring Wheat
G - W. Great Plains Range and Irrigated
H - W. Great Plains Winter Wheat and Range
I - SW. Plateaus and Plains Range and Cotton
J - SW. Prairies Cotton and Forage

K - N. Lake States Forest and Range
L - Lake States Fruit, Truck, and Dairy
M - Central Feed Grains and Livestock
N - East and Central Farming and Forest
O - Mississippi Delta Cotton and Feed Grains
P - S. Atl. & Gulf Slope Cash Crops, Forest, Lvst.
R - Northeast Forage and Forest
S - North Atlantic Slope Diversified Farming
T - Atlantic & Gulf Coast Lowland Forest and Crop
U - Fla. Subtropical Fruit, Truck Crop, Range

USMP model region nomendature is the concatenation of abbreviations for farm production and land resource region, e.g. CBM is the intersection of FPR Corn Belt and LR Region M.

Figure 3

Depiction of transformation curves as used in REAP

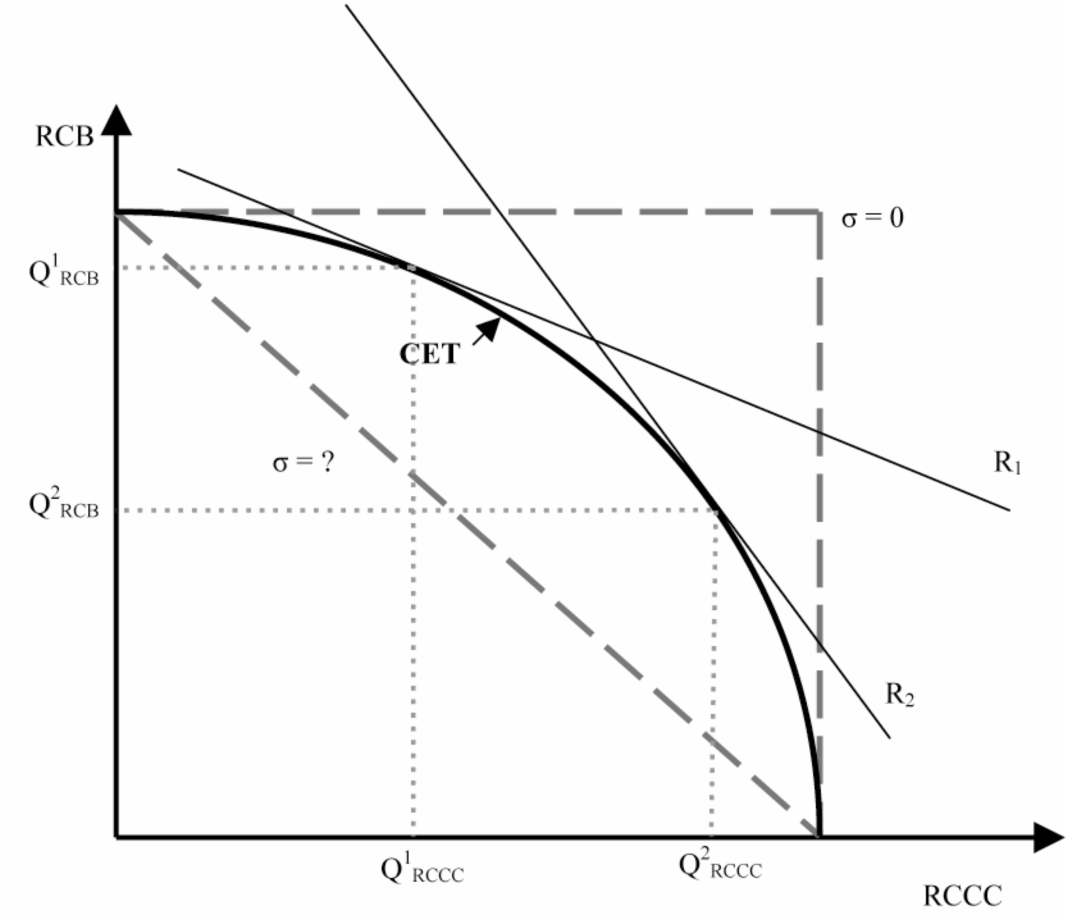


Figure 4

Comparison of flexibility constraints to CET curve

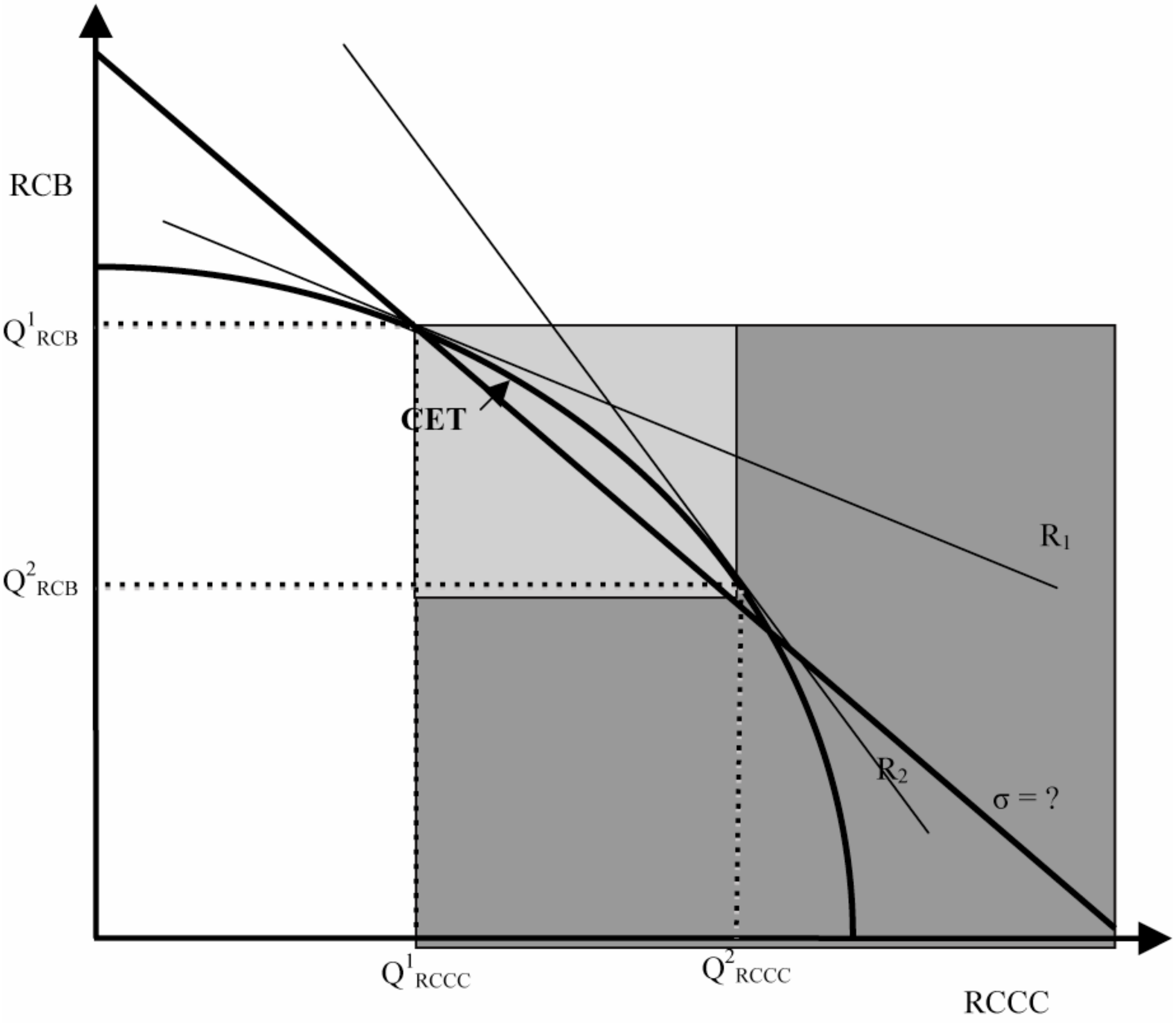


Table 1

REAP Inputs and Outputs

Inputs		Outputs		
Regional	National	Livestock	Crops	Processed
cropland	nitrogen fertilizer	fed beef for slaughter	corn	soybean meal
pasture land	potassium fertilizer	nonfed beef for slaughter	soybeans	soybean oil
	potash fertilizer	beef calves for slaughter	sorghum	livestock feed mixes
	lime	beef feeder yearlings	barley	dairy feed supplements
	other variable costs	beef feeder calves	oats	swine feed supplements
	public grazing land	cull beef cows	wheat	fed beef
	custom farming operations	cull dairy cows	cotton	nonfed beef
	chemicals	cull dairy calves	rice	veal
	seed	milk	silage	pork
	interest on operating capital	hogs for slaughter	hay	broilers
	machinery and equipment repair	cull sows for slaughter		turkeys
	veterinary and medical costs	feeder pigs		eggs
	marketing and storage	other livestock		butter
	ownership costs			american cheese
	labor and management costs			other cheese
	land taxes and rent			ice cream
	general farm overhead			nonfat dry milk
	irrigation water application			manufacturing milk
	energy costs			ethanol
	insurance			corn syrup

Table 2

List of tables contained in ENVACTGA

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*---------------------------------------------------------------*

*        PARAMETER DEFINITIONS FOR ENVACTGB.GMS                 *

*---------------------------------------------------------------*

PARAMETER   BTIL(B,T,R,CAS) SUM OF TILLAGE ACREAGE BY MDR;
PARAMETER   BTIL_N(B,T,CAS) SUM OF TILACRES NATIONALLY;
PARAMETER   TIL_CPSR(T,R,CAS) REG. SUM OF TIL ACRES LIKE CROPPING PRACTICES SURVEY;
PARAMETER   TIL_CPSN(T,CAS) NAT. SUM OF TIL ACRES LIKE CROPPING PRACTICES SURVEY;
PARAMETER   TCROP(RL,R,CAS) TOTAL PROGRAM AND FLEX AND ARP ACREAGE, BY MDR;
PARAMETER   TCROP_P(R,CAS) TOTAL PROGRAM AND FLEX AND ARP ACREAGE, BY FPR;

PARAMETER   SACPP1(B,G,H,Y,T,U,UR) PP ACTIVITY SHARE OF TOTAL CROP ACRES BY MDR;
PARAMETER   CHGCROPAC(B,G,H,Y,T,U,UR,*)  PP CHANGE IN CROP ACRES PLANTED;
PARAMETER   RCHGCROPAC(U,UR,*)  REGIONAL CHANGE IN CROP ACRES PLANTED;

PARAMETER   ACRES059(RL,R) 0-92 AND 50-92 ACREAGE WEIGHTED BY MDR CROP ACREAGE;
PARAMETER   OLUADJ(RL,R,OTHRLAND,CAS) OTHER LAND USE - ADJUSTED TO CURRENT YEAR;
PARAMETER   OLUTD(RL,R,CAS) DIFFERENCE BETWEEN ACTUAL AND CALCULATED LANDUSE TOTALS;
PARAMETER   PR_ER_RTS(RL,PRLAND) PASTURE AND RANGE WATER EROSION RATES;
PARAMETER   PR_WR_RTS(RL,PRLAND) PASTURE AND RANGE WIND EROSION RATES;
PARAMETER   CL_ERSN(RL,R,CAS)  CROP LAND SOIL EROSION TOTAL IN TONS MDR;
PARAMETER   ARP_ERSN(RL,R,CAS)  ARP EROSION TOTAL IN TONS BY MDR;
PARAMETER   DIV_ERSN(RL,R)  50-92 AND 0-92 EROSION BY MDR;
PARAMETER   CRP_ERSN_L(RL,R)  CONS. RESERVE PROGRAM SOIL EROSION TOTAL IN TONS BY PRODUCTION REGION;
PARAMETER   DIV_WERSN(RL,R)  50-92 AND 0-92 WIND EROSION BY MDR;
PARAMETER   CRP_WRSN_L(RL,R)  CONS. RESERVE PROGRAM WIND EROSION TOTAL IN TONS BY PRODUCTION REGION;
PARAMETER   PR_EROSN(PRLAND,RL,R,CAS)  PASTURE AND RANGE LAND SOIL EROSION TOTAL IN TONS BY LAND RESOURCE
REGION;

PARAMETER   TEROSN_L(RL,R,CAS)  TOTAL SOIL EROSION IN TONS BY LR IN MILLIONS OF TONS;
PARAMETER   TEROSN_P(R,CAS)   TOTAL SOIL EROSION IN TONS BY PRODUCTION REGION IN MILLIONS OF TONS;
PARAMETER   TEROSN_N(CAS)   TOTAL NATIONAL SOIL EROSION IN TONS IN MILLIONS OF TONS;

PARAMETER   SEROSN_L(RL,R,CAS)  SHEET AND RILL SOIL EROSION IN TONS BY LR IN MILLIONS OF TONS;
PARAMETER   SEROSN_P(R,CAS)   SHEET AND RILL SOIL EROSION IN TONS BY PRODUCTION REGION IN MILLIONS OF TONS;
PARAMETER   SEROSN_N(CAS)   SHEET AND RILL NATIONAL SOIL EROSION IN TONS IN MILLIONS OF TONS;

PARAMETER   WINDERSN_L(RL,R,CAS)  TOTAL WIND EROSION IN TONS BY LR IN MILLIONS OF TONS;
PARAMETER   WINDERSN_P(R,CAS)   TOTAL WIND EROSION IN TONS BY PRODUCTION REGION IN MILLIONS OF TONS;
PARAMETER   WINDERSN_N(CAS)   TOTAL NATIONAL WIND EROSION IN TONS IN MILLIONS OF TONS;

PARAMETER   AVGCLERSN(RL,R,CAS) AVERAGE CROPLAND (WATER) EROSION RATE IN TONS PER ACRE;
PARAMETER   AVGCLECST(RL,R,CAS) AVERAGE CROPLAND (WATER) EROSION COST IN DOLLARS PER ACRE;

PARAMETER   ERSNCST_L(RL,R,CAS) OFF-SITE SOIL EROSION DAMAGES BY RESOURCE REGION IN MILLIONS OF DOLLARS;
PARAMETER   ERSNCST_P(R,CAS) OFF-SITE SOIL EROSION DAMAGES BY PRODUCTION REGION IN MILLIONS OF DOLLARS;
PARAMETER   ERSNCST_N(CAS)    TOTAL NATIONAL OFF-SITE SOIL EROSION DAMAGES IN BILLIONS OF DOLLARS;
PARAMETER   EMENERGY_L(RL,R,CAS)  EMBODIED ENERGY USE BY MDR IN MILLIONS OF BARRELS DIESEL EQUIV;
PARAMETER   EMENERGY_P(R,CAS)  EMBODIED ENERGY USE BY PRODUCTION REGION IN MILLIONS OF BARRELS DIESEL
EQUIV;
PARAMETER   EMENERGY_N(CAS) NATIONAL EMBODIED ENERGY USE IN MILLIONS OF BARRELS DIESEL FUEL EQUIV;
PARAMETER   EMCARBON_L(RL,R,CAS)  EMBODIED CARBON IN PRODUCTION ACTIVITY INPUTS BY LR IN MILLIONS OF METRIC
TONS;
PARAMETER   EMCARBON_P(R,CAS)  EMBODIED CARBON IN PRODUCTION ACTIVITY INPUTS BY FPR IN MILLIONS OF METRIC
TONS;
PARAMETER   EMCARBON_N(CAS) EMBODIED CARBON IN PRODUCTION ACTIVITY INPUTS NATIONAL TOTOAL IN MILLIONS
METRIC OF TONS;
PARAMETER   PR_C_RTS(U,UR,PRLAND) PASTURE AND RANGE CARBON SEQ RATES;
PARAMETER   CRP_CRBN(U,UR)       LAND CARBON SEQ TOTAL IN METRIC TONS;
PARAMETER   ARP_CRBN(U,UR)       ARP CARBON SEQ TOTAL IN METRIC TONS BY MDR;
PARAMETER   DIV_CRBN(U,UR)       50-92 AND 0-92 CARBON SEQUESTERED BY MDR;

PARAMETER   PPCFLUX(B,G,H,Y,T,U,UR) C SEQ ESTIMATE FOR PRODUCTION ACTIVITIES BASED OFF OF ARS TOFROM
ESTIMATES;
PARAMETER   RCFLUX(U,UR) CARBON SEQUESTERED BY REGION;
PARAMETER   RACRES(U,UR) CROPLAND ACRES BY REGION;
PARAMETER   RAVGCFLUX(U,UR) AVERAGE CARBON SEQUESTERED ON CROPLAND BY REGION;
PARAMETER   PMTBASE(B,G,H,Y,T,U,UR) CARBON PAYMENT BASE;
PARAMETER   CRP_NLOS_L(RL,R)  CONS. RESERVE PROGRAM TOTAL NITORGEN LOSSS IN TONS BY RESOURCE REGION;
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Table 2

List of tables contained in ENVACTGA—continued

```
PARAMETER   GHG_L(RL,R,CAS) GREENHOUSE GAS EMISSIONS BY MDR IN MM TONS C EQUIV;
PARAMETER   GHG_P(R,CAS)  GREENHOUSE GAS EMISSIONS BY PR IN MM TONS C EQUIV;
PARAMETER   GHG_N(CAS) TOTAL GREENHOUSE GAS EMSSIONS IN MM OF TONS C EQUIV;
PARAMETER   NLOSS_L(RL,R,CAS)  NITRATE LOSSES BY MDR IN MILLION TONS;
PARAMETER   NLOSS_P(R,CAS)  NITRATE LOSSES BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   NLOSS_N(CAS) NATIONAL NITRATE LOSSES IN MILLION TONS;
PARAMETER   ANLOSS(RL,R,CAS) AVERAGE N LOSS IN POUNDS PER ACRE FOR CROPPED ACRES;
PARAMETER   PNLOSS_L(RL,R,CAS) PERCENT N LOSSES PER ACRE FOR CROPPED ACRES;

PARAMETER   NLEACH_L(RL,R,CAS) TOTAL NITROGEN LEACHED TO GROUNDWATER BY MDR;
PARAMETER   NLEACH_P(   R,CAS) TOTAL NITROGEN LEACHED TO GROUNDWATER BY PR;
PARAMETER   NLEACH_N(     CAS) TOTAL NITROGEN LEACHED TO GROUNDWATER;
PARAMETER   ANLEACH(RL,R,CAS) AVERAGE N LEACHED TO GROUNDWATER BY MDR;
PARAMETER   CRP_NLCH_L(RL,R)  CONS. RESERVE PROGRAM NITORGEN LEACHE DTO GROUNDWATER IN TONS BY REOURCE
REGION;

PARAMETER   NSOLN_L(RL,R,CAS) TOTAL NITROGEN LOST IN SOLUTION BY MDR;
PARAMETER   NSOLN_P(   R,CAS) TOTAL NITROGEN LOST IN SOLUTION BY PR;
PARAMETER   NSOLN_N(     CAS) TOTAL NITROGEN LOST IN SOLUTION;
PARAMETER   ANSOLN(RL,R,CAS) AVERAGE N LOST IN SOLUTION BY MDR;
PARAMETER   CRP_NSOL_L(RL,R)  CONS. RESERVE PROGRAM TOTAL NITORGEN LOST IN SOLUTION IN TONS BY RESOURCE
REGION;

PARAMETER   NSEDMNT_L(RL,R,CAS) TOTAL NITROGEN LOST IN SEDIMENT BY MDR;
PARAMETER   NSEDMNT_P(   R,CAS) TOTAL NITROGEN LOST IN SEDIMENT BY PR;
PARAMETER   NSEDMNT_N(     CAS) TOTAL NITROGEN LOST IN SEDIMENT;
PARAMETER   ANSEDMNT(RL,R,CAS) AVERAGE N LOST IN SEDIMENT BY MDR;
PARAMETER   CRP_NSDM_L(RL,R)  CONS. RESERVE PROGRAM TOTAL NITORGEN LOST IN SEDIMENT IN TONS BY RESOURCE
REGION;

PARAMETER   NDENITE_L(RL,R,CAS) TOTAL NITROGEN LOST IN ATMOSPHERE BY MDR;
PARAMETER   NDENITE_P(   R,CAS) TOTAL NITROGEN LOST IN ATMOSPHERE BY PR;
PARAMETER   NDENITE_N(     CAS) TOTAL NITROGEN LOST IN ATMOSPHERE;
PARAMETER   ANDENITE(RL,R,CAS) AVERAGE N LOST IN ATMOSPHERE BY MDR;
PARAMETER   CRP_NDNI_L(RL,R)  CONS. RESERVE PROGRAM TOTAL NITROGEN LOST IN ATMOSPHERE IN TONS BY RESOURCE
REGION;

PARAMETER   NVOL_L(RL,R,CAS) TOTAL NITROGEN LOST IN ATMOSPHERE BY MDR;
PARAMETER   NVOL_P(   R,CAS) TOTAL NITROGEN LOST IN ATMOSPHERE BY PR;
PARAMETER   NVOL_N(     CAS) TOTAL NITROGEN LOST IN ATMOSPHERE;
PARAMETER   ANVOL(RL,R,CAS) AVERAGE N LOST IN ATMOSPHERE BY MDR;
PARAMETER   CRP_NVOL_L(RL,R)  CONS. RESERVE PROGRAM TOTAL NIOROGEN LOST IN ATMOSPHERE IN TONS BY RESOURCE
REGION;

PARAMETER   NLOSSGS_N(CAS) NATIONAL NITRATE LOSSES TO GROUND AND SURFACE WATER IN MILLION TONS;
PARAMETER   NLOSSGS_L(RL,R,CAS)  NITRATE LOSSES TO GROUND AND SURFACE WATER BY MDR IN MILLION TONS;
PARAMETER   NLOSSGS_P(R,CAS)  NITRATE LOSSES TO GROUND AND SURFACE WATER BY PRODUCTION REGION IN MILLION
TONS;

PARAMETER   NWATCST_L(RL,R,CAS) OFF-SITE VALUE OF REDUCTION IN NITROGEN LOSS TO WATER BY RESOURCE REGION IN
MILLIONS OF DOLLARS;
PARAMETER   NWATCST_P(R,CAS) OFF-SITE VALUE OF REDUCTION IN NITROGEN LOSS TO WATER BY PRODUCTION REGION IN
MILLIONS OF DOLLARS;
PARAMETER   NWATCST_N(CAS)   OFF-SITE VALUE OF REDUCTION IN NITROGEN LOSS TO WATER IN MILLIONS OF DOLLARS;

*NOTE MAY WANT TO PUT IN AN AVERAGE HERE

PARAMETER   PLOSS_L(RL,R,CAS)  PHOSPHATE LOSSES BY MDR IN MILLION TONS;
PARAMETER   PLOSS_P(R,CAS)  PHOSPHATE LOSSES BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   PLOSS_N(CAS) NATIONAL NITRATE LOSSES IN MILLION TONS;
PARAMETER   APLOSS(RL,R,CAS) AVERAGE N LOSS IN POUNDS PER ACRE FOR CROPPED ACRES;

PARAMETER   PLEACH_L(RL,R,CAS) TOTAL PHOSPHATE LEACHED TO GROUNDWATER BY MDR;
PARAMETER   PLEACH_P(   R,CAS) TOTAL PHOSPHATE LEACHED TO GROUNDWATER BY PR;
PARAMETER   PLEACH_N(     CAS) TOTAL PHOSPHATE LEACHED TO GROUNDWATER;
PARAMETER   APLEACH(RL,R,CAS) AVERAGE P LEACHED TO GROUNDWATER BY MDR;

PARAMETER   PSOLN_L(RL,R,CAS) TOTAL PHOSPHATE LOST IN SOLUTION BY MDR;
PARAMETER   PSOLN_P(   R,CAS) TOTAL PHOSPHATE LOST IN SOLUTION BY PR;
PARAMETER   PSOLN_N(     CAS) TOTAL PHOSPHATE LOST IN SOLUTION;
PARAMETER   APSOLN(RL,R,CAS) AVERAGE P LOST IN SOLUTION BY MDR;

PARAMETER   PSEDMNT_L(RL,R,CAS) TOTAL PHOSPHATE LOST IN SEDIMENT BY MDR;
PARAMETER   PSEDMNT_P(   R,CAS) TOTAL PHOSPHATE LOST IN SEDIMENT BY PR;
PARAMETER   PSEDMNT_N(     CAS) TOTAL PHOSPHATE LOST IN SEDIMENT;
PARAMETER   APSEDMNT(RL,R,CAS) AVERAGE P LOST IN SEDIMENT BY MDR;
```

Table 2

List of tables contained in ENVACTGA—continued

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PARAMETER   NUSED_L(RL,R,CAS)  NITRATE USED BY MDR IN MILLION TONS;
PARAMETER   NUSED_P(R,CAS)  NITRATE USED BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   NUSED_N(CAS) NATIONAL NITRATE USED IN MILLION TONS;
PARAMETER   ANUSE_L(RL,R,CAS) AVERAGE N USE POUNDS PER ACRE MDR CROPPED ACRES;
PARAMETER   ANUSE_P(R,CAS) AVERAGE N USE POUNDS PER ACRE FPR CROPPED ACRES;

PARAMETER   PUSED_L(RL,R,CAS)  PHOSPHATE USED BY MDR IN MILLION TONS;
PARAMETER   PUSED_P(R,CAS)  PHOSPHATE USED BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   PUSED_N(CAS) NATIONAL PHOSPHATE USED IN MILLION TONS;
PARAMETER   APUSE_L(RL,R,CAS) AVERAGE P USE POUNDS PER ACRE MDR CROPPED ACRES;
PARAMETER   APUSE_P(R,CAS) AVERAGE P USE POUNDS PER ACRE FPR CROPPED ACRES;

PARAMETER   KUSED_L(RL,R,CAS)  POTASH USED BY MDR IN MILLION TONS;
PARAMETER   KUSED_P(R,CAS)  POTASH USED BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   KUSED_N(CAS) NATIONAL POTASH USED IN MILLION TONS;
PARAMETER   AKUSE_L(RL,R,CAS) AVERAGE K USE POUNDS PER ACRE MDR CROPPED ACRES;
PARAMETER   AKUSE_P(R,CAS) AVERAGE K USE POUNDS PER ACRE FPR CROPPED ACRES;

*PARAMETER   PKLOSS_L(RL,R,CAS) PERCENT K LOSSES PER ACRE FOR CROPPED ACRES;

PARAMETER   R_SDA(R,CAS) regional soil depreciation allowances ;
PARAMETER   N_SDA(CAS) national soil depreciation allowance ;

PARAMETER   ROTACRES_L(B,RL,R,CAS) SUM OF ROTATION ACREAGE BY MDR;
PARAMETER   ROTACRES_P(B,R,CAS) SUM OF ROTACRES BY PRODUCTION REGION;
PARAMETER   ROTACRES_N(B,CAS) SUM OF ROTACRES NATIONALLY;

PARAMETER   ROTACRET_L(B,T,RL,R,CAS) ROT_TIL ACREAGE BY MDR;
PARAMETER   ROTACRET_P(B,T,R,CAS) ROT_TIL ACRES BY PRODUCTION REGION;
PARAMETER   ROTACRET_N(B,T,CAS) ROT_TIL ACRES NATIONALLY;

PARAMETER   ROTACRE_P(T,R,CAS) SUM OF ROT_TIL ACRES BY PRODUCTION REGION;
PARAMETER   ROTACRE_N(T,CAS) SUM OF ROT_TIL ACRES NATIONALLY;

PARAMETER   ALTACRES_L(Y,RL,R,CAS) SUM OF ACREAGE BY MDR AND ALTERNATIVE;
PARAMETER   ALTACRES_P(Y,R,CAS) SUM OF ACRES BY PRODUCTION REGION AND ALTERNATIVE;
PARAMETER   ALTACRES_N(Y,CAS) SUM OF ACRES NATIONALLY AND BY ALTERNATIVE;

PARAMETER   CHEMCOSTP(R,CAS) TOTAL CHEMICAL COSTS BY PR;
PARAMETER   CHEMCOSTN(CAS) TOTAL NATIONAL CHEMICAL COSTS;

PARAMETER   NITCOSTP(R,CAS) TOTAL NITROGEN COSTS BY PR;
PARAMETER   NITCOSTN(CAS) TOTAL NATIONAL NITROGEN COSTS;

PARAMETER   PHOSCOSTP(R,CAS) TOTAL PHOSPHATE COSTS BY PR;
PARAMETER   PHOSCOSTN(CAS) TOTAL NATIONAL PHOSPHATE COSTS;

PARAMETER   POTCOSTP(R,CAS) TOTAL POTASH COSTS BY PR;
PARAMETER   POTCOSTN(CAS) TOTAL POTASH CHEMICAL COSTS;

**NITROGEN
*INPUTS

PARAMETER   BTN_L(RL,R,CAS) BEGINNING TOTAL NITROGEN BY MDR;
PARAMETER   BTN_P(   R,CAS) BEGINNING TOTAL NITROGEN BY PR;
PARAMETER   BTN_N(     CAS) BEGINNING TOTAL NITROGEN;
PARAMETER   BTN_LA(RL,R,CAS) BEGINNING TOTAL NITROGEN PER ACRE BY MDR;
PARAMETER   BTN_PA(R,CAS) BEGINNING TOTAL NITROGEN PER ACRE BY FPR;

PARAMETER   FNH3_L(RL,R,CAS)  AMMONIA FERT BY MDR IN MILLION TONS;
PARAMETER   FNH3_P(R,CAS)  AMMONIA FERT BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   FNH3_N(CAS) NATIONAL AMMONIA FERT IN MILLION TONS;
PARAMETER   FNH3_LA(RL,R,CAS) AMMONIA FERT PER ACRE BY MDR;
PARAMETER   FNH3_PA(R,CAS) AMMONIA FERT PER ACRE BY FPR;

PARAMETER   FNO3_L(RL,R,CAS)  NITRATE FERT BY MDR IN MILLION TONS;
PARAMETER   FNO3_P(R,CAS)  NITRATE FERT BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   FNO3_N(CAS) NATIONAL NITRATE FERT IN MILLION TONS;
PARAMETER   FNO3_LA(RL,R,CAS) NITRATE FERT PER ACRE BY MDR;
PARAMETER   FNO3_PA(R,CAS) NITRATE FERT PER ACRE BY FPR;

PARAMETER   FNTOT_L(RL,R,CAS)  TOTAL N FERT BY MDR IN MILLION TONS;
PARAMETER   FNTOT_P(R,CAS)  TOTAL N FERT BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   FNTOT_N(CAS) NATIONAL TOTAL N FERT IN MILLION TONS;
PARAMETER   FNTOT_LA(RL,R,CAS) TOTAL N FERT PER ACRE BY MDR;
PARAMETER   FNTOT_PA(R,CAS) TOTAL N FERT PER ACRE BY FPR;
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Table 2

List of tables contained in ENVACTGA—continued

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PARAMETER   FX_L(RL,R,CAS)  NITROGEN FIXED BY MDR IN MILLION TONS;
PARAMETER   FX_P(R,CAS)  NITROGEN FIXED BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   FX_N(CAS) NATIONAL NITROGEN FIXED IN MILLION TONS;
PARAMETER   FX_LA(RL,R,CAS) NITROGEN FIXED PER ACRE BY MDR;
PARAMETER   FX_PA(R,CAS) NITROGEN FIXED PER ACRE BY FPR;

PARAMETER   RN_L(RL,R,CAS) NITROGEN IN RAIN BY MDR;
PARAMETER   RN_P(   R,CAS) NITROGEN IN RAIN BY PR;
PARAMETER   RN_N(     CAS) NITROGEN IN RAIN;
PARAMETER   RN_LA(RL,R,CAS) NITROGEN IN RAIN PER ACRE BY MDR;
PARAMETER   RN_PA(R,CAS) NITROGEN IN RAIN PER ACRE BY FPR;

*OUTPUTS

PARAMETER   YLN_L(RL,R,CAS) NITROGEN IN CROP YIELD BY MDR;
PARAMETER   YLN_P(   R,CAS) NITROGEN IN CROP YIELD BY PR;
PARAMETER   YLN_N(     CAS) NITROGEN IN CROP YIELD;
PARAMETER   YLN_LA(RL,R,CAS) NITROGEN IN CROP YIELD PER ACRE BY MDR;
PARAMETER   YLN_PA(R,CAS) NITROGEN IN CROP YIELD PER ACRE BY FPR;

PARAMETER   TFO_L(RL,R,CAS) NITROGEN IN CROP RESIDUE BY MDR;
PARAMETER   TFO_P(   R,CAS) NITROGEN IN CROP RESIDUE BY PR;
PARAMETER   TFO_N(     CAS) NITROGEN IN CROP RESIDUE;
PARAMETER   TFO_LA(RL,R,CAS) NITROGEN IN CROP RESIDUE PER ACRE BY MDR;
PARAMETER   TFO_PA(R,CAS) NITROGEN IN CROP RESIDUE PER ACRE BY FPR;

PARAMETER   PRKN_L(RL,R,CAS) NITROGEN LEACHED BY MDR;
PARAMETER   PRKN_P(   R,CAS) NITROGEN LEACHED BY PR;
PARAMETER   PRKN_N(     CAS) NITROGEN LEACHED;
PARAMETER   PRKN_LA(RL,R,CAS) NITROGEN LEACHED PER ACRE BY MDR;
PARAMETER   PRKN_PA(R,CAS) NITROGEN LEACHED PER ACRE BY FPR;

PARAMETER   YNO3_L(RL,R,CAS) NITRATE IN SOLUTION BY MDR;
PARAMETER   YNO3_P(   R,CAS) NITRATE IN SOLUTION BY PR;
PARAMETER   YNO3_N(     CAS) NITRATE IN SOLUTION;
PARAMETER   YNO3_LA(RL,R,CAS) NITRATE IN SOLUTION PER ACRE BY MDR;
PARAMETER   YNO3_PA(R,CAS) NITRATE IN SOLUTION PER ACRE BY FPR;

PARAMETER   YON_L(RL,R,CAS) ORGANIC NITROGEN IN SEDIMENT BY MDR;
PARAMETER   YON_P(   R,CAS) ORGANIC NITROGEN IN SEDIMENT BY PR;
PARAMETER   YON_N(     CAS) ORGANIC NITROGEN IN SEDIMENT;
PARAMETER   YON_LA(RL,R,CAS) ORGANIC NITROGEN IN SEDIMENT PER ACRE BY MDR;
PARAMETER   YON_PA(R,CAS) ORGANIC NITROGEN IN SEDIMENT PER ACRE BY FPR;

PARAMETER   SSFN_L(RL,R,CAS) NITRATE IN SUBSURFACE FLOW BY MDR;
PARAMETER   SSFN_P(   R,CAS) NITRATE IN SUBSURFACE FLOW BY PR;
PARAMETER   SSFN_N(     CAS) NITRATE IN SUBSURFACE FLOW;
PARAMETER   SSFN_LA(RL,R,CAS) NITRATE IN SUBSURFACE FLOW PER ACRE BY MDR;
PARAMETER   SSFN_PA(R,CAS) NITRATE IN SUBSURFACE FLOW PER ACRE BY FPR;

PARAMETER   DN_L(RL,R,CAS) DENITRIFICATION BY MDR;
PARAMETER   DN_P(   R,CAS) DENITRIFICATION BY PR;
PARAMETER   DN_N(     CAS) DENITRIFICATION NATIONAL;
PARAMETER   DN_LA(RL,R,CAS) DENITRIFICATION PER ACRE BY MDR;
PARAMETER   DN_PA(R,CAS) DENITRIFICATION PER ACRE BY FPR;

PARAMETER   AVOL_L(RL,R,CAS) NITROGEN VOLITILIZATION BY MDR;
PARAMETER   AVOL_P(   R,CAS) NITROGEN VOLITILIZATION BY PR;
PARAMETER   AVOL_N(     CAS) NITROGEN VOLITILIZATION;
PARAMETER   AVOL_LA(RL,R,CAS) NITROGEN VOLITILIZATION PER ACRE BY MDR;
PARAMETER   AVOL_PA(R,CAS) NITROGEN VOLITILIZATION PER ACRE BY FPR;

PARAMETER   AIRN_L(RL,R,CAS) NITROGEN LOST TO ATMOSPHERE BY MDR;
PARAMETER   AIRN_P(   R,CAS) NITROGEN LOST TO ATMOSPHERE BY PR;
PARAMETER   AIRN_N(     CAS) NITROGEN LOST TO ATMOSPHERE;
PARAMETER   AIRN_LA(RL,R,CAS) NITROGEN LOST TO ATMOSPHERE PER ACRE BY MDR;
PARAMETER   AIRN_PA(R,CAS) NITROGEN LOST TO ATMOSPHERE PER ACRE BY FPR;

PARAMETER   WATN_L(RL,R,CAS) NITROGEN LOST TO WATER BY MDR;
PARAMETER   WATN_P(   R,CAS) NITROGEN LOST TO WATER BY PR;
PARAMETER   WATN_N(     CAS) NITROGEN LOST TO WATER;
PARAMETER   WATN_LA(RL,R,CAS) NITROGEN LOST TO WATER PER ACRE BY MDR;
PARAMETER   WATN_PA(R,CAS) NITROGEN LOST TO WATER PER ACRE BY FPR;

PARAMETER   FTN_L(RL,R,CAS) FINAL TOTAL NITROGEN BY MDR;
PARAMETER   FTN_P(   R,CAS) FINAL TOTAL NITROGEN BY PR;
PARAMETER   FTN_N(     CAS) FINAL TOTAL NITROGEN;
PARAMETER   FTN_LA(RL,R,CAS) FINAL TOTAL NITROGEN PER ACRE BY MDR;
PARAMETER   FTN_PA(R,CAS) FINAL TOTAL NITROGEN PER ACRE BY FPR;
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Table 2
List of tables contained in ENVACTGA—continued

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*BALANCES

PARAMETER   NBAL_L(RL,R,CAS) EPIC NITROGEN BALANCE BY MDR;
PARAMETER   NBAL_P(   R,CAS) EPIC NITROGEN BALANCE BY PR;
PARAMETER   NBAL_N(     CAS) EPIC NIROGEN BALANCE;
PARAMETER   NBAL_LA(RL,R,CAS) EPIC NITROGEN BALANCE PER ACRE BY MDR;
PARAMETER   NBAL_PA(R,CAS) EPIC NITROGEN BALANCE PER ACRE BY FPR;

PARAMETER   XNBAL_L(RL,R,CAS) EXCESS NITROGEN BALANCE BY MDR;
PARAMETER   XNBAL_P(   R,CAS) EXCESS NITROGEN BALANCE BY PR;
PARAMETER   XNBAL_N(     CAS) EXCESS NIROGEN BALANCE;
PARAMETER   XNBAL_LA(RL,R,CAS) EXCESS NITROGEN BALANCE PER ACRE BY MDR;
PARAMETER   XNBAL_PA(R,CAS) EXCESS NITROGEN BALANCE PER ACRE BY FPR;

**PHOSPHOROUS
*INPUT
PARAMETER   BTP_L(RL,R,CAS) BEGINNING TOTAL PHOSPHOROUS BY MDR;
PARAMETER   BTP_P(   R,CAS) BEGINNING TOTAL PHOSPHOROUS BY PR;
PARAMETER   BTP_N(     CAS) BEGINNING TOTAL PHOSPHOROUS;
PARAMETER   BTP_LA(RL,R,CAS) BEGINNING TOTAL PHOSPHOROUS PER ACRE BY MDR;
PARAMETER   BTP_PA(R,CAS) BEGINNING TOTAL PHOSPHOROUS PER ACRE BY FPR;

PARAMETER   PLAB_L(RL,R,CAS)  LABILE PHOSPHORUS BY MDR IN MILLION TONS;
PARAMETER   PLAB_P(R,CAS)  LABILE PHOSPHORUS BY PRODUCTION REGION IN MILLION TONS;
PARAMETER   PLAB_N(CAS) LABILE PHOSPHORUS IN MILLION TONS;
PARAMETER   PLAB_LA(RL,R,CAS) LABILE PHOSPHORUS PER ACRE BY MDR;
PARAMETER   PLAB_PA(R,CAS) LABILE PHOSPHORUS PER ACRE BY FPR;

*OUTPUTS

PARAMETER   YLP_L(RL,R,CAS) PHOSPHOROUS IN CROP YIELD BY MDR;
PARAMETER   YLP_P(   R,CAS) PHOSPHOROUS IN CROP YIELD BY PR;
PARAMETER   YLP_N(     CAS) PHOSPHOROUS IN CROP YIELD;
PARAMETER   YLP_LA(RL,R,CAS) PHOSPHOROUS IN CROP YIELD PER ACRE BY MDR;
PARAMETER   YLP_PA(R,CAS) PHOSPHOROUS IN CROP YIELD PER ACRE BY FPR;

PARAMETER   PRKP_L(RL,R,CAS) PHOSPHOROUS LEACHED BY MDR;
PARAMETER   PRKP_P(   R,CAS) PHOSPHOROUS LEACHED BY PR;
PARAMETER   PRKP_N(     CAS) PHOSPHOROUS LEACHED;
PARAMETER   PRKP_LA(RL,R,CAS) PHOSPHOROUS LEACHED PER ACRE BY MDR;
PARAMETER   PRKP_PA(R,CAS) PHOSPHOROUS LEACHED PER ACRE BY FPR;

PARAMETER   YAP_L(RL,R,CAS) PHOSPHOROUS IN SOLUTION BY MDR;
PARAMETER   YAP_P(   R,CAS) PHOSPHOROUS IN SOLUTION BY PR;
PARAMETER   YAP_N(     CAS) PHOSPHOROUS IN SOLUTION;
PARAMETER   YAP_LA(RL,R,CAS) PHOSPHOROUS IN SOLUTION PER ACRE BY MDR;
PARAMETER   YAP_PA(R,CAS) PHOSPHOROUS IN SOLUTION PER ACRE BY FPR;

PARAMETER   YP_L(RL,R,CAS) PHOSPHOROUS IN SEDIMENT BY MDR;
PARAMETER   YP_P(   R,CAS) PHOSPHOROUS IN SEDIMENT BY PR;
PARAMETER   YP_N(     CAS) PHOSPHOROUS IN SEDIMENT;
PARAMETER   YP_LA(RL,R,CAS) PHOSPHOROUS IN SEDIMENT PER ACRE BY MDR;
PARAMETER   YP_PA(R,CAS) PHOSPHOROUS IN SEDIMENT PER ACRE BY FPR;

PARAMETER   WATP_L(RL,R,CAS) PHOSPHOROUS LOST TO WATER BY MDR;
PARAMETER   WATP_P(   R,CAS) PHOSPHOROUS LOST TO WATER BY PR;
PARAMETER   WATP_N(     CAS) PHOSPHOROUS LOST TO WATER;
PARAMETER   WATP_LA(RL,R,CAS) PHOSPHOROUS LOST TO WATER PER ACRE BY MDR;
PARAMETER   WATP_PA(R,CAS) PHOSPHOROUS LOST TO WATER PER ACRE BY FPR;

PARAMETER   FTP_L(RL,R,CAS) FINAL TOTAL PHOSPHOROUS BY MDR;
PARAMETER   FTP_P(   R,CAS) FINAL TOTAL PHOSPHOROUS BY PR;
PARAMETER   FTP_N(     CAS) FINAL TOTAL PHOSPHOROUS;
PARAMETER   FTP_LA(RL,R,CAS) FINAL TOTAL PHOSPHOROUS PER ACRE BY MDR;
PARAMETER   FTP_PA(R,CAS) FINAL TOTAL PHOSPHOROUS PER ACRE BY FPR;

*BALANCES

PARAMETER   PBAL_L(RL,R,CAS) EPIC PHOSPHOROUS BALANCE BY MDR;
PARAMETER   PBAL_P(   R,CAS) EPIC PHOSPHOROUS BALANCE BY PR;
PARAMETER   PBAL_N(     CAS) EPIC PHOSPHOROUS BALANCE;
PARAMETER   PBAL_LA(RL,R,CAS) EPIC PHOSPHOROUS BALANCE PER ACRE BY MDR;
PARAMETER   PBAL_PA(R,CAS) EPIC PHOSPHOROUS BALANCE PER ACRE BY FPR;

PARAMETER   XPLBAL_L(RL,R,CAS) EXCESS LABILE PHOSPHOROUS BALANCE BY MDR;
PARAMETER   XPLBAL_P(   R,CAS) EXCESS LABILE PHOSPHOROUS BALANCE BY PR;
PARAMETER   XPLBAL_N(     CAS) EXCESS LABILE PHOSPHOROUS BALANCE;
PARAMETER   XPLBAL_LA(RL,R,CAS) EXCESS LABILE PHOSPHOROUS BALANCE PER ACRE BY MDR;
PARAMETER   XPLBAL_PA(R,CAS) EXCESS LABILE PHOSPHOROUS BALANCE PER ACRE BY FPR;
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Table 2

List of tables contained in ENVACTGA—continued

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PARAMETER   XPFBAL_L(RL,R,CAS) EXCESS FERT. PHOSPHOROUS BALANCE BY MDR;
PARAMETER   XPFBAL_P(   R,CAS) EXCESS FERT. PHOSPHOROUS BALANCE BY PR;
PARAMETER   XPFBAL_N(     CAS) EXCESS FERT. PHOSPHOROUS BALANCE;
PARAMETER   XPFBAL_LA(RL,R,CAS) EXCESS FERT. PHOSPHOROUS BALANCE PER ACRE BY MDR;
PARAMETER   XPFBAL_PA(R,CAS) EXCESS FERT. PHOSPHOROUS BALANCE PER ACRE BY FPR;
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Table 3

DEMSUP: commodity demand and supply data

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PARAMETER DEMSUP        COMMODITY DEMAND AND SUPPLY DATA

                       PBASE       QBASE        ELAS         MIN         MAX
CORN      .SCB         2.600     917.000
CORN      .PRDN        2.600   11235.000
CORN      .IMP         2.600      10.000       0.201
CORN      .DOM         2.600    1715.800      -0.070
CORN      .PRPC                 6904.200
CORN      .EXP         2.600    2675.000      -0.530
CORN      .SGE         1.890
CORN      .SCE         2.600     867.000      -0.800
SORGHUM   .SCB         2.350      71.000
SORGHUM   .PRDN        2.350     670.000
SORGHUM   .IMP         2.350
SORGHUM   .DOM         2.350      80.000      -0.840
SORGHUM   .PRPC                  280.000
SORGHUM   .EXP         2.350     315.000      -1.170
SORGHUM   .SGE         1.660
SORGHUM   .SCE         2.350      66.000      -0.440
BARLEY    .SCB         2.400     107.000
BARLEY    .PRDN        2.400     365.000
BARLEY    .IMP         2.400      55.000       0.201
BARLEY    .DOM         2.400     172.000      -0.260
BARLEY    .PRPC                  175.000
BARLEY    .EXP         2.400      14.000      -0.650
BARLEY    .EEP         0.859      56.000      -0.650
BARLEY    .SGE         1.570
BARLEY    .SCE         2.400     110.000      -0.810
OATS      .SCB         1.450      56.000
OATS      .PRDN        1.450     150.000
OATS      .IMP         1.450     125.000       0.201
OATS      .DOM         1.450      78.000      -0.100
OATS      .PRPC                  195.000
OATS      .EXP         1.450       2.000      -0.650
OATS      .SGE         1.090
OATS      .SCE         1.450      56.000      -1.530
WHEAT     .SCB         3.700     591.000
WHEAT     .PRDN        3.700    2545.000
WHEAT     .IMP         3.700     115.000       0.201
WHEAT     .DOM         3.700    1131.000      -0.090
WHEAT     .PRPC                  225.000
WHEAT     .EXP         3.700     491.362      -1.440
WHEAT     .EEP         2.816     833.638      -1.440
WHEAT     .SGE         2.580
WHEAT     .SCE         3.700     570.000      -0.370
RICE      .SCB         7.710      27.160
RICE      .PRDN        7.710     194.200
RICE      .IMP         7.710      13.120       0.201
RICE      .DOM         7.710     153.100      -0.330
RICE      .PRPC                    0.000
RICE      .EXP         7.710      52.202      -2.410
RICE      .EEP         5.344       2.298      -2.410
RICE      .SGE         6.500
RICE      .SCE         7.710      26.880      -0.630
SOYBEANS  .SCB         6.300     225.000
SOYBEANS  .PRDN        6.300    3245.000
SOYBEANS  .IMP         6.300      10.000       0.201
SOYBEANS  .DOM         6.300     189.600      -0.380
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Table 3

DEMSUP: commodity demand and supply data—continued

```
PARAMETER DEMSUP        COMMODITY DEMAND AND SUPPLY DATA

                      PBASE       QBASE        ELAS         MIN         MAX

SOYBEANS  .PRPC                1995.000
SOYBEANS  .EXP        6.300    1070.000      -0.730
SOYBEANS  .SGE        5.070
SOYBEANS  .SCE        6.300     225.400      -6.670
COTTON    .SGB                    2.500
COTTON    .SCB      312.000       1.759
COTTON    .PRDN     312.000      17.500
COTTON    .IMP      312.000       0.025       0.201
COTTON    .DOM      312.000       9.300      -1.020
COTTON    .PRPC                   0.005
COTTON    .EXP      312.000       8.300      -1.260
COTTON    .SGE      249.600       2.500
COTTON    .SCE      312.000       1.679      -0.890
SILAGE    .PRDN      20.000      51.771
SILAGE    .DOM       20.000      51.771      -5.000                 517.713
HAY       .PRDN      59.600     160.190
HAY       .DOM       59.600      84.533      -5.000                 845.330
OTHRLVSTK .PRDN     209.720       9.000
OTHRLVSTK .DOM      209.720       9.000      -0.201
EGGS      .SCB        0.684       5.000
EGGS      .PRDN       0.684    7586.570
EGGS      .IMP        0.684       5.000       0.201
EGGS      .DOM        0.684    7401.570      -0.720
EGGS      .EXP        0.684     190.000      -0.601
EGGS      .SCE        0.684       5.000      -0.201
BROILERS  .SCB        0.356     880.000
BROILERS  .PRDN       0.356   34942.970
BROILERS  .DOM        0.356   29246.970      -0.020
BROILERS  .EXP        0.356    5700.000      -0.601
BROILERS  .SCE        0.356     880.000      -0.201
TURKEY    .SCB        0.385     275.000
TURKEY    .PRDN       0.385    5950.010
TURKEY    .DOM        0.385    5456.010      -0.030
TURKEY    .EXP        0.385     495.000      -0.601
TURKEY    .SCE        0.385     275.000      -0.201
FLUIDMLK  .PRDN       0.135   93462.600
FLUIDMLK  .DOM        0.135   93462.600      -0.260
MFGMILK   .PRDN      11.980     884.600
MFGMILK   .DOM       11.980
MFGMILK   .PRPC      11.980     884.600
BUTTER    .SCB        1.072      58.250
BUTTER    .PRDN       1.072    1360.300
BUTTER    .IMP        1.072       6.180       0.201
BUTTER    .DOM        1.072    1349.220      -0.470
BUTTER    .EXP        1.072       0.010      -0.601
BUTTER    .SGE        1.072
BUTTER    .SCE        1.072      75.500      -0.201
BUTTER    .SGV        1.072     442.800
BUTTER    .SGD        1.072
BUTTER    .SGX        1.072
NFDMILK   .SCB        1.014     114.600
NFDMILK   .PRDN       1.014     879.000
NFDMILK   .IMP        1.014       1.150       0.201
NFDMILK   .DOM        1.014     933.740      -1.490
NFDMILK   .EXP        1.014       0.010      -0.601
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Table 3

DEMSUP: commodity demand and supply data—continued

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PARAMETER DEMSUP        COMMODITY DEMAND AND SUPPLY DATA

                      PBASE       QBASE        ELAS         MIN         MAX

NFDMILK   .SGE        1.014
NFDMILK   .SCE        1.014      61.000      -0.201
NFDMILK   .SGV        1.014     279.000
NFDMILK   .SGD        1.014
NFDMILK   .SGX        1.014
AMCHEESE  .SCB        1.343     435.100
AMCHEESE  .PRDN       1.343    2776.900
AMCHEESE  .IMP        1.343      21.060       0.201
AMCHEESE  .DOM        1.343    2837.550      -0.390
AMCHEESE  .EXP        1.343       0.010      -0.601
AMCHEESE  .SGE        1.343
AMCHEESE  .SCE        1.343     395.500      -0.201
AMCHEESE  .SGV        1.343      81.600
AMCHEESE  .SGD        1.343
AMCHEESE  .SGX        1.343
OTCHEESE  .SCB        1.608     107.500
OTCHEESE  .PRDN       1.608    3229.300
OTCHEESE  .IMP        1.608     200.200       0.201
OTCHEESE  .DOM        1.608    3438.090      -0.390
OTCHEESE  .EXP        1.608       0.010      -0.601
OTCHEESE  .SCE        1.608      98.900      -0.201
ICECREAM  .PRDN       1.381    1193.100
ICECREAM  .IMP        1.381       5.710       0.201
ICECREAM  .DOM        1.381    1198.800      -0.330
EVDRYMLK  .SCB        0.615      70.000
EVDRYMLK  .PRDN       0.615     671.100
EVDRYMLK  .IMP        0.615       5.270       0.201
EVDRYMLK  .DOM        0.615     643.060      -1.490
EVDRYMLK  .EXP        0.615       0.010      -0.601
EVDRYMLK  .SCE        0.615     103.300      -0.201
ETHSOA    .PRDN       1.760
ETHSOA    .DOM        1.760
CLDARYCF  .PRDN      58.880
CLDARYCF  .DOM       58.880
CLDARYCW  .PRDN     518.400
CLDARYCW  .DOM      518.400
MILK      .PRDN      14.300    1794.900
MILK      .IMP       14.300      26.000       0.201
MILK      .DOM       14.300      20.000                  20.000      20.000
MILK      .PRPC      14.300    1800.900
FEEDERPIG .PRDN      72.042
FEEDERPIG .DOM       72.042
CULLSOW   .PRDN      36.023
CULLSOW   .DOM       36.023
HOGSLAUGH .PRDN      41.300
HOGSLAUGH .IMP       41.300       2.297       0.201
HOGSLAUGH .DOM       41.300
HOGSLAUGH .EXP       41.300       0.557      -0.201
LIVCALF   .PRDN      99.340
LIVCALF   .IMP       99.340       4.358       0.201
LIVCALF   .DOM       99.340
BFYRLINGS .PRDN      84.410
BFYRLINGS .IMP       84.410      10.256       0.201
BFYRLINGS .DOM       84.410
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Table 3

DEMSUP: commodity demand and supply data—continued

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PARAMETER DEMSUP        COMMODITY DEMAND AND SUPPLY DATA

                      PBASE       QBASE        ELAS         MIN         MAX

BFYRLINGS .EXP       84.410       0.896      -0.201
CALFSLA   .PRDN      85.392
CALFSLA   .DOM       85.392
CLBFCOW   .PRDN      53.262
CLBFCOW   .DOM       53.262
CLBULLSTAG.PRDN      53.262
CLBULLSTAG.DOM       53.262
NONFDSL   .PRDN      53.262
NONFDSL   .IMP       53.262       0.420       0.201
NONFDSL   .DOM       53.262
FEDSLA    .PRDN      77.650
FEDSLA    .IMP       77.650       0.050       0.201
FEDSLA    .DOM       77.650
FEDSLA    .EXP       77.650       0.050      -0.201
FEDSLACF  .PRDN      77.650
FEDSLACF  .DOM       77.650
BEANMEAL  .SCB        9.360       5.000
BEANMEAL  .PRDN       8.140     947.000
BEANMEAL  .IMP        8.250       2.000       0.201
BEANMEAL  .DOM        8.250
BEANMEAL  .PRPC                 768.000
BEANMEAL  .EXP        8.140     181.000      -1.020
BEANMEAL  .SCE        8.140       5.000      -0.210
BEANOIL   .SCB       15.400      16.150
BEANOIL   .PRDN      15.400     228.400
BEANOIL   .IMP       19.000       1.150       0.201
BEANOIL   .DOM       15.400     206.426      -0.460
BEANOIL   .PRPC                  -6.426
BEANOIL   .EXP       15.400      29.000      -1.340
BEANOIL   .SCE       15.400      16.700      -0.260
OOSMEAL   .PRDN       8.250      40.120       0.801      30.000      50.000
OOSMEAL   .PRPC                  40.120
ANPROTEIN .PRDN       8.250      72.280       0.801      65.000     100.000
ANPROTEIN .PRPC                  72.280
HIPROFEED .DOM        8.250
FEDBEEF   .SCB      334.000       1.889
FEDBEEF   .PRDN     334.000     152.219
FEDBEEF   .IMP      334.000       0.010       0.201
FEDBEEF   .DOM      334.000     133.944      -0.480
FEDBEEF   .EXP      334.000      18.295      -0.601
FEDBEEF   .SCE      334.000       1.889      -0.201
NONFDBEEF .SCB      243.820       0.630
NONFDBEEF .PRDN     243.820      21.470
NONFDBEEF .IMP      243.820      20.182       0.201
NONFDBEEF .DOM      243.820      41.652      -0.480
NONFDBEEF .SCE      243.820       0.630      -0.201
VEAL      .SCB      484.300       0.033
VEAL      .PRDN     484.300       1.527
VEAL      .IMP      484.300       0.000       0.201
VEAL      .DOM      484.300       1.527      -3.120
VEAL      .EXP      484.300       0.060      -0.601
VEAL      .SCE      484.300       0.033      -0.201
PORK      .SCB      263.000       5.225
PORK      .PRDN     263.000     189.817
```

Table 3

DEMSUP: commodity demand and supply data—continued

```
PARAMETER DEMSUP        COMMODITY DEMAND AND SUPPLY DATA

                      PBASE       QBASE        ELAS         MIN         MAX

PORK      .IMP      263.000      10.450       0.201
PORK      .DOM      263.000     185.780      -0.070
PORK      .EXP      263.000      14.487      -0.601
PORK      .SCE      263.000       5.225      -0.201
CORNOIL   .PRDN      20.180
CORNOIL   .DOM       20.180T
GLUTMEAL  .SGB       12.830      25.035
GLUTMEAL  .PRDN      12.829       8.997
GLUTMEAL  .IMP       12.829       0.049       0.201                   0.050
GLUTMEAL  .DOM       12.829
GLUTMEAL  .PRPC                   6.681
GLUTMEAL  .EXP       12.829      27.400      -2.500                  90.000
GLUTFEED  .SGB        5.040     127.537
GLUTFEED  .PRDN       5.041      45.832
GLUTFEED  .IMP        5.041       0.462       0.201                   0.470
GLUTFEED  .DOM        5.041
GLUTFEED  .EXP        5.041     173.828      -3.500                 300.000
DDG       .SGB        6.220       7.157
DDG       .PRDN       6.218      24.483
DDG       .DOM        6.218
DDG       .PRPC                  14.364
DDG       .EXP        9.370      17.276      -3.500                 300.000
ETHANOL   .PRDN       1.760    1212.500
ETHANOL   .DOM        1.760    1212.500                1212.000    1212.500
CARBON    .DOM        0.010    1000.000
```

Table 4

Regional production input supply data

	PBASE	QBASE	ELAS	MAXIMUM
NT.CROPLAND	38.000	14.704	0.300	17.000
NT.PASTURE	21.830	2.144	0.600	6.800
LA.CROPLAND	51.000	39.253	0.300	45.000
LA.PASTURE	21.410	3.858	0.600	11.800
CB.CROPLAND	82.000	101.700	0.300	100.400
CB.PASTURE	27.860	17.391	0.600	30.800
CB.AUM		17.391		30.800
NP.CROPLAND	36.000	69.603	0.300	106.900
NP.PASTURE	10.190		5.000	
NP.AUM		132.550		132.550
AP.CROPLAND	46.000	19.690	0.300	30.400
AP.PASTURE	22.650	13.547	0.600	20.600
SE.CROPLAND	43.000	8.408	0.300	20.400
SE.PASTURE	20.300	10.807	0.600	24.600
DL.CROPLAND	43.000	18.419	0.300	24.900
DL.PASTURE	16.960	7.953	0.600	28.600
SP.CROPLAND	24.000	33.162	0.300	54.600
SP.PASTURE	7.380		5.000	
SP.AUM		216.580		216.580
MN.CROPLAND	40.000	24.614	0.300	43.900
MN.PASTURE	11.020		5.000	
MN.AUM		288.760		288.760
PA.CROPLAND	94.000	8.619	0.300	25.400
PA.PASTURE	29.360		5.000	
PA.AUM		73.000		73.000

Table 5

Supply elasticities for crops used in REAP

```
TABLE PES(B,*) DIRECT PRICE ELASTICITY OF SUPPLY

                        PLNT      HARV     PRDN

           CORN         .38       .37      .33

           SORGHUM      .51       .48      .50

           BARLEY       .34       .32      .32

           OATS         .15       .16      .24

           WHEAT        .29       .29      .23

           RICE         .40       .37      .35

           SOYBEANS     .25       .25      .27

           COTTON       .56       .54      .73

           SILAGE       .2        .2       .17

           HAY          .2        .2       .17

           ;
```

Table 6

Supply elasticities for livestock used in REAP

```
TABLE PESL(B,P,*) PRICE ELASTICITY OF SUPPLY

                        PRDN      NAAF                <<4/

 FEEDLOT .FEDSLA          .32      .7271              <<1/

 CFEEDLOT.FEDSLA          .32      .7271

*UFEEDLOT.FEDSLA          .32      .7271

 BFCOWEN .BFYRLINGS       .32      .7271              <<1/

 BFCOWCF .BFYRLINGS       .32      .7271

 FAROFIN .HOGSLAUGH       .38      .4019              <<2/

 FEEDRPIG.FEEDERPIG       .38      .4019

 PIGFIN  .HOGSLAUGH       .38      .4019

 DAIRY   .MILK            .11      .9936              <<3/

 EGGS    .EGGS            .11     1.0                 <<5/

 BROILERS.BROILERS        .10     1.0

 TURKEY  .TURKEY          .10     1.0

 ;
```

Table 7

Demand and supply function active combo map

	SGB	SCB	PRDN	IMP	RESS	DOM	PRPC	EXP	EEP	SGE	SCE	RESD
CORN		YES		YES	YES	YES		YES		YES	YES	YES
SORGHUM		YES			YES	YES		YES		YES	YES	YES
BARLEY		YES		YES	YES	YES		YES	YES	YES	YES	YES
OATS		YES		YES	YES	YES		YES		YES	YES	YES
WHEAT		YES		YES	YES	YES		YES	YES	YES	YES	YES
RICE		YES		YES	YES	YES		YES	YES	YES	YES	YES
SOYBEANS		YES		YES	YES	YES		YES		YES	YES	YES
COTTON		YES		YES	YES	YES		YES		YES	YES	YES
SILAGE						YES						
HAY						YES						
OTHRLVSTK						YES						
EGGS		YES		YES		YES		YES			YES	
BROILERS		YES				YES		YES			YES	
TURKEY		YES				YES		YES			YES	
FLUIDMLK						YES						
MFGMILK							YES					
BUTTER		YES		YES		YES		YES		YES	YES	
NFDMILK		YES		YES		YES		YES		YES	YES	
AMCHEESE		YES		YES		YES		YES		YES	YES	
OTCHEESE		YES		YES		YES		YES			YES	
ICECREAM				YES		YES						
EVDRYMLK		YES		YES		YES		YES			YES	
MILK				YES		YES	YES					
HOGSLAUGH				YES				YES				
LIVCALF				YES								
BFYRLINGS				YES				YES				

Table 7

Demand and supply function active combo map—continued

	SGB	SCB	PRDN	IMP	RESS	DOM	PRPC	EXP	EEP	SGE	SCE	RESD
NONFDSL				YES								
FEDSLA				YES				YES				
BEANMEAL		YES		YES	YES			YES			YES	YES
BEANOIL		YES		YES		YES		YES			YES	
OOSMEAL			YES									
ANPROTEIN			YES									
FEDBEEF		YES		YES		YES		YES			YES	
NONFDBEEF		YES		YES		YES					YES	
VEAL		YES		YES		YES		YES			YES	
PORK		YES		YES		YES		YES			YES	
GLUTMEAL	YES			YES				YES				
GLUTFEED	YES			YES				YES				
DDG	YES							YES				
ETHANOL						YES						

Table 8

List of tables contained in A1A0RPT00.GMS

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$STITLE REAP REPORT MODULE:  DECLARATIONS AND HST SPECS

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*
*   REPORT MODULE DECLARATIONS AND HST SPECS
*
* ------------------------------------------------------------------------------
PARAMETER SUPC(P,CAS,*)               CROP PRODUCT SUPPLY AND USE: BASE DATA AND SOLUTION
          SUPL(P,CAS,*)               LIVESTOCK PRODUCT SUPPLY AND USE: BASE DATA AND SOLUTION
          SUPX(P,CAS,*)               PROCESSED PRODUCT SUPPLY AND USE: BASE DATA AND SOLUTION

          XACTL(B,G,H,Y,T,U,UR,CAS)   OPTIMAL PRODUCTION ACTIVITY USE LEVELS: UNSCALED
          XFCTL(B,G,H,Y,T,U,UR,CAS)   SUM OF XACTL & FACTL & AACTL
          XACTM(B,G,H,Y,T,U,UR,CAS)   SHADOW PRICES (MARGINALS) ON PRODUCTION ACTIVITIES
          XACTSL(B,G,H,Y,T,U,UR,CAS)  OPTIMAL PRODUCTION ACTIVITY SUPPLY LEVELS: UNSCALED
          YACTL(C,CAS)                OPTIMAL PROCESSING ACTIVITY LEVELS: UNSCALED
          RIR(IR,*,*,U)               REGIONAL INPUT PRICE AND USE: BASE DATA AND SOLUTION

          PROCINC(*,*,C)              REVENUE  COST  INCOME PER UNIT OF AN ACTIVITY - PROCESSING
          FEEDU(FCCAT,CAS,*,IO)       FEED AND COPRODUCT USE BY ANIMAL TYPE OR INDUSTRY
          INCOME(INCITEMS,*,UR)       INCOME ACCOUNTING TABLE

          CRPVALUES(*,*,R)            ENDOGENOUS AND EXOGENOUS CRP VALUES
          EEPVALUES(P,*,*)            ENDOGENOUS AND EXOGENOUS EEP VALUES

          EXPEN(P,CAS,Q)              GOVERNMENT PROGRAM EXPENDITURES

          SRPC(P,*,U)                 CROP PRODUCTION BY REGION
          SRPL(P,*,U)                 LIVESTOCK PRODUCTION BY REGION

          ACPNP(P,UR)                TEMPORARY ARRAY
          PPMK(IO)                   COMMODITY MARKET PRICES FOR PART & NONPARTIC.

* ------------------------------------------------------------------------------
* ACREAGE TABLES AND DEFICIENCY PAYMENTS, HISTORICAL DATA
* ------------------------------------------------------------------------------

PARAMETER ACTOTPC(  P,*,U)       TOTAL ACRES PLANTED BY CROP AND REGION (MIL. AC.)
          YIELDTPC( P,*,U)       YIELD PER ACRE BY CROP AND REGION
          PFCPMT(   P,*,U)       PRODUCTION FLEXIBILITY CONTRACT PAYMENTS BY CROP AND REGION
       (MIL. DOL.)
          ACIRRPC(  P,*,U)       IRRIGATED ACRES PLANTED BY CROP AND REGION (MIL. AC.)
          ACDRYPC(  P,*,U)       DRYLAND ACRES PLANTED BY CROP AND REGION (MIL. AC.)
          ACSADPC(  P,*,U)       ACRES SET-ASIDE AND DIVERTED BY CROP AND REGION (MIL. AC.)
          NCHG                   PERCENTAGE INCREASE IN NITROGEN FERT PRICE
          PCHG                   PERCENTAGE INCREASE IN PHOSPHAT FERT PRICE
          KCHG                   PERCENTAGE INCREASE IN POTASH FERT PRICE
          CSVPMT(B,G,H,Y,T,U,UR) CONSERVATION PAYMENT TO PRODUCTION ACTIVITY PER ACRE
          GGRPMT(    P,*,U)      GOVERNMENT ENVIRONMENTAL PAYMENTS (MIL DOL)
          GPR(U,CAS)             TOTAL GOVERNMENT GREEN PAYMENTS RECEIVED BY FARMERS BY REGION
       (MIL DOL)
          DAMAGE(U)              ENVIRONMENTAL DAMAGE (DOLLARS)
          LANDR                  LAND RETIREMENT SWITCH
          TEEROS                 TRADE AND ENVIRONMENT EROSION SCENARIOS
          TPRAC                  TURN TILLAGE PRACTICE OPTION ON
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Table 8

List of tables contained in A1A0RPT00.GMS—continued

```
     LANDREDER(U)           REDUCTION IN CROPLAND BY ECONOMIC REGION
     LANDREDRR(U)           REDUCTION IN CROPLAND BY RESOURCE REGION
     NBUFFR(*)              NITROGEN BUFFERRING RATE FROM RETIRED LAND (TONS PER AC)
     LR2REAPR               LAND RETIREMENT PROGRAM TO REAP ACRE RATIO
     ETBALM(EC,U,UR,CAS)    ENVIRONMENTAL TARGET BALANCE EQUATION SHADOW VALUE
     CSTSHRPMT(P,*,*,U)     COST SHARE PAYMENTS BY CROP AND REGION (MIL. DOLLARS)
     ACTOTLR(  P,*,U)       TOTAL ACRES PLANTED BY CROP AND LAND RESOURCE SUB-REGION
   (MIL. AC.)
     YLDTPCLR( P,*,U)           YIELD PER ACRE BY CROP AND LAND RESOURCE SUB-REGION
     SRPCLR(P,*,U)              CROP PRODUCTION BY LAND RESOURCE SUB-REGION
```

Table 9

ARPT20 report fragment

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TABLE 2 --CROP PRODUCT SUPPLY AND USE: BASE DATA AND SOLUTION
-------------------------------------------------------------------------------------------------------------------------------
                                                     SUPPLY                                          USE
                                     ------------------------------------  ----------------------------------------------------
                                      BEGINNING STOCKS                                                         ENDING STOCKS
                                     ------------------                                                      ------------------
PRODUCT   UNITS               PRICE    GOVERN-  COMMER-  PRODUC-  IMPORTS  DOMES-  FEED AND  EXPORTS  EXPORT   GOVERN-  COMMER-
                                        MENT    CIAL      TION              TIC    RESIDUAL  COMMRCL  ENHANCE   MENT     CIAL
-------------------------------------------------------------------------------------------------------------------------------
                             $/UNIT                               -- MILLION UNITS --

CORN        BU     BASE        2.60      0.0    917.0  11234.4     10.0   1715.8   6903.6   2675.0      0.0      0.0    867.0
                   SHOCK       3.11      0.0    917.0  10693.2     10.4   1692.4   6798.1   2398.4      0.0      0.0    731.7
                   CHANGE      0.51      0.0      0.0   -541.3      0.4    -23.4   -105.5   -276.6      0.0      0.0   -135.3
                   %CHANGE    19.51      0.0      0.0     -4.8      3.9     -1.4     -1.5    -10.3      0.0      0.0    -15.6
SORGHUM     BU     BASE        2.35      0.0     71.0    670.2      0.0     79.9    280.7    314.6      0.0      0.0     66.0
                   SHOCK       2.78      0.0     71.0    553.7      0.0     67.8    248.0    248.1      0.0      0.0     60.7
                   CHANGE      0.42      0.0      0.0   -116.5      0.0    -12.1    -32.7    -66.5      0.0      0.0     -5.2
                   %CHANGE    18.02      0.0      0.0    -17.4      0.0    -15.2    -11.6    -21.1      0.0      0.0     -7.9
BARLEY      BU     BASE        2.40      0.0    107.0    365.0     55.0    172.0    175.0     14.0     56.0      0.0    110.0
                   SHOCK       2.56      0.0    107.0    334.8     55.7    169.0    161.8     13.4     49.2      0.0    104.1
                   CHANGE      0.16      0.0      0.0    -30.2      0.7     -3.0    -13.2     -0.6     -6.8      0.0     -5.9
                   %CHANGE     6.64      0.0      0.0     -8.3      1.3     -1.7     -7.6     -4.3    -12.1      0.0     -5.4
OATS        BU     BASE        1.45      0.0     56.0    150.0    125.0     78.0    195.0      2.0      0.0      0.0     56.0
                   SHOCK       1.98      0.0     56.0     90.5    134.1     75.2    178.9      1.5      0.0      0.0     25.0
                   CHANGE      0.53      0.0      0.0    -59.5      9.1     -2.8    -16.1     -0.5      0.0      0.0    -31.0
                   %CHANGE    36.22      0.0      0.0    -39.7      7.3     -3.6     -8.2    -23.5      0.0      0.0    -55.4
WHEAT       BU     BASE        3.70      0.0    591.0   2545.3    115.0   1131.0    225.3    491.4    833.6      0.0    570.0
                   SHOCK       4.09      0.0    591.0   2269.1    117.4   1120.3    225.3    416.8    667.4      0.0    547.8
                   CHANGE      0.39      0.0      0.0   -276.2      2.4    -10.7      0.0    -74.6   -166.2      0.0    -22.2
                   %CHANGE    10.54      0.0      0.0    -10.9      2.1     -0.9      0.0    -15.2    -19.9      0.0     -3.9
RICE        CWT    BASE        7.71      0.0     27.2    194.2     13.1    153.1      0.0     52.2      2.3      0.0     26.9
                   SHOCK       8.70      0.0     27.2    168.0     13.5    146.6      0.0     36.1      1.3      0.0     24.7
                   CHANGE      0.99      0.0      0.0    -26.2      0.3     -6.5      0.0    -16.1     -1.0      0.0     -2.2
                   %CHANGE    12.83      0.0      0.0    -13.5      2.6     -4.2      0.0    -30.9    -44.6      0.0     -8.1
SOYBEANS    BU     BASE        6.30      0.0    225.0   3245.0     10.0    189.6   1995.0   1070.0      0.0      0.0    225.4
                   SHOCK       6.96      0.0    225.0   2885.9     10.2    182.1   1882.8    988.2      0.0      0.0     68.0
                   CHANGE      0.66      0.0      0.0   -359.1      0.2     -7.5   -112.2    -81.8      0.0      0.0   -157.4
                   %CHANGE    10.47      0.0      0.0    -11.1      2.1     -4.0     -5.6     -7.6      0.0      0.0    -69.8
```

Table 9

ARPT20 report fragment—continued

```
TABLE 2 --CROP PRODUCT SUPPLY AND USE: BASE DATA AND SOLUTION
-------------------------------------------------------------------------------------------------------------------------------
                                                     SUPPLY                                         USE
                                     ------------------------------------  ----------------------------------------------------
                                      BEGINNING STOCKS                                                        ENDING STOCKS
                                     ------------------                                                      ------------------
PRODUCT   UNITS               PRICE    GOVERN-  COMMER-  PRODUC-  IMPORTS  DOMES-  FEED AND  EXPORTS  EXPORT   GOVERN-  COMMER-
                                        MENT     CIAL     TION              TIC    RESIDUAL  COMMRCL  ENHANCE  MENT      CIAL
-------------------------------------------------------------------------------------------------------------------------------
                             $/UNIT                               -- MILLION UNITS --

COTTON      BALE   BASE      312.00      2.5      1.8     17.5      0.0      9.3      0.0      8.3      0.0      2.5      1.7
                   SHOCK     336.10      2.5      1.8     15.8      0.0      8.6      0.0      7.5      0.0      2.5      1.6
                   CHANGE     24.10      0.0      0.0     -1.7      0.0     -0.7      0.0     -0.8      0.0      0.0     -0.1
                   %CHANGE     7.72      0.0      0.0     -9.5      1.6     -7.9      0.0     -9.7      0.0      0.0     -6.9
SILAGE      TON    BASE       21.68      0.0      0.0     95.6      0.0     30.1     65.5      0.0      0.0      0.0      0.0
                   SHOCK      22.50      0.0      0.0     84.9      0.0     19.4     65.5      0.0      0.0      0.0      0.0
                   CHANGE      0.82      0.0      0.0    -10.7      0.0    -10.7     -0.1      0.0      0.0      0.0      0.0
                   %CHANGE     3.80      0.0      0.0    -11.2      0.0    -35.4     -0.1      0.0      0.0      0.0      0.0
HAY         TON    BASE       60.58      0.0      0.0    155.6      0.0     77.5     78.0      0.0      0.0      0.0      0.0
                   SHOCK      62.77      0.0      0.0    136.8      0.0     62.1     74.7      0.0      0.0      0.0      0.0
                   CHANGE      2.18      0.0      0.0    -18.8      0.0    -15.5     -3.3      0.0      0.0      0.0      0.0
                   %CHANGE     3.60      0.0      0.0    -12.1      0.0    -20.0     -4.2      0.0      0.0      0.0      0.0
------------------------------------------------------------------------------------------------------------------------------
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Appendix A
Installing and Using REAP

Installation Instructions for Base REAP

REAP is written in the GAMS language. The installation instructions are written with the assumption that GAMS-IDE has been installed and a nonlinear solver (e.g., CONOPT or MINOS) has been selected as the default solver.

The files necessary to run REAP are contained in REAPv1.ZIP. This file contains several control files and three folders: A1A0, A1A0LIB, and AREPORT. A1A0 contains the main model files and consists of several subdirectories that contain files for running different versions of the model. A1AOLIB contains the report writing files as well as supporting data files, such as crop and livestock data baseline files. AREPORT contains files for generating summary reports of results.

All files in REAPv1.ZIP need to be extracted into a directory called REAPv1 retaining the directory structure.

REAP is driven by a series of control files and a master program. The master program is called REAPDRIVER.GMS. The control files are PARAMDEFAULT.INC, PARAMUSER.INC, PARAMS.INC, and OPTIONS.INC. The file REAPDRIVER.GMS calls in all the component files automatically. To run REAPDRIVER, open a GAMS-IDE project in the same directory (REAPv1) as the control files. A new project is created from the GAMS-IDE by selecting File -> Project -> New Project and specifying the name of the project. Open REAPDRIVER.GMS (File -> Open) into the GAMS-IDE.

Calibrating to a Baseline Year

To calibrate to a year in the USDA baseline, first open the file PARAMDEFAULT.INC. Change the name of parameter “run_name” (“test_run2” in the example) to a name that reflects the nature of the run (for example “Cal2010”). This name will become the name of a new directory in the REAPv1 folder. All the REAP output will be saved in this new directory. If the directory already exists, files contained within it will be overwritten. You may also give the run a title. Parameter runyear must be specified. Be sure to save the file.

```
* The run_name is the name of a directory where results
* are written. The results include key listing files and
* GDX files with result data.
$setglobal run_name test_run2

* Goes to the $title of the input file
$setglobal run_title This is a test run

*
* runyear
*

$setglobal runyear 2010    {calibration year}
$setglobal rym1    2009    {runyear minus 1}
$setglobal ryp1    2011    {runyear plus 1}
```

Excerpt from PARAMDEFAULT.INC

To run the calibration, make sure REAPDRIVER.GMS is active in the project window. Press the Run GAMS toolbar button (or select File -> Run from the menu). A new window will open in the project that will display the progress of REAP. When the runs are complete, the output (LST and GDX files) is in the directory specified by the run_name parameter.

There are four steps or jobs submitted through the REAPDRIVER.GMS to obtain a base solution off of which scenarios can be run. The purpose of these steps are described below, followed by the steps needed for submitting a scenario run and generating summary reports.

Step 1: The file A1A0A.GMS in the A1A0 directory is called "REAPDRIVER.GMS" to calibrate rotation acreage based on NRI data to individual crop acreage from the selected base year as reported in the baseline data. This file also updates cost of production estimates to the latest data contained in the selected year from the baseline data.

Step 2: The file ALF4N00.GMS in the ALF subdirectory of A1A0 is called "REAPDRIVER.GMS" work files. The main purpose of this run is to find shadow values for calibrating the CET parameters.

Step 3: The file CET4N00.GMS in the CET subdirectory of A1A0 is called "REAPDRIVER.GMS" to derive the parameters for the CET functions. The file contains two sequential solves. The first solve specifies the parameters for the CET functions for tillage practices. The second solve specifies the parameters for the rotations.

Step 4: A1A0VC.GMS in the A1A0 directory is called "REAPDRIVER" to specify the PMP functions for crop and livestock production. Step 4 represents the full verify or base run from which all the shocks will be run. At this stage, all calibration bounds have been removed.

Appendix B
Environmental Parameters

Environmental Policy Integrated Climate Model

Environmental indicators contained in REAP production activities were generated using the EPIC model. EPIC is a crop biophysical simulation model that is used to estimate the effect of management practices on crop yields, soil quality, and various environmental emissions at the field level. EPIC uses information on soils, weather, and management practices, including specific fertilizer rates, and produces information on crop yields, erosion, and chemical losses—including nitrogen losses—to the environment.

Management practices used in the EPIC management files are consistent with agronomic practices for the 45 regions as reported in the USDA ARMS, which has absorbed the CPS.

We generated crop yields and the array of environmental indicators associated with each crop production activity represented in REAP by running EPIC in four sequential steps. The first step is to condition the soil while the next three are used to calculate short-term yield, average rate of emission, and long-term yield (app. table B.1).

The first or conditioning step allows EPIC to rectify any inconsistencies in the soil profile imported from the SOILS5 database. This first step involves running EPIC for a period of 5 years with the soil erosion module turned off. The output of this step has the added advantage of making the soils profile at the beginning of the second step consistent with a field that has been subjected to the management practices being simulated. This is important because any particular soil profile used does not necessarily come from a field where the system being simulated has been used.

In step two, we calculate the short-term yield. EPIC is run for a period of 7 years, again with its soil erosion module turned off and short-term yield calculated as average yield during this period. By turning the erosion off, any variation in yield will be due strictly to variation in weather.

In step three, we calculate the environmental indicators by running EPIC for 60 years, this time with soil erosion turned on. Total emissions for each environmental indicator are tabulated and divided by the length of the simulation to obtain the annual rate of emission. Running the systems for 60 years eliminates any dependence of the emissions from the sequence of weather for any particular time period and provides a consistent base for comparing systems. By eliminating the dependence of the systems on a specific weather pattern, we did not need to coordinate weather patterns among the various weather sites. In this step, all systems are run through two full weather cycles. At the same time, each management regime is run through at least five full management cycles.

In step four, we calculate the long-term yields. EPIC is run as described in step two, except that EPIC uses the soil profile generated from the previous 60-year simulations. The difference between shortrun and longrun yield represents the change in soil productivity associated with each management system.

While EPIC was designed for use over a wide range of soil and climatic conditions, we found that crop yields were highly variable. For some regions and some crops, EPIC's yield projections matched USDA yield data, but in others, its yield projections were over or under yields reported for those areas. More importantly, EPIC's estimated yields alter the ranking of the regions with respect to crop yield.

It could be argued that since yield has little effect on erosion that the errors in EPIC’s yield estimates are not that important. However, yield is a critical factor determining plant nutrient uptake and, consequently, nitrogen emissions to the environment. Yield, especially the relative yield between crops and regions are important for determining the economic relationships as well. We found it necessary, therefore, to calibrate EPIC so that its simulated yields matched the reported yields.

In order to calibrate EPIC, we conduct sensitivity analysis over EPIC parameters for a large number of production systems in a consistent fashion. A variety of factors can be used to calibrate the EPIC parameters; the two most common factors are crop yield and soil profile. We selected crop yield because data on yield is readily available down to the county level; yield affects many of the environmental relationships pertaining to chemical emissions of interest; and we lacked the expertise to calibrate EPIC parameters to changes in soil profile.

Outside information needed to calibrate the systems includes yields, weather, growing degree days, and soils. Yields were obtained by aggregating USDA's NASS county yield data up to the REAP region. Weather information was obtained by aggregating rainfall and temperature data for NOAA weather districts to REAP regions. Growing degree days were obtained from a USDA database put together by EPIC developers called "Potential Heat Unit." Soils information was obtained from the SOILS5 database and selected by using a distance function procedure that took into account a set of soil characteristics related to soil quality and productivity.

EPIC parameters used in the calibration were WA, HI, and nitrogen demand (ba1, ba2, and ba3). WA is a growth parameter and controls the efficiency by which the plant converts sunlight into biomass. HI is the harvest index and specifies the ratio of above ground to below ground biomass. Nitrogen demand parameters (ba1, ba2, and ba3) control plant demand for nitrogen throughout the growing season. These parameters affect the sensitivity of yield to available nitrogen and play a critical role in determining nitrogen uptake and nitrogen loss.

The yield target used to calibrate EPIC parameters was the 7-year average yield for 1987-1995 for each REAP region. The 7-year average yields were calculated by aggregating NASS county yield data up to REAP regions. Because EPIC does not account for all factors, primarily disease and insects, which affect yields, EPIC should overestimate yield relative to reported yield. Consequently, we adjusted the target yield by setting it 10 percent above each crop's average yield.

The EPIC parameters were calibrated in two steps. In the first step, WA and HI were adjusted up or down until the simulated yield came within 10 percent of the target yield. The parameters were varied in sequence, first WA and then HI, until the simulated yield fell within the desired range.

In the second step, nitrogen demand was shifted up or down until the nitrogen-yield response was consistent with fertilizer application rates reported in the CPS and profit-maximizing behavior in an uncertain environment. To do this, we assumed that the nitrogen-yield relationship can be represented with a nondifferentiable plateau response model. The von Liebig and quadratic-plateau response models have this characteristic. A study by Cerrato and Blackmer (1990) found that these two functions best represented the nitrogen-yield response relationship based on data from experimental plots in Iowa. A study by Babcock (1992) demonstrated that given these types of response functions, farmers should apply the same amount of fertilizer every year based on yield potential. This, in turn, implies that the nitrogen-yield response function obtained from an average yield over a specific time period should be discontinuous at the optimal fertilizer application rate. We then shifted the nitrogen demand function until the discontinuity in the simulated nitrogen-yield response was centered over the nitrogen application rate.

Soil Selection

Reliability of the EPIC simulation of crop yield and environmental indicators depends not only on the management practices used, but also on weather and soils. Both soils and weather play important roles in crop growth, nutrient uptake, erosion, chemical losses to air, run off, and leaching. Therefore, it is important that the soils and weather sites selected be as representative of conditions as possible in each REAP region.

Representative soils were chosen for each REAP model region by using factors that reflect the susceptibility of the soil to erosion, surface runoff, and leaching. These soils were used in the EPIC crop simulations for each region. Soils were selected for each of 45 REAP regions. Soils can be separated by HEL and NHEL soils, or combined (app. tables B.2 and B.3). From the NRI, a subset of polygons was selected on the basis of REAP crops grown. The hydrologic groups, erodibility factors, slope lengths, and steepness were obtained from NRI and SOILS5 data. These variables summarize the inherent characteristics of the soil and land pertaining to water erosion, surface runoff, and leaching. Soils for each REAP region were selected by considering proximity to the centroid of these variables for each region and by acreage.

Soil Selection Factors

Environmental losses of soil and chemicals in crop production can be divided into surface and subsurface categories. Chemicals can move from the field in solution with the runoff water and on soil particles eroded from the field. Chemicals can leach through the soil into subsurface flows and groundwater. Surface runoff and sheet and rill erosion generally increase with slope length and steepness and are further affected by precipitation, the soil hydrological group, inherent erodibility of the soil, and physical cropping system attributes. The erodibility of soil, depending in part on the proportions of silt, sand, and clay, increases with the value of the USLE K factor. Hydrologic groups reflect runoff potential and are negatively related to the infiltration and leaching potential of soils. As runoff potential declines, the rate of infiltration increases along with the amount of precipitation absorbed into the soil and the potential for chemical leaching. Thus, the slope length and steepness, USLE erodibility factor (K factor), and hydrological group are included in the soil selection. Background information and data conversions and calculations of averages and distance from the centroids for each region are summarized below.

Representative Soil Delineation by Erodibility

Soils are chosen to be representative of the individual REAP regions. The separation of highly erodible and nonhighly erodible soils is desirable for some analyses. Thus, a single soil is chosen to be representative of each REAP region as well as separate soils representing highly erodible and nonhighly erodible land. The highly erodible designation by NRCS is reserved for soil inherently susceptible to erosion, considering rainfall, soil characteristics, and slope length and steepness (Magleby et al., 1995).

The choice of soils begins with choosing the relevant cropland. Crop acreage where any one of REAP crops was grown within 4 years was selected from the 1992 NRI. The relevant SOILS5 records were merged with the NRI polygons in the REAP crop acreage. From this data set, the hydrologic group, erodibility, slope length, and steepness were extracted for the NRI data points. These data were converted to variables ranging from 0 to 1, and averages were calculated for each model region for HEL, NHEL, and combined soils by using the NRI polygon expansion factor as a weight. Observations are limited to those where the slope steepness is no greater than 30 percent. Vector distances from the means of the four variables or the centroid were calculated as deviation scores for each NRI point. Soils in each category were ranked by ascending score, with lower scores being the most desirable. Among soils with similar scores, those associated with the greatest acreage were given preference. Representative soil parameters for each region are presented in tables B.1 through B.3)

Weather Selection

Weather sites used in the EPIC simulations were originally selected based on the proximity to the geographical center of the region (app. table B.4). However, selecting a representative weather site based on its proximity to the geographical center of a REAP region can cause the weather represented by the selected weather site to be inconsistent with weather conditions where a majority of the crops are grown. In relatively homogeneous regions—such as the Corn Belt—this does not present much of a problem, but in many REAP regions, weather varies considerably and poses a problem. Consequently, before calibrating

EPIC system parameters, we reselected weather sites that were more representative, with respect to average rainfall and temperature for areas within the REAP region with crop production rather than selecting sites based on their proximity to the center of the region.

The average rainfall and temperature for the 7-year period (1987-95) used to calculate average crop yields were used as the basis for selecting representative weather sites. This information was obtained by aggregating NOAA weather districts into REAP regions based on their share of crop acreage in each REAP region. Weather sites from EPIC's database were selected based on the average rainfall and temperatures from the NOAA data (see table B.4 for locations of selected sites).

After the weather site was selected for each region, the weather generator was set so that average rainfall and temperature generated by EPIC matched the 7-year average calculated from the NOAA data. This was needed because the EPIC weather generator is designed to replicate 30-year average rainfalls and temperatures at any specific weather site. As a result, any length of time shorter than 30 years will have average temperatures and rainfall that deviate from the 30-year average. The shorter the timespan selected and the greater the variability in weather at the site means the greater the deviations associated with any one draw from the weather distribution is likely to be. Since we wanted to calibrate EPIC parameters to the 7-year average yields, we needed to set the weather generator seed so that the average temperature and rainfall during the simulation period were equal to the averages recorded for the period used in calculating crop yields.

Erosion Calibration

Surface Runoff, Leaching, and Lateral Surface Flow

Surface run off is estimated by the EPIC system as a function of soil hydrological groups, slope, crop type, and daily rainfall (EPIC Model Documentation pages 4-5, EPIC Users Manual, table II.1). Hydrologic groups reflect runoff potential of the soils. The negative relationship between surface runoff and leaching was exploited by Williams and Kissel (1991) in the development of a leaching index by using EPIC for eight sites to simulate a range of soils and climates (Kellogg et al., 1992). Thus, the hydrological group captures the various chemical and physical soil characteristics pertinent to both surface run off and leaching.

Group A—Lowest runoff potential—highest percolation or leaching potential. High infiltration rate even when wet. Deep, well-drained sand or gravel. High water transmission rate.

Group B—Moderate infiltration rate—Moderately deep soils, with moderately fine-course texture. Moderate water transmission rate.

Group C—Slow infiltration rate—Soils with a layer impeding downward flow, or soil with moderately fine to fine texture. Slow water transmission rate.

Group D—High runoff potential—lowest percolation or leaching potential. Slow infiltration rate. Clay soils with high swelling potential, permanent high water table, clay layer near surface, and shallow soils over impervious material. Very slow water transmission rate.

Water Erosion

Water erosion estimation variables capture the remaining slope and soil characteristics used for selecting the REAP representative soils.

The USLE equation is represented in EPIC as follows:

$Y = (EI)\ (K)\ (CE)\ (PE)\ (LS)\ (ROKF)$

where:

Y is the sediment yield

EI is the rainfall intensity measure

K is the soil erodibility factor

CE is the crop management factor (tillage)

PE is the erosion control factor

LS is the slope length and steepness factor

ROKF is the course fragment factor

The REAP representative soils choice factors include slope length and steepness and directly affect the USLE soil erodibility factor (K). The hydrologic group reflects the course fragment factor (ROKF). The crop management factor is determined by the REAP crop system, and rainfall parameters are incorporated in the EPIC simulation for each of the 45 regions. Thus, all USLE variables are accounted for by REAP values other than the erosion control factor (PE). The absence of PE could result in low erosion estimates, where such physical controls such as terracing are needed but have not been incorporated. However, over the years much of such land has either been taken out of tilled crop production or has undergone treatment.

Appendix table B-1—Representative soils combined erodiblility class

Farm Resource Region	Erodibility Class	Soil	SOILS5 ID	SURFACE TEXTURE	ACRES	HYDRO-LOGIC GROUP	K FACTOR	SLOPE LENGTH	SLOPE PERCENT
APN	HEL	ZANESVILLE	KY0001	SICL	165700	C	0.37	150	6.0
APO	HEL	LORING	TN0011	SIL	455400	C	0.49	110	3.0
APP	NHEL	APPLING	NC0032	SL	177700	B	0.24	200	4.0
APT	NHEL	GOLDSBORO	NC0041	FSL	162800	B	0.20	200	1.0
CBL	NHEL	ELSTON	IN0029	L	33000	B	0.28	300	1.0
CBM	NHEL	GALVA	IA0163	SICL	562200	B	0.32	200	3.0
CBN	NHEL	BARDEN	MO0032	SIL	49000	C	0.37	279	5.0
CBO	NHEL	WARDELL	MO0045	L	38700	C	0.37	250	0.1
CBR	NHEL	CANFIELD	OH0057	SIL	131300	C	0.37	200	4.0
DLN	NHEL	ROXANA	LA0067	SIL	36200	B	0.43	200	1.5
DLO	NHEL	DUNDEE	MS0057	VFSL	938000	C	0.37	150	0.8
DLP	NHEL	SAVANNAH	MS0083	L	41100	C	0.37	200	2.0
DLT	NHEL	MIDLAND	LA0017	SICL	156300	D	0.43	125	0.2
LAF	NHEL	VALLERS	MN0055	L	31900	C	0.28	120	0.5
LAK	NHEL	CHETEK	WI0120	SL	111400	B	0.24	150	3.0
LAL	NHEL	KIBBIE	MI0041	L	75900	B	0.28	200	3.0
LAM	NHEL	CLARION	IA0521	L	108100	B	0.28	125	3.0
MNB	NHEL	TETONIA	ID0217	SIL	18700	B	0.37	500	4.0
MND	NHEL	PARLEYS	UT0062	SIL	61000	B	0.32	600	2.0

Appendix table B-1—Representative soils combined erodiblility class— continued

MNE	NHEL	NUNN	CO0038	CL	15300	C	0.28	250	4.0
MNF	HEL	SCOBEY	MT0124	CL	792100	C	0.37	300	3.0
MNG	HEL	NORKA	CO0071	SIL	197800	B	0.32	400	3.0
MNH	HEL	CLOVIS	NM0969	FSL	107800	B	0.28	250	0.7
NPF	NHEL	BARNES	ND0119	L	3486600	B	0.28	250	3.0
NPG	HEL	HUGGINS	SD0093	SIL	6600	C	0.32	310	3.0
NPH	NHEL	HARNEY	KS0047	SIL	3101300	B	0.32	220	2.0
NPM	NHEL	MOODY	SD0343	SICL	696300	B	0.32	200	4.0
NTL	NHEL	APPLETON	NY0145	SIL	60000	C	0.32	235	4.0
NTN	HEL	GILPIN	PA0007	SIL	229100	C	0.32	150	10.0
NTR	HEL	WELLSBORO	PA0027	L	134700	C	0.28	160	6.0
NTS	HEL	GLENELG	MD0021	L	181900	B	0.32	220	6.0
NTT	NHEL	SASSAFRAS	MD0039	SL	243600	B	0.28	160	1.0
PAA	NHEL	WOODBURN	OR0325	SIL	81600	C	0.32	350	2.0
PAB	NHEL	WALLA WALLA	WA0026	SIL	349700	B	0.43	400	7.0
PAC	NHEL	TWISSELMAN	CA0699	C	122600	C	0.32	850	2.0
PAD	NHEL	FURY	ID0568	SIL	64500	C	0.32	800	1.0
PAE	NHEL	CLAYTON	WA0302	FSL	13700	B	0.28	350	5.0
SEN	NHEL	CHENNEBY	AL0026	SICL	33600	C	0.32	45	2.0
SEP	NHEL	TIFTON	GA0001	SL	1249100	B	0.17	150	3.0
SET	NHEL	DOTHAN	AL0010	LS	30000	B	0.15	200	1.0
SPH	NHEL	ROWENA	TX0159	CL	492900	C	0.32	240	1.0
SPI	HEL	DUVAL	TX0208	VFSL	113800	B	0.32	300	1.0

Appendix table B-1—Representative soils combined erodiblility class— continued

SPJ	NHEL	AUSTIN	TX0144	SIC	84100	C	0.32	200	2.0
SPM	NHEL	DENNIS	OK0004	SIL	96200	C	0.43	100	1.0
SPT	NHEL	LAKE CHARLES	TX0020	C	611200	D	0.32	200	0.2

Appendix table B-2—HEL Representative soils

Region	Erodibility	SOIL	SOILS5	MUSYM	State	SCH_TOT	Acres	S.text	H.Gr.	K Fact	S.Length	Slope	USLE92
APN	NHEL	BELKNAP	IL0004	Bn	KY	0.150455	131200	SIL	C	0.37	200	2	3.306
APO	NHEL	COLLINS	MS0030	8	KY	0.035029	205100	SIL	C	0.43	120	1	6.61
APP	NHEL	APPLING	NC0032	ApB	VA	0.092878	177700	FSL	B	0.24	200	3	3.335
APS	NHEL	HAGERSTOWN	MD0004	HcC	WV	0.142632	25800	SIL	C	0.32	175	4	1.44
APT	NHEL	GOLDSBORO	NC0041	GoA	NC	0.130436	162800	FSL	B	0.2	200	1	3.6175
CBL	NHEL	ELBURN	IL0136	198	IL	0.130818	26200	SIL	B	0.28	350	1	2.96
CBM	NHEL	GALVA	IA0163	GaA	IA	0.096073	562200	SICL	B	0.32	210	2	2.41
CBN	NHEL	STENDAL	IN0058	St	OH	0.120973	65400	SIL	C	0.37	200	2	2.545
CBO	NHEL	COMMERCE	LA0041	42	MO	0.065068	127500	SICL	C	0.37	250	0.2	3.63
CBR	NHEL	CANFIELD	OH0057	CdB	OH	0.038391	131300	SIL	C	0.37	200	2	2.27
DLN	NHEL	BARLING	AR0029	2	AR	0.118307	6400	SIL	C	0.37	150	1	0.19
DLO	NHEL	SHARKEY	LA0050	Sb	MS	0.165205	1990100	SICL	D	0.37	165	0.5	4.58
DLP	NHEL	SAVANNAH	MS0083	SaA	MS	0.074307	41100	SIL	C	0.37	200	1	4.583
DLT	NHEL	CROWLEY	LA0044	CrA	LA	0.073238	423800	SIL	D	0.49	125	0.3	3.105
LAF	NHEL	BEARDEN	ND0296	67A	MN	0.089325	428700	SIL	C	0.28	100	0.5	0.488
LAK	NHEL	ROSHOLT	WI0226	RoB	WI	0.061142	185600	SL	B	0.24	200	3	0.19
LAL	NHEL	FOX	WI0026	FoB	MI	0.046413	176400	SL	B	0.24	200	2	0.975
LAM	NHEL	CLARION	IA0074	ClB	MN	0.057651	480500	L	B	0.24	100	2	2.078
MNB	NHEL	REXBURG	ID0083	700A	ID	0.156065	84000	SIL	B	0.43	600	3	6.62
MND	NHEL	WITT	NM1122	R0B	CO	0.167687	95000	L	B	0.37	500	2	0.07
MNE	NHEL	AMSTERDAM	MT0499	11	MT	0.187658	85700	SIL	B	0.32	250	3	0.015
MNF	NHEL	WILLIAMS	ND0258	69	MT	0.152982	492400	L	B	0.43	250	3	1.98
MNG	NHEL	WELD	CO0054	WeB	CO	0.178504	220100	SIL	C	0.32	400	3	1.325

Appendix table B-2—HEL Representative soils— continued

MNH	NHEL	KUMA	CO0028	25	CO	0.148546	137700	SIL	B	0.32	300	2	4.66
NPF	NHEL	BARNES	ND0119	BhA	ND	0.128394	3486600	L	B	0.28	240	2	0.52
NPG	NHEL	KEITH	NE0049	KeC	NE	0.153496	214300	L	B	0.28	200	3	0.74
NPH	NHEL	HARNEY	KS0047	HB	KS	0.100918	3101300	SIL	B	0.32	225	2	0.898
NPM	NHEL	NORA	SD0060	NoC	NE	0.164418	721900	SIL	B	0.32	225	3	2.35
NTL	NHEL	LIMA	NY0120	Lo	NY	0.179558	194700	FSL	B	0.32	200	3	1.4775
NTN	NHEL	GILPIN	PA0007	GNB	PA	0.073243	28200	SIL	C	0.32	200	5	1.02
NTR	NHEL	MARDIN	NY0060	MrB	NY	0.148794	139200	SIL	C	0.24	200	4	0.676
NTS	NHEL	HAGERSTOWN	MD0004	35B2	PA	0.146413	103900	SIL	C	0.32	250	4	2.16
PAA	NHEL	WOODBURN	OR0325	77A	OR	0.03915	81600	SIL	C	0.32	350	2	0.65
PAB	NHEL	WALLA	WA0026	31B	OR	0.069468	349700	SIL	B	0.43	450	5	3.503
PAC	NHEL	COLUMBIA	CA0188	144	CA	0.018474	22500	FSL	C	0.32	990	1	0.33
PAD	NHEL	FURY	ID0568	7A	OR	0.055534	64500	SIL	C	0.32	500	0.5	0
PAE	NHEL	NARCISSE	WA0103	NcA	WA	0.157449	8000	SIL	C	0.37	200	3	1.06
SEN	NHEL	CHENNEBY	AL0026	Lk	AL	0.139673	33600	SICL	C	0.32	45	2	4.46
SEP	NHEL	TIFTON	GA0001	TuB	GA	0.029616	1249100	SL	B	0.17	150	2	5.161
SET	NHEL	GOLDSBORO	NC0041	Gb	SC	0.083078	178200	LS	B	0.17	200	1	2.618
SPH	NHEL	OLTON	TX0129	OcA	TX	0.037056	892300	CL	C	0.32	240	0.9	2.29
SPI	NHEL	CLAREVILLE	TX0207	12B	TX	0.046369	26900	CL	C	0.32	200	1	2.78
SPJ	NHEL	HOUSTON B.	TX0093	HoB2	TX	0.14973	756500	C	D	0.32	175	2	4.57
SPM	NHEL	DENNIS	OK0004	DtB	OK	0.068226	96200	SIL	C	0.43	100	1	2.49
SPT	NHEL	L.CHARLES	TX0020	24	TX	0.043141	611200	C	D	0.32	180	0.2	1.55

Appendix table B-3—Representative soils, NHEL

Region	Erodibility	SOIL	SOILS5	MUSYM	State	SCH_TOT	Acres	S.text	H.Gr.	K Fact	S.Length	Slope	USLE92
APN	HEL	LOWELL	KY0032	LoC	KY	0.16414	218500	SIL	C	0.37	160	8	1.06
APO	HEL	LORING	TN0011	LoC3	TN	0.088049	455400	SIL	C	0.49	110	5	19
APP	HEL	CECIL	NC0018	Cf	VA	0.093005	308600	FSL	B	0.28	200	7	0.74
APS	HEL	FREDERICK	VA0059	29C2	VA	0.155668	55900	SIL	B	0.32	200	10	29.47
APT	HEL	MUNDEN	VA0162	MuA	VA	0.064154	3600	SL	B	0.2	250	2	2.78
CBL	HEL	HITT	IL0216	506C	IL	0.04111	18000	SIL	B	0.32	200	6	6.58
CBM	HEL	FAYETTE	IA0564	163C2	IA	0.146531	694600	SIL	B	0.37	180	8	24.99
CBN	HEL	COSHOCTON	OH0104	CnC	OH	0.093539	86400	SIL	C	0.37	200	10	0.32
CBO	HEL	LORING	TN0011	3C2	MO	0.166762	18800	SIL	C	0.49	100	7	34.365
CBR	HEL	WOOSTER	OH0017	WsC2	OH	0.073686	104400	SIL	C	0.37	200	8	7.24
DLN	HEL	ENDERS	AR0002	20	AR	0.096942	2500	FSL	C	0.32	100	8	0.26
DLO	HEL	LORING	TN0011	33B	MS	0.033393	284600	SIL	C	0.49	125	4	14.48
DLP	HEL	SAVANNAH	MS0083	SaC2	MS	0.03369	53300	SIL	C	0.37	150	4	0.79
DLT	HEL	MIDLAND	LA0017	McA	LA	0.088073	1800	SICL	D	0.43	135	0.2	0.04
LAF	HEL	POPPLETON	MN0131	148	MN	0.122787	20900	LFS	A	0.15	150	0.5	0.4166
LAK	HEL	ROSHOLT	WI0226	RrC2	WI	0.082225	34600	SL	B	0.24	180	7	4.14
LAL	HEL	MARLETTE	MI0083	36C	MI	0.072976	90600	L	B	0.32	200	7	0.11
LAM	HEL	VALTON	WI0127	DtC2	WI	0.030537	159200	SIL	B	0.32	175	10	6.49
MNB	HEL	TETONIA	ID0217	58	ID	0.167971	55300	SIL	B	0.37	400	6	9.39
MND	HEL	GLENDALE	AZ0130	Gf	NM	0.113567	39800	L	B	0.32	700	0.4	0.07
MNE	HEL	WINIFRED	MT0135	602WM	MT	0.145761	42300	C	C	0.32	300	4	1.76
MNF	HEL	SCOBEY	MT0124	657156	MT	0.039211	792100	CL	C	0.37	300	3	1.555
MNG	HEL	NORKA	CO0071	WBC	CO	0.147358	197800	SIL	B	0.32	400	3	7.95

Appendix table B-3—Representative soils, NHEL— continued

MNH	HEL	AMARILLO	TX0130	Ab	NM	0.101994	246600	FSL	B	0.24	300	0.8	0.61
NPF	HEL	WILLIAMS	ND0042	341C	ND	0.12297	197700	L	B	0.28	300	4	0.23
NPG	HEL	SAVO	SD0084	86B	SD	0.150627	5200	SIL	C	0.32	300	4	0.5
NPH	HEL	RICHFIELD	KS0096	RN	KS	0.057905	1580300	SIL	B	0.32	200	2	0.69
NPM	HEL	SHARPSBURG	IA0033	ShD2	NE	0.189385	350200	SICL	B	0.32	150	7	8.8
NTL	HEL	HONEOYE	NY0117	HnB	NY	0.146097	58400	SIL	B	0.32	200	7	2.63
NTN	HEL	GILPIN	PA0007	GgC2	PA	0.122794	229100	SIL	C	0.32	125	11	3.04
NTR	HEL	WELLSBORO	PA0027	32C	NY	0.060963	134700	L	C	0.28	150	9	0.68
NTS	HEL	GLENELG	MD0021	GEB2	PA	0.129692	181900	SIL	B	0.32	200	8	3.84
PAA	HEL	MANITA	OR0650	53B	OR	0.094004	800	L	C	0.32	400	7	0.78
PAB	HEL	ATHENA	OR0002	AsE2	WA	0.090662	319900	SIL	B	0.37	400	11	6.99
PAC	HEL	NACIMIENTO	CA0045	175	CA	0.08746	72500	SICL	C	0.32	100	12	2.23
PAD	HEL	HOLTVILLE	CA0279	110	CA	0.078941	27600	SIC	C	0.32	1200	0.2	0.05
PAE	HEL	BONNER	ID0232	35	WA	0.139642	10400	SIL	B	0.32	40	10	2.4
SEN	HEL	WYNNVILLE	AL0042	Tk	AL	0.157549	95500	SIL	C	0.28	80	5	12.88
SEP	HEL	CECIL	NC0018	CeB	SC	0.099457	171000	SL	B	0.28	120	5	9.9
SET	HEL	CARNEGIE	GA0027	CoC2	GA	0.217712	4900	SL	C	0.28	300	3	10.57
SPH	HEL	AMARILLO	TX0130	Aa	TX	0.082723	1767600	FSL	B	0.24	250	1.5	2.6
SPI	HEL	KNIPPA	TX0435	KnA	TX	0.121015	63600	C	C	0.32	300	1	0.93
SPJ	HEL	AUSTIN	TX0144	8	TX	0.059579	28000	SIC	C	0.32	150	3	0.41
SPM	HEL	DENNIS	OK0004	DeC	OK	0.069785	26100	SIL	C	0.43	120	3	0.11
SPT	HEL	VICTORIA	TX0224	7A1	TX	0.117146	36000	C	D	0.32	300	0.5	4.64

Appendix table B.4—Selected weather sites and their location

Model Region	State	Station	Lat	Long
APN	KY	09	36.75	86.20
APP	NC	10	35.73	81.38
APS	WV	03	39.27	80.35
CBL	OH	04	41.40	81.85
CBM	IL	10	40.47	87.67
CBN	IN	08	38.60	86.10
CBO	TN	11	35.62	85.20
CBR	OH	10	40.50	81.45
DLN	AR	01	34.55	92.62
DLO	MS	11	31.95	90.98
DLP	MS	02	31.57	90.43
DLT	MS	13	30.63	89.05
LAF	MN	31	48.57	95.63
LAK	WI	13	46.35	91.82
LAL	MI	24	47.17	88.50
LAM	WI	15	43.55	90.88
MNB	ID	16	42.32	111.30
MND	AZ	27	36.28	113.07
MNE	MT	32	48.40	115.53
MNF	MT	13	48.40	115.53
MNG	CO	01	40.12	103.17
MNH	CO	14	40.58	102.30
NPF	ND	15 & 03	46.40	97.23 & 46.38
NPG	NE	13	42.27	101.35
NPH	KS	01	39.47	98.83
NPM	NE	06	41.43	96.48
NTL	NY	12	41.85	73.62
NTN	PA	12	41.48	79.43
NTR	ME	01	44.32	69.80
NTS	NJ	02	40.25	74.28
NTT	DE	01	38.63	75.47
PAA	OR	05	44.57	123.28
PAB	OR	09	45.35	119.55
PAC	CA	17	36.73	119.82
PAD	OR	12	43.28	118.83
PAE	WA	06	48.53	117.87
SPH	TX	01	32.43	99.68
SPI	TX	09	25.92	97.47
SPJ	TX	66	33.60	96.65
SPM	OK	20	36.30	95.32
SPT	LA	04	29.88	93.42
STN	GA	06	34.52	83.53
STP	AL	02	33.57	86.75
STT	FL	14	30.42	81.65

Appendix C
Accessing REAP and Contributing to Model Design

Accessing the Model

A current version of REAP is available on CD from the Economic Research Service, U.S. Department of Agriculture:

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Economic Research Service—U.S. Department of Agriculture
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Washington, DC 20036-5831
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Contributing to the Model Design

New members of the REAP-user network will be asked to sign a Memorandum of Understanding. This agreement stipulates that model innovations will be well documented and shared with ERS for inclusion in the module library. In this way, the model will continue to expand its range of applications and will facilitate updating of the background data sources.