INTRODUCTION 1

What is POLYSYS?

The Policy Analysis System (POLYSYS) modeling framework was developed to simulate changes in policy, economic or resource conditions and estimate the resulting impacts for the U.S. agricultural sector. At its core, POLYSYS is structured as a system of interdependent modules simulating crop supply for 305 production regions[1], national crop demand and prices, national livestock supply and demand, and agricultural income. Other modules are available within the POLYSYS modeling framework to expand its analytical capabilities to endogenously consider (*a*) a wide variety of region-specific crop rotations and management practices, (*b*) environmental impacts, (*c*) production of energy crops characterized by multi-year production cycles, (*d*) crop derivative products such as fats and oils, and (*e*) community economic impacts.

POLYSYS anchors its analyses to a published baseline of projections. Generally, the benchmark for POLYSYS simulation is U.S. Department of Agriculture (USDA), Food and Agriculture Policy Research Institute (FAPRI), or U.S. Congressional Budget Office (CBO) national baseline projections and related assumptions. Baselines generally embody five- to ten-year projection periods, allowing POLYSYS to simulate a five- to ten-year projection period. Using a baseline as a starting point, POLYSYS can introduce a wide variety of exogenous shocks and simulate the resulting impacts for U.S. crop and livestock supply and demand and agricultural income. Examples of variables for which POLYSYS may simulate changes include commodity program specifications, land retirement scenarios, input prices and quantities,

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[1] The 305 POLYSYS production regions correspond to Agricultural Statistic Districts (ASD), which are defined by the USDA's National Agricultural Statistics Service and were formerly termed Crop Reporting Districts (CRD) (NASS, 1988).

environmental targets or constraints, and international trade variables, among others. Some variables estimated endogenously by POLYSYS also may be exogenously specified, including regional planted and harvested acreage, regional market prices, national and regional yields, and export demand. Additionally, price-response parameters (elasticities) and long run demand adjustment factors which are exogenous to the model may also be the subject of a POLYSYS simulation.

Crops endogenously considered in POLYSYS include corn, grain sorghum, oats, barley, wheat, soybeans, cotton, and rice. Endogenous livestock commodities include beef, pork, lamb and mutton, broilers, turkeys, eggs, and milk. For model crop and livestock commodities, POLYSYS simulates the impacts of changes from the baseline upon a variety of national crop and livestock supply and demand variables including planted and harvested acreage, yield, production, exports, costs of production, demand by use, farm price, cash receipts, government program outlays, and net realized income. In addition to estimation of national level variables, POLYSYS also estimates model crop planted and harvested acreage, production, prices, government program participation and payments, production expenses, and net returns for 305 geographic regions with relatively homogeneous production characteristics. Regional POLYSYS variables may also be aggregated to 48 individual states or ten USDA production regions.

What is the Role of POLYSYS?

Agricultural policy researchers have been confronted with the need to provide timely, cost-effective answers to a myriad of questions spanning multiple disciplines, so that analytical results may be used as inputs in the policy- and rule-making processes of legislatures and implementing agencies. Ideally, impact assessments which address these broad, evolving demands would examine all market linkages and consider efficiency and equity issues. Such comprehensive research inevitably requires vast resources and time. On the other hand, limiting the scope of quantitative analysis to narrowly-defined impact areas and policy alternatives which are only incrementally different from current policy can result in relatively quick and inexpensive analyses; but such a limitation of the scope of policy analysis neither helps policymakers weigh the trade-offs associated with policy options nor allows researchers to study the underlying causal relationships.

Fitting between the two extremes, POLYSYS offers analysts and researchers a core modeling framework that can be expanded as necessary to serve a variety of analytical needs. The core POLYSYS framework can simulate incremental changes in a variety of policy, resource, or other conditions to produce supply, demand, and income impact estimates quickly and with relatively few resources. POLYSYS is also capable of considering environmental impacts, a wide range of region-specific management practices and commodities, community and industry economic impacts, crop derivative products, and multi-year production cycle commodities. While such capabilities are always available in POLYSYS, they require more time, data, and resources to implement. Thus, analysts may tailor the modeling framework to balance the particular need for timely estimates using minimal resources with the need for in-depth systems analysis.

Relationship to Other Agricultural Modeling Tools

POLYSYS is one of several tools available to provide information about the U.S. agricultural economy and useful for policy analysis.[2]

Public and private
Firm level to global
Comprehensive and data-intensive to commodity-specific
Spatial level of detail
Solution methods

POLYSYS is most closely related to a group of national and international large-scale, comprehensive quantitative models of the agricultural sector. Among this group of models are (*a*) FAPSIM, the major USDA in-house national agricultural sector simulation model, (*b*) CARD LP, a regional linear programming model of crop and livestock production in the United States developed and maintained by the Center for Agricultural and Rural Development at Iowa State University, (*c*) FAPRI, an econometric-simulation model of agricultural supply, demand,

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[2] A workshop devoted to describing and applying major national agricultural models in use in the late 1980's was held in 1988 and led to the publication of *Agricultural Sector Models of the United States: Descriptions and Selected Policy Applications*, edited by Taylor, Reichelderfer, and Johnson (1993).

and trade in major trading countries developed and maintained by the Food and Agricultural Policy Research Institute, at the University of Missouri, (*d*) ASM, a national macroeconomic agricultural simulation model developed and maintained by Texas A&M University, (*e*) AGSIM, a regional econometric-simulation model of crop and livestock production in the United States with stochastic and nonstochastic versions, developed by Taylor while at the University of Illinois (*f*) AGMOD, a national econometrically-based simulation model of crop and livestock production in the United States.

The set of available tools includes both publicly and privately developed global, national macroeconomic, input/output, general equilibrium, and sector-specific models. Some modeling tools are comprehensive and data-intensive, while others are commodity or sector specific (e.g., Taylor, Reichelderfer, and Johnson, 1993). A wide range of agricultural sector models are currently available to conduct policy analysis. This section attempts to place POLYSYS in context with other available agricultural sector models, highlighting primary similarities and differences. It would be convenient if all agricultural sector models were cataloged and easily compared and contrasted. But entire conferences, books, and careers have been devoted to the task, and all concur that the task is very difficult, at best. This section does not attempt to analyze major agricultural sector models. However, it does attempt to briefly highlight some important features of some of the models most commonly used for agricultural sector analysis for the purpose of placing POLYSYS in the context of other available modeling efforts.

In general, interregional activity analysis models, or national LP models, are useful for evaluating certain policies that lead to changes in yield, production costs, or resource availability that are far outside the range of recent experiences (re-word). However, they do not have a good track record of accurately estimating the aggregate consequences of policies that result in relatively small (i.e., less than 15%) changes in crop yield or production costs, or in evaluating some of the finer points of changes in farm program parameters (Taylor, 1992, p. 32 in TRJ).

Organization of the POLYSYS Overview

This publication is intended to provide a non-technical presentation of (*a*) the historical development of POLYSYS, (*b*) the present structure of the modeling framework, and (*c*) appropriate uses of POLYSYS.[3] In the next section, the paper describes the historical development of the present POLYSYS modeling framework and the primary precursor models that contributed toward the present model. The section also presents a brief description of key features of the present modeling framework and provides some context for POLYSYS as one of several macro models of U.S. agriculture. Section 3 then presents a general description of the core components of the model, which is structured as a set of interdependent crop supply, crop demand, livestock supply and demand, and agricultural income modules. This is followed by a brief description of add-in POLYSYS modules which may be enabled to consider a variety of region-specific resources, management practices, commodities and derivative products, environmental impacts, and community economic impacts. Also presented is a description of POLYSYS data requirements and data sources, along with a description of the APAC Budgeting System (ABS), a tools to organize and manage input data. Section 4 provides a sampling of POLYSYS applications and discusses uses of the model. The final section summarizes key characteristics of POLYSYS.

MODEL DEVELOPMENT 2

Development of the POLYSYS modeling framework has been a joint effort among the University of Tennessee's Agricultural Policy Analysis Center, the U.S. Department of Agriculture's Economic Research

[3] Companion publications providing a formal documentation of the model and a technical guide for users of POLYSYS are also available (Ray, et al., 1997; Tiller, De La Torre Ugarte, and Ray, 1997). Publications detailing the interaction of the Environmental Policy Integrated Climate (EPIC) model and the APAC Budgeting System (ABS) with POLYSYS are forthcoming. Therefore, extensive detail in these areas is omitted from this publication.

Service, and Oklahoma State University's Great Plains Agricultural Policy Center. The current POLYSYS framework has roots in models that began to emerge in the early 1970's, and is continually undergoing expansion and refinement. POLYSYS operates as an umbrella framework, facilitating the interaction of core crop and livestock supply, demand, and income modules, and capable of incorporating additional modules such as regional crop rotation, environment, crop derivative products, energy crops, and community economic impacts. Although the entire framework is collectively the POLYSYS model, disaggregating it by individual modules provides both historical understanding of the model's development, as well as further insight into the organization and structure of the larger modeling framework.

The primary precursor models in which POLYSYS has its roots are (1) the Policy Simulation Model (POLYSIM), a collection of national crop sector, livestock, and agricultural income econometric models, and (2) the Regional Allocation Summary System (RASS), a regional linear programming model of the crop supply sector. The core of the POLYSYS modeling framework is based on earlier versions of these two models.

Policy Simulator (POLYSIM)

The econometric model from which the national demand, livestock, and income modules of POLYSYS were developed is POLYSIM, which was used extensively by the U.S. Department of Agriculture's Economic Research Service during the mid- to late-1970s prior to their development of the Food and Agriculture Policy Simulator (FAPSIM) model. POLYSIM was composed of national crop sector, livestock, and agricultural income models (Ray and Moriak, 1976; Ray and Richardson, 1978; Banker, 1981; Ray, 1993). POLYSIM was designed to solve quickly and provide cost-effective estimates of changes in policies on a set of farm program variables. POLYSIM estimates changes in endogenous variables using elasticities in more than 300 equations. The use of elasticities in POLYSIM allows simulations to be performed using relatively few parameters and exogenous variables. "POLYSIM streamlines the simulation process by focusing only on the response parameters most pertinent to agricultural policy analysis (Ray, 1993, p. 12)."

Simulations performed by POLYSIM are linked to a five- to ten-year baseline such as those provided by USDA, FAPRI or CBO. Use of a baseline approach not only allowed POLYSIM to employ a slimmer analytical process, but once the model was calibrated to a baseline, the analysis focused solely on changes introduced by alternative policies. Thus, POLYSIM analyses should be thought of essentially as policy-induced shifts away from the baseline in use for a particular simulation.

Regional Allocation Summary System (RASS)

The linear programming (LP) model which originally formed the basis for POLYSYS' regional supply module is the Regional Allocation Summary System (RASS). In its early versions, RASS estimated the crop acreage, production, price, production cost, yield, and erosion rate for 105 sub-areas of the United States (Dicks and Li, 1987; Dicks, 1990). RASS originally was developed as a smaller scale version of the National Inter-Regional Linear Programming Model (NRLP), developed to estimate impacts of a single policy change (Huang, et al., 1988). Optimal NRLP solutions – which reflect policy-driven, resource-allocation changes – were summarized into RASS's series of commodity and sub-area spreadsheets. Then, each sub-area was optimized. To maintain the reliability of RASS, the larger NRLP model had to be solved periodically to update the set of optimal solutions. An alternative would have been to independently collect annual average yield, cost, and acreage data for each sub-area, which would have been very resource and time consuming (Dicks and Li, 1987). This summarizing process provided quicker solutions than running the NRLP alone, and RASS, too, utilized the baseline approach in its linkages with NRLP.

Evolution of POLYSYS

The merger of POLYSIM's demand projections and RASS's estimation of supply allocation stemmed in part from changes in agricultural policy and the demands of policymakers as well as the structural characteristics of each model. POLYSIM alone was an appropriate model as long as national estimates were all that was desired by analytical consumers. RASS was appropriate as long as the distribution of production was the central concern of analytical consumers.

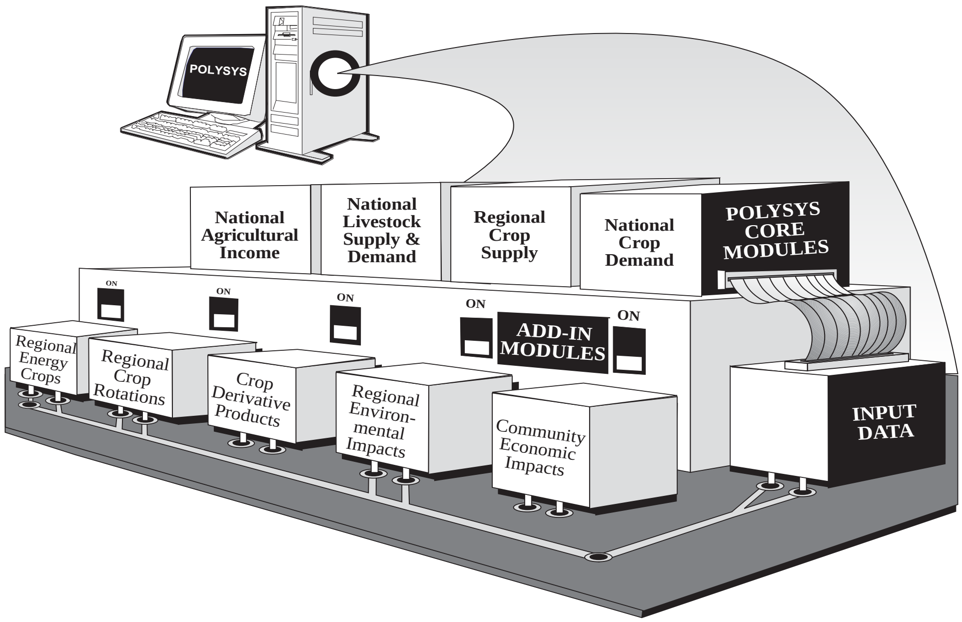
But policy concerns grew broader during the 1980s, as policy instruments were no longer the primary explanatory variables describing changes in agricultural production and income. Market forces, comparative advantages, and regional variations have become increasing important factors in U.S. agriculture. With the increasing complexity of the U.S. agricultural policy environment, the need for a more comprehensive, quantitative, analytical framework with which to examine agricultural policy has become evident.

The two models were a natural analytical fit in terms of the information each required and produced. In POLYSYS, expected prices are used to estimate production responses for a particular period through a set of regional LP models. The POLYSIM-based crop demand module and livestock supply and demand module are used to estimate national demands and prices. Inclusion of regional LP crop supply models in POLYSYS also precludes the need for the production allocation information provided by the larger NRLP model. Through interaction with the demand module, sequential LP runs provide the allocation of production across 305 regions, summing to national crop production totals. POLYSYS employs the baseline concept in its simulation, producing a composite system which retains the computational ease and turn-around of its original, separate models.

Current Modeling Framework

In the early 1990's, model developers began to expand the existing POLYSIM and RASS models and organize them as a modeling framework of interdependent but highly autonomous core modules. POLYSYS can perhaps best be thought of as a core of supply, demand, and income modules, with additional modules that may be enabled or disabled depending upon the issues being addressed by the analyst. The core POLYSYS modules, add-in modules that may be enabled to enhance a POLYSYS simulation, and POLYSYS data sources are presented in Figure 1. The core POLYSYS modules required to conduct a simulation include national livestock supply and demand, regional crop supply, national crop demand, and national agricultural income. Available add-ins include a regional crop rotation module, regional environment module, regional energy crops module, national crop derivative products module, and community economic impact module. Each of these modules is described in more detail in Section 3.

Figure 1. POLYSYS Modeling Framework Core Modules and Add-In Modules.



<u>Commodities</u>

Core POLYSYS modules endogenously consider eight model crops and seven model livestock categories. Model crops include major crops which comprise the bulk of U.S. crop production: corn, soybeans, wheat, cotton, grain sorghum, oats, barley, and rice. For these eight crops, market impacts are endogenous in POLYSYS. An add-in crop derivative products module is available to disaggregate demand for some model crops by derivative products including soybean oil, soybean meal, peanut oil, and corn oil. Add-in modules that expand the capabilities of the core crop supply module are also able to consider up to 15 crops for each of the 305 production regions. This second category of crops includes those which may be of regional significance or which may play a key role in the definition of crop rotations, but whose market impacts are not endogenous in the modeling system. These crops may include tobacco, peanuts, leguminous hay, non-leguminous hay, and switchgrass, among others. A national livestock module links crop supply to livestock supply and demand. The livestock module explicitly considers seven livestock categories: beef, pork, lamb and mutton, broilers, turkeys, eggs, and milk.

Geographic Resolution and Levels of Aggregation

Livestock supply and demand, crop demand, and agricultural income are estimated nationally by POLYSYS. Crop supply is estimated regionally for 305 production regions corresponding to Agricultural Statistic Districts (ASDs). While regional estimates may be aggregated for any combination of the 305 POLYSYS regions, production and environmental variables are most commonly reported at the POLYSYS region level, by state, by the ten USDA production regions, or nationally. A map of the continental United States by POLYSYS production regions is presented in Figure 2.

Figure 2. Continental United States by POLYSYS Production Regions.

Baseline Approach

The POLYSYS framework is designed to anchor its analyses to a published baseline of projections. The published baselines compatible with POLYSYS and most commonly used for POLYSYS analysis include those of the USDA, FAPRI, or CBO. Published baseline projections are derived from a series of assumptions regarding existing agricultural policies, economic conditions, weather, technological change, and other factors that influence U.S. agriculture. One or more change in baseline policies, economic conditions, resource situations, input-substitution scenarios, or other baseline assumptions is then exogenously imposed. A POLYSYS simulation estimates the impacts that imposed deviations from the baseline will have on agricultural supply, demand, prices, and income. The projection period for a POLYSYS analysis is directly related to the projection period of the relevant baseline for the analysis. Baselines are generally five- to ten-year projections, allowing POLYSYS to simulate a five- to ten-year projection period. However, 25-year projections have been estimated and longer intervals may be supported.

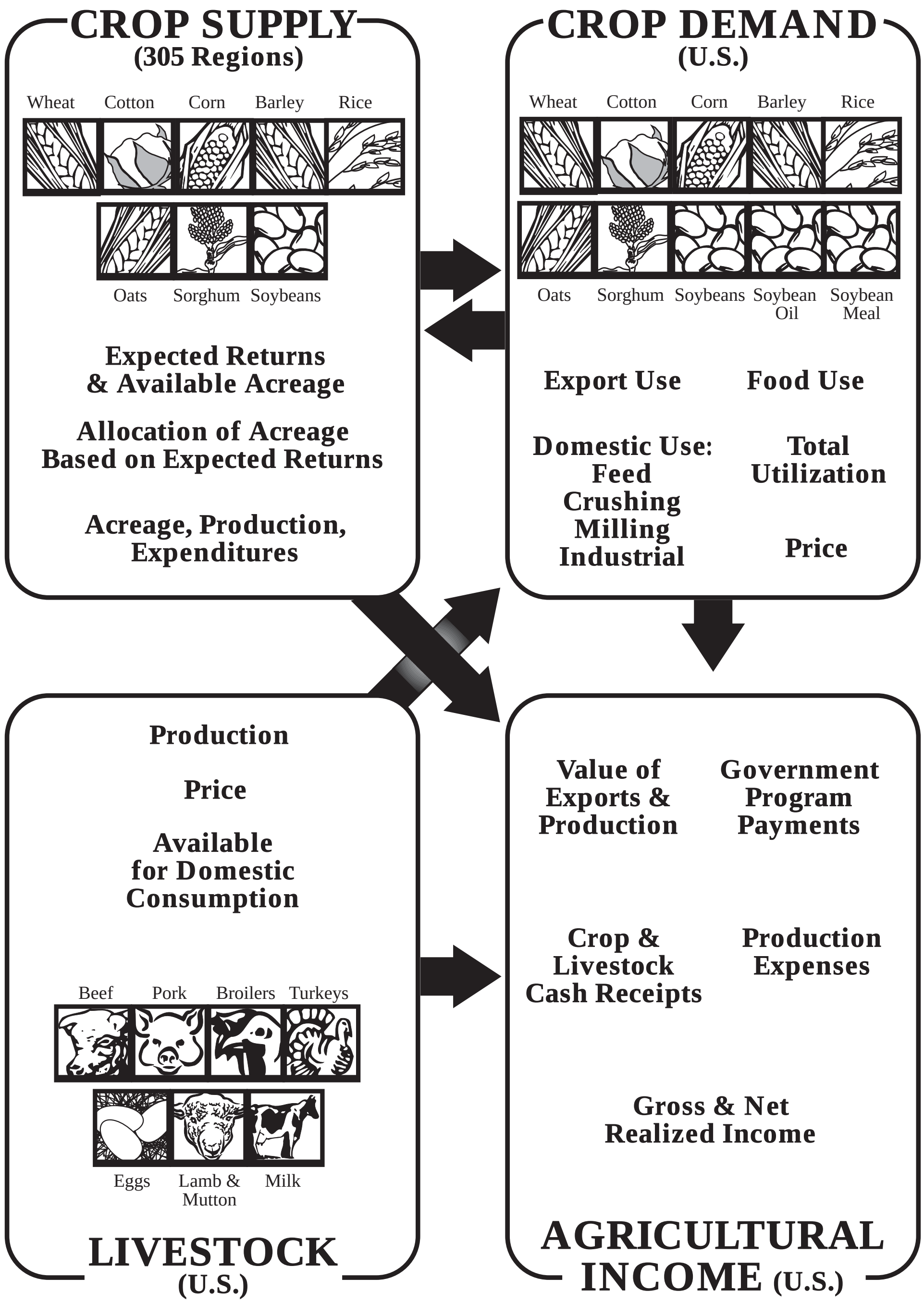
3 POLYSYS MODULES

Core POLYSYS Modules

As shown in Figure 1, the core POLYSYS modules include national livestock supply and demand, regional crop supply, national crop demand, and national agricultural income. Operationally, a POLYSYS simulation incorporates numerous identity equations, 305 regional linear programming (LP) crop supply models, and a crop demand and price simultaneous block to recursively estimate supply, demand, price, and income variables over the simulation period. Thus, a POLYSYS simulation yields a dynamic performance path for all model variables. The calculation of most variables is driven by deviations from a baseline and elasticity parameters.[4] The basic functions and interactions of the four core modules are presented in Figure 3.

Figure 3. Basic Functions of and Interactions Among POLYSYS Core Modules.

[4] A formal documentation of the core POLYSYS modules, their organization, and underlying computational procedures is available in Ray et al., 1997.


CROP SUPPLY
(305 Regions)
Wheat
Cotton
Corn
Barley
Rice
Oats
Sorghum
Soybeans
Expected Returns & Available Acreage
Allocation of Acreage Based on Expected Returns
Acreage, Production, Expenditures
CROP DEMAND
(U.S.)
Wheat
Cotton
Corn
Barley
Rice
Oats
Sorghum
Soybeans
Soybean Oil
Soybean Meal
Export Use
Food Use
Domestic Use: Feed Crushing Milling Industrial
Total Utilization
Price
Production
Price
Available for Domestic Consumption
Beef
Pork
Broilers
Turkeys
Eggs
Lamb & Mutton
Milk
LIVESTOCK
(U.S.)
Value of Exports & Production
Government Program Payments
Crop & Livestock Cash Receipts
Production Expenses
Gross & Net Realized Income
AGRICULTURAL INCOME (U.S.)

National Livestock Supply and Demand Module

The objective of the livestock module is to estimate national production, demand, and prices for seven livestock commodities. The model livestock commodities endogenously considered by POLYSYS include beef, pork, broilers, turkeys, eggs, lamb and mutton, and milk. Due to the length of livestock production cycles, production of any livestock category in a given simulation year is determined by lagged livestock prices and production input prices. Baseline and predetermined production and prices interact with production elasticities to estimate production of model livestock commodities. Because livestock ending stocks are minimal, domestic demand is equivalent to the quantity available for domestic consumption. Since livestock imports and exports are exogenous to the model, the quantity of livestock commodities available for domestic consumption is calculated as the level of production adjusted for imports and exports. These estimates are then combined with direct and cross price flexibilities to estimate prices for each livestock commodity. Indices of livestock prices and production are later used by the crop demand and income modules to estimate feed demand, cash receipts, and production expenditures.

Regional Crop Supply Module

The crop supply module estimates production of corn, grain sorghum, oats, barley, wheat, soybeans, cotton, and rice. As noted earlier, factors influencing crop production vary subnationally. Therefore, crop production is estimated for 305 production regions. POLYSYS regions correspond to Agricultural Statistic Districts and are geographically defined areas with relatively homogeneous crop production characteristics. Initially, POLYSYS uses baseline and exogenous variables to estimate average expenditures per acre, price expectations, government program participation (as appropriate), and expected returns for a simulation period. Using this data, POLYSYS then makes a portion of baseline acreage available to 305 regional LP models to allocate among competing model crops based on expected net returns. Upon allocation of marginal changes in acreage over the baseline, the supply module estimates regional planted and harvested acreage, total variable and cash expenditures, acreage enrolled in government programs, and production. Regional crop supply variables are then aggregated over all 305 regions to estimate national crop acreages, production, and expenditures. Crop supply estimates are used by the crop demand module in the estimation of crop prices, and also by the income module in the estimation of value of crop production, government program outlays, crop cash receipts, and production expenditures.

National Crop Demand Module

The crop demand module in POLYSYS estimates demand by use and prices for eight model crops and two crop derivative products. Crops endogenously considered include corn, grain sorghum, barley, oats, wheat, soybeans, cotton, and rice. Crop derivative products considered include soybean oil and soybean meal. The demand module combines estimated demand elasticities, price flexibilities, exogenous, and baseline variables to estimate prices and demands by utilization – export demand, food demand, and domestic demand (including demand for feed, crushing, milling, and industrial uses). Crop demands and prices are estimated recursively as a simultaneous block. Estimated national prices are then returned to the crop supply module where they are used to estimate regional market prices for 305 regions.[5]

National Agricultural Income Module

The national agricultural income module utilizes crop supply, crop demand, and livestock module estimates to calculate gross and net realized agricultural income. The income module calculates national crop and livestock cash receipts, production expenses, and relevant government program payments for individual model crops and livestock commodities and also for aggregate model crops and aggregate model livestock commodities. Finally, model crop and livestock receipt, payment, and expense estimates are combined with exogenous non-model crop and livestock receipt, payment, and expense estimates to yield net realized agricultural income.

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[5] Estimates of national crop prices are also used by the supply module to estimate crop year deficiency payments, as appropriate.

POLYSYS Add-In Modules

The core POLYSYS modules are designed to quickly estimate impacts of changes from the baseline for a set of commonly-needed supply, demand, price, and income variables. Depending upon the complexity of the changes being simulated, the core POLYSYS model can be assembled in a matter of minutes and the actual simulation can be performed in a matter of seconds. While quick estimation of a wide variety of baseline shocks is an advantage of POLYSYS, the capability to broaden the scope of a simulation beyond consideration of the core model elements – supply, demand, price, and income for eight model crop and seven model livestock categories – further extends the contributions of POLYSYS as a quantitative decision support and analysis tool. Five add-in modules are currently available to extend the simulation capabilities of the core POLYSYS modules: a crop derivative products module, a regional crop rotation module, a regional environment module, a regional energy crops module, and a community economic impacts module. Each of the add-in modules is always available to POLYSYS, but must be enabled by the modeler to interact with the core modules.

Crop Derivative Products Module

The crop demand module in POLYSYS estimates demand by use and prices for eight model crops. By enabling the crop derivative products module, the model core crop demand module is expanded to estimate demands and prices for model crop derivative products as it simultaneously estimates model crop demands and prices. Derivative products currently available include soybean meal, soybean oil, peanut oil, and corn oil. When the module is enabled, the crop demand module is expanded to simultaneously estimate demands by use and prices for all model crops as well as demands by use, effective supply, prices, and crushing margins for derivative products.

Regional Crop Rotation Module

In each simulation period, the core regional crop supply module calculates an average variable expenditure per acre for each crop in each region. This cost of production is netted from the expected value of production for that crop and region (expected price times expected quantity). The regional LP models then allocate available acreage in each region to model crops based on expected returns in that region. The core supply module draws upon the Farm Costs and Returns Survey to estimate costs of production for each crop and region (ERS, 1992).

The regional crop rotation module replaces the core module's 305 regional LP models with an alternative set of 305 regional LP models capable of allocating available acreage among model crops and a set of secondary crops determined to be of regional or rotational significance. The add-in LP models are capable of handling dry and irrigated land and up to 40 rotational activities. Thus, acreage is allocated among not only model crops and other regionally important crops, but across a variety of management practices or rotations that are relevant for that region. Enabling the regional crop rotation module requires a significant level of region-specific crop, rotation, management practice, and cost of production data. While such data can be supplied from a variety of sources, the POLYSYS add-in data module, APAC Budgeting System (ABS), is most commonly used to provide rotational and budget data and is discussed in the following section.

Regional Environment Module

The environment module employs the Environmental Policy Integrated Climate Model (EPIC) (Williams et al., 1990) to generate estimates of yield, soil erosion, chemical runoff and leaching, nutrient availability, organic carbon, soil structure and PH values, water-holding capacity, pesticide indicators, and other environmental variables for a variety of regional rotations and dominant regional soils. Estimates obtained from EPIC are based on mathematical relationships between soil erosion and productivity, using available inputs and a wide range of physical characteristics to simulate soil erosion processes and their impacts on productivity. The model originally was developed to evaluate the relationship between soil erosion and crop productivity but can examine broader environmental impacts of agricultural practices (Jones et al., 1991; Dyke et al., 1992).

The environment module add-in works in conjunction with the regional crop rotation module to augment the core crop supply module. The environment module further extends the LP model to consider not only a variety of regional rotations, but also a variety of soil types dominant in that region. For any given rotation, the environment module allows calculation of yield differences across soil types. For any given rotation on any soil in that region, the environment module also provides a set of per unit environmental indicators including nutrient runoff and leaching, chemical risk, soil erosion, and final carbon, among others. Once the augmented supply module allocates available acreage among rotations on various soils, these environmental indicators may then be calculated for that region. The regional crop rotation module add-in can be enabled independent of the environment module, but the environment module can only be enabled in conjunction with the regional crop rotation module. Data required for the environment module is most commonly provided by the POLYSYS data module, ABS.

Regional Energy Crops Module

Similar to the regional crop rotation module, the regional energy crops module extends the core crop supply module by modifying the regional LP models to consider a wider variety of crops – energy crops in this case – grown according to a variety of rotations and management practices. The primary difference between this module and the regional crop rotation module is the time horizon associated with crop production cycles. The crop rotation module can consider multi-period crop rotations. However, each period within a rotation is a complete production cycle. Some of the energy crops considered by the regional energy crops module – for example, hybrid poplars and hybrid willows – are characterized by multi-period production cycles. Thus, the regional energy crops module add-in further modifies the regional LP models to allocate available acreage over model crops and energy crops grown using various rotations and management practices, and over multi-period production cycles. The environment module can also be implemented in conjunction with the regional energy crops module to consider various soils dominant in a given region and to track performance of various environmental indicator variables.

Community Economic Impacts Module

When enabled, variables estimated in the agricultural income module are fed to the community economic impacts module, which is an input-output model used to describe the flow of goods throughout a predefined economy and trace and accumulate community and industry impacts. The module employs the Impact Analysis for Planning (IMPLAN) model and measures direct, indirect, and induced economic activities among economic sectors using input-output accounts. Estimates are provided at a regional, state, or county level. Estimated changes in final commodity demand are distributed among industries within a sector and across economic sectors according to IMPLAN-calculated response coefficients for each commodity. Response coefficients behave similarly to multipliers and are created by adjusting technical coefficients to define the change in economic activity attributable to a final demand-induced change in total gross output.

POLYSYS Data Sources

A POLYSYS simulation involving only core supply, demand, and income modules requires relatively little exogenous data beyond an external baseline, crop cost and return data for the regional LP models, and data that may be required to impose a shock to the baseline. While incorporation of add-in modules can broaden the scope of a POLYSYS analysis, they can also increase the data requirements significantly. This section identifies the major POLYSYS data requirements. While required data may be obtained from a variety of sources, this section also identifies the most widely used sources of data for POLYSYS.

Table 1 presents. In addition to published data, an extensive list of individuals with narrowly-defined fields of specialization have provided data and collaborated to review data as necessary.

Data Needed	Source of Data	Data Instrument
Baseline for U.S. agriculture	USDA	USDA Baseline
	Food and Agriculture Policy Research Institute (FAPRI)	FAPRI Baseline
	U.S. Congressional Budget Office (CBO)	CBO Baseline
Crop rotations		National Resource Inventory (NRI) Cropping Practices Survey
	Economic Research Service (ERS), USDA; National Agricultural Statistics Service (NASS), USDA	Farm Cost and Returns Survey (FCRS)
Regional dominant soils		GRASS STATSGO
Land uses, acreage	USDA	Conservation Reserve Program (CRP)
Crop, livestock cost and return data	NASS, USDA; ERS, USDA	Costs of Production

APAC Budgeting System (ABS)

To facilitate the accumulation and management of required data, a data module is currently available as a POLYSYS add-in.

Several of the add-in modules require a significant level of region-specific data. In particular, the regional crop rotation module and the energy crops module require region-specific crop, rotation, management practice, and cost of production data. In addition, the environment module requires specification of detailed operations schedules, which include information on dates of operation, equipment, and the amounts and dates of fertilizer, insecticide, herbicide and other chemical applications. While such data can be supplied by a variety of sources, the POLYSYS add-in data module, APAC Budgeting System (ABS), is most commonly used to provide rotational and budget data and is directly linked to the POLYSYS modeling framework.

ABS uses internal databases to generate detailed field operations schedules and associated per-acre crop production costs for all production systems considered in a POLYSYS analysis. Once a set of rotations and soils has been determined to be relevant for a given region, ABS is used to produce associated budgets containing production costs and returns, labor requirements, operations schedules, input use levels, levels of crop residue, and nutrient contributions from leguminous crops and manure applications. ABS includes databases for machinery, labor costs, chemical prices, application rates and rotation restrictions for herbicides and insecticides, and fertilizer and seed prices.

POLYSYS APPLICATIONS 4

To provide further information about how the POLYSYS modeling framework may be useful for policy analysis and impact estimation, this section identifies several diverse applications of the modeling framework. The purpose of this section is to present a sampling of the range of POLYSYS applications and to demonstrate how POLYSYS output may be organized to provide useful information for policy analysis and impact evaluation. Applications are presented involving only core POLYSYS modules, as well as more in-depth applications involving add-in modules to expand the model's capabilities.

Using the POLYSYS Core Modules

Impacts of Alternative Agricultural Policies

POLYSYS has been used both ex ante and ex post to project and analyze impacts of recent farm bill policies and programs (Ray, et al., 1995; Ray, 1997). Such applications have generally been at the aggregate national level to correspond with the national level of the legislation. However, some state-level analysis has also been conducted to allow comparison of the distribution of impacts.

Impacts of Unanticipated Supply Shifters

Core POLYSYS modules have been used to estimate the impacts of unanticipated shifts in supply. One example is estimation of the impacts of significant flooding in the Mid-West in 1993 (Bhat, et al., 1994; Chembezi, et al., 1993; Chembezi, De La Torre Ugarte, and Ray, 1993). For such an analysis, POLYSYS was used to generate estimates of the overall impacts on crop acreages, prices, export and domestic demand, government outlays, and net farm income. In particular, analysts were interested in the impacts to the most severely affected Mid-West region.

Impacts of Alternative Trade Scenarios

Another group of applications involving core POLYSYS modules has related to analysis of agriculture's performance under a diverse set of export and trade policy scenarios (e.g., Ray and Tiller, 1997). In such applications, analysts have focused on the impacts of alternative export projection assumptions on the quantity of export demand for individual commodities and induced effects on other commodities, as well as price, acreage, and income effects.

Implementing the Regional Crop Rotation Module

Input Sector Impacts of Sustainable Agriculture

The core POLYSYS modules were augmented by the regional crop rotation module to estimate the impacts accruing to production input sectors resulting from maximizing the use of available sustainable agricultural practices (De La Torre Ugarte, Tiller, and Slinsky, 1997). A set of sustainable agricultural practices and rotations that were currently available though not widely used was developed specific to each of the POLYSYS production regions. The crop supply models were artificially forced to maximize the use of the sustainable rotations. Resulting impacts were then estimated nationally for the hired labor, seed, fertilizer, pesticide, herbicide, and machinery services input sectors. Additionally, impacts were examined for disaggregated individual components of the six input sector categories for selected regions in the Southeastern United States. The analysis examined the causal relationships between cropping practices and crop acreage assignment and input use for selected Southeastern regions.

Implementing the Environment Module

Movement Toward A More Sustainable U.S. Agriculture

POLYSYS has been used to examine the economic and environmental impacts of movement toward a more environmentally sustainable agriculture in the United States (De La Torre Ugarte, et al., 1996a; 1996b). Under consideration were (1) the role that increased cropland production flexibility may have on the adoption of more sustainable practices, and (2) potential impacts of maximizing the use of existing sustainable production alternatives. Analysts were interested in the impacts these alternative scenarios would have on crop yields, prices, changes in crop acreage allocations, domestic and export demand, costs of production, net returns, and government program participation and costs. Environmental impacts of interest to analysts included levels of erosion, chemical use, organic carbon, nutrient availability, and nitrogen and phosphorous movement.

This application is also useful for illustrating the significance of disaggregated regional impact estimation, especially for environmental variables. One variable of interest was the level of soil erosion under a more sustainable agriculture. In the case of increased production flexibility, the eight-year average change in the erosion level over the baseline erosion level was found to be 0.01 percent – almost unchanged. At the level of POLYSYS regions, some regions were found to reduce soil erosion by as much as five tons per acre, while some regions were found to increase soil erosion by as much as five tons per acre, although regional variation was masked entirely by aggregation.

A similar analysis of the adoption of alternative production practices was also conducted, but with a more narrow focus – the Ogalala Aquifer region (USGS, 1994). Limiting the scope to a specific geographic region allowed analysts to further refine the definition of alternative practices, estimation of associated costs, and identification of environmental characteristics for the region of interest.

Impacts of Expiring CRP Contracts

Prior to the expiration of the first Conservation Reserve Program (CRP) acreage diversion contracts in 1996, POLYSYS was used to model a post-CRP-contract agriculture (De La Torre Ugarte, Ray, and Dicks, 1996; De La Torre Ugarte, et al., 1995). Analysts were particularly interested in the net changes in acreages devoted to individual crops, and the resulting impacts on production, prices, demand, and income. Since the program was initiated as a means to enhance and restore the environmental performance of agriculture, researchers also focused the analysis on future performance of environmental parameters beyond expiration of CRP contracts.

Implementing the Energy Crops Module

POLYSYS analysis has also been conducted implementing the energy crops module to estimate the potential impacts of expanded demand for energy crops including switchgrass, hybrid poplars, and hybrid willows. Regional budgets were developed for the alternative energy crops, then they were made available to the regional LP models, along with model crops, to allocate to available acreage. Need a better description here.

Implementing the Derivative Products Module

The model has been used to estimate the impacts of projected increases in alternative uses for existing crops. One example is a simulation of the impacts that a higher percentage of fuel supplied by ethanol would have on crop production, allocation of land among crops, and returns to crops and farmers (Alexander, et al., 1993). Of particular importance for such an analysis was the performance of economic and production variables for individual crops by regions to illustrate the tradeoffs associated with reallocation of a near-fixed cropland resource base and with regional comparative advantages in the production of corn.

Another example is the evaluation of the impacts of increased use of soybean oil as a substitute for petroleum-based products in fruit tree pest control (Deyton an Sams, 1996; Gary, 1996). With appropriate performance and cost data for the new use, POLYSYS was used to estimate the impacts to regional crop acreages and national demand, prices, and agricultural income.

SUMMARY 5

This section is provided to summarize the key features and characteristics of the POLYSYS modeling framework that are presented throughout this overview. Additional information regarding POLYSYS may be obtained by examining the publications cited in this overview, or by contacting the authors.

- **A systems approach to policy analysis** – POLYSYS explicitly links the performance of the agricultural sector to the performance of the environment, regional economies, and related industries.

- **POLYSYS is regional in scope** – POLYSYS can estimate agricultural production response, resource use, and environmental indicators in 305 geographic regions with relatively homogeneous production characteristics

- **POLYSYS impacts are easily interpreted** – Since most agricultural policies introduce incremental changes from the current policy environment or scenario, providing impact estimates in the context of a marginal change from a baseline scenario makes POLYSYS estimates easily interpreted and understood by decision makers and those charged with implementing and evaluating policies.

- **POLYSYS estimates a dynamic impact path** – Price and output paths associated with a specific change scenario are traceable, and the direct and indirect effects on other agricultural and nonagricultural activities can be determined.

- **Quick turnaround for analysis** – Once a baseline projection is established, POLYSYS can produce impact estimates of changes away from the baseline in as little as a few minutes using a desktop personal computer without requiring extensive technical expertise.

- **Takes advantage of prior research and expert knowledge** – Reliance on demand and supply price-response parameters, or elasticities, allows POLYSYS to incorporate the most up-to-date commodity research into its estimation quickly and easily, and speeds up estimation of a POLYSYS simulation.

- **Variable projection period** – POLYSYS generally simulates a five- to ten-year projection period; however, 25-year projections have been estimated and longer intervals may be supported.

- **POLYSYS is easily tailored to specific needs** – Although core and add-in modules are designed to work interdependently, each is characterized by a high degree of autonomy which facilitates updating a module, adding new modules, or excluding modules to tailor an analysis to a specific problem in the most appropriate and efficient manner.

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