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SPECIFICATION OF A REGIONAL-NATIONAL RECURSIVE MODEL FOR IIASA/FAP's IOWA TASK 2 CASE STUDY

Earl O. Heady
James A. Langley

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

AUTHORS

Earl O. Heady is Distinguished Professor and Director of the Center for Agricultural and Rural Development at Iowa State University, Ames, Iowa. He is the principal investigator in this study.

James A. Langley is a Research Scholar at IIASA, and a Research Associate at Iowa State University. He is the project leader in this study.

FOREWORD

The major objectives of the Food and Agriculture Program (FAP) of the International Institute for Applied Systems Analysis are to evaluate the nature and dimensions of the world food situation, to identify factors affecting it, and to suggest policy alternatives at the national, regional, and global levels to alleviate current food problems and to prevent future ones. The present shortrun problems of policy are explored in FAP's Task 1, "Strategies: National Policy Models for Food and Agriculture" by means of a set of descriptive, general-equilibrium, price-endogenous national models of various countries linked in a consistent international framework.

From a longer term perspective the food problem acquires added dimensions; and questions of availability of resources to produce adequate food, efficiency of techniques, and environmental consequences become important. These questions are addressed by FAP's Task 2 "Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences". Quantitative knowledge of the interactions between agriculture and the environment requires a great deal of detailed information on the site-specific nature of resource inputs and on alternative land use practices. A general-equilibrium approach to such types of investigation is not empirically feasible. The research methodology of Task 2 is to formulate a series of region-specific case studies within a general recursive programming framework.

The regional-national recursive model specified in this paper represents the intermediate stage of development of the Iowa Case Study. The Iowa model has been specified by a team of researchers including Dr. Earl O. Heady, James Langley, Andrew Morton, and Burton English of the Center for Agricultural and Rural Development, Iowa State University, and Wen-yuan Huang and Klaus Alt of the Natural Resources Economics Division, U.S. Department of Agriculture. Work is continuing on the specification of various components of the Iowa model along with preliminary applications in accordance with the framework of FAP's Task 2.

Kirit Parikh
Acting Program Leader
Food and Agriculture Program

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Introduction

Task 2 of IIASA's Food and Agriculture Program (FAP) is concerned with examining the important relationships between agricultural production technologies, resource use, and the environment which will affect the stability and sustainability of the global food and agricultural system in the long run. In order to carry out these investigations, a series of case studies incorporating the site-specific nature of resource inputs and environmental impacts of agricultural production in a general methodological framework have been proposed (Reneau, et al., 1981).

The specification of a model for the United States which is capable of analyzing most of the desired research questions would be prohibitively large and expensive. Hence, a decision has been made to narrow the scope of the U.S. model to focus upon the State of Iowa as one of the case studies. Necessary attention is given to Iowa's relationship within the agricultural economy of the United States.

The purpose of this paper is to present a specification of the regional-national recursive model developed for the Iowa Task 2 Study. The model presented is in an intermediate through operational form. The methodology used is flexible enough to be applied with some restructuring to other situations. It is hoped that this report will stimulate discussion and feedback which may be incorporated in future versions of this model.

The paper is divided into five parts. Part 1 describes the characteristics and importance of agriculture in Iowa. This description will help the reader establish a basic understanding of Iowa agriculture. Part 2 presents a brief review of methods of modeling regional agricultural activity and a justification for the regional-national recursive approach used in this study. Part 3 specifies the individual components of the Iowa model and the organization of the overall modeling framework. Part 4 reviews the potential applications of the Iowa Task 2 model. Finally, Part 5 discusses shortcomings of the current version of the Iowa model and suggestions for refinement.

1. Overview of Agriculture Within the State of Iowa

The geographic location of Iowa is shown in Figure 1. Iowa is one of the most important agricultural areas in the United States. The role of Iowa in U.S. agriculture and the nature of farm size and structure within Iowa are examined to gain some insights into Iowa agriculture. Some of the problems faced in Iowa concerning the relationships between agricultural production and the environment are also presented.

1.1. Importance and Structure of Iowa Agriculture

Iowa is primarily an agricultural state. Excluding government payments, Iowa farmers received $8.2 billion from farm marketings in 1978 and ranked second behind California's $10.4 billion in total cash receipts and first in livestock and livestock products with cash receipts of $5.4 billion (Iowa Crop and Livestock Reporting Service, 1979). Primary crops, produced on 90 per cent of the acres harvested in 1979, include corn, oats, soybeans, grain sorghum, wheat, and hay (Table 1). Iowa production of corn, soybeans, and oats accounted for 21, 14, and 12 percent, respectively, of national production in 1979. Iowa is also prominent in commercial meat production, particularly beef and pork. In 1979, cattle and calf slaughter amounted to 3.7 billion pounds (total-live-weight), or 10.3 percent of the national total. Iowa's share of 1979 U.S. pork production was 5.7 billion pounds (total-live-weight), or 26.8 percent of national production (Iowa Crop and Livestock Reporting Service, 1980). Iowa is also a significant producer of milk and poultry.

Yield trends in Iowa during the 1970's for the six primary crops are shown in Table 2. Yields generally advanced during the decade with the exception of sorghum. Increases in yields were led by hay and corn at 38 and 24 percent, respectively. Advances are expected to continue in the 1980's, but at reduced rates of growth, due to a variety of factors including the increased cost of fertilizer, continued soil erosion, and the increased adoption of conservation-oriented tillage practices.

The prevailing trend in Iowa and in U.S. agriculture has been for average farm size to increase and number of farms to decrease (Table 3)*. The number of farms in Iowa has decreased at about 2 percent per year between 1975 and 1980, while average farm size has increased at about the same rate leaving total land in farms basically unchanged.

A random sample of Iowa farms with 100 or more acres of land was made in 1975 by the U.S. Department of Agriculture in conjunction with a national survey to obtain data on the cost of producing major farm products (Griffins, Treffeisen, and Heady, 1978). Table 4 summarizes some of the regional differences revealed in the survey. Land area operated by a single farm unit averaged significantly larger in the west and south than in the north and east. Western Iowa farms also grossed significantly higher sales in crops and livestock than in other regions of

* A farm here is defined as a place which has annual sales of agricultural products of $1,000 or more.

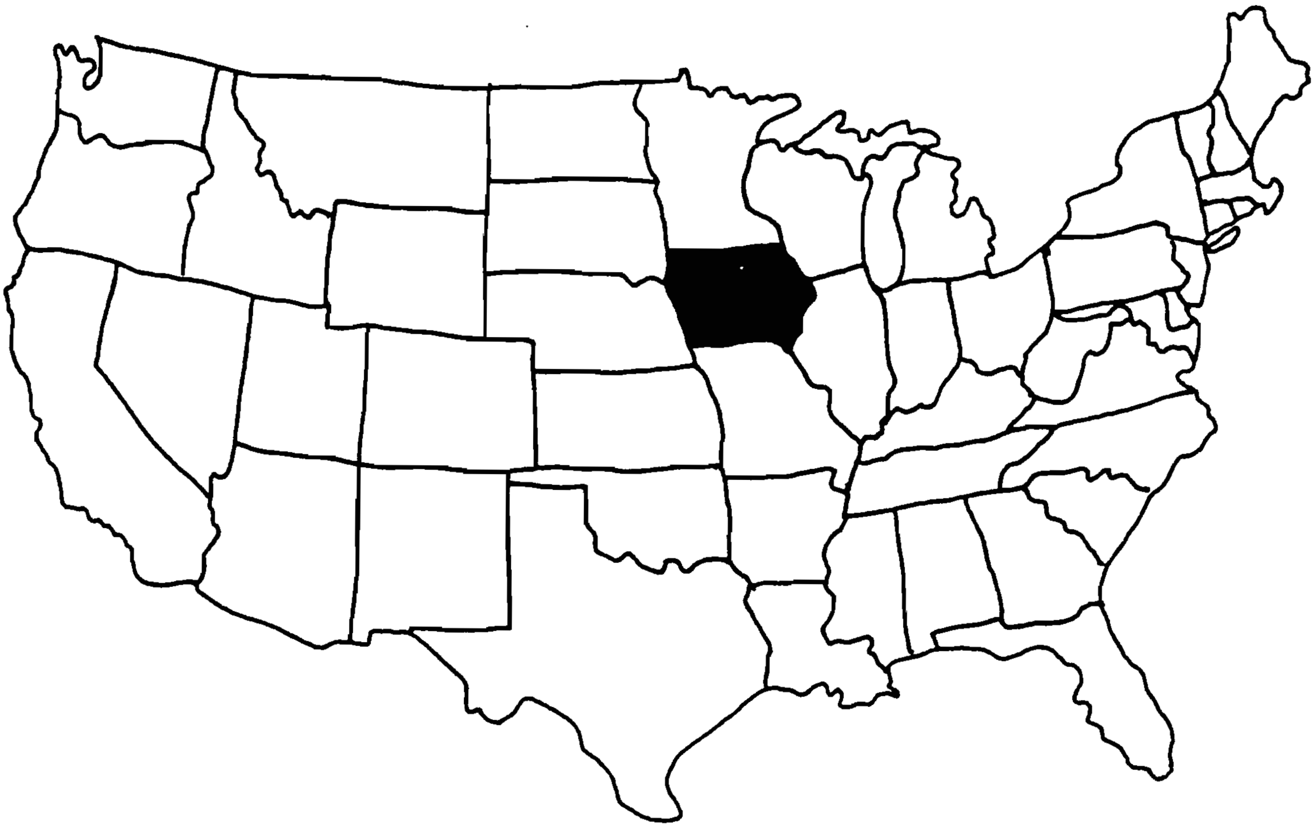

Figure 1. Geographical location of Iowa

Table 1. Harvested acreage and quantity of corn, oats, soybeans, sorghum, and wheat in Iowa and in the U.S., 1979.

Crop	Acres harvested		Quantity produced	
	Iowa	U.S.	Iowa	U.S.
	(thousands of acres)		(millions of bushels)	
Corn, grain	12,800	70,984	1,625.6	7,763.8
Oats	1,000	9,831	63.0	534.4
Soybeans for beans	8,170	70,530	310.5	2,267.6
Sorghum	19	12,949	.1	814.3
Wheat	72	62,600	2.7	2,141.7
Hay*	2,210	61,162	1.3	145.9

* Quantity produced of hay in million short tons.

SOURCE: [Iowa Crop and Livestock Reporting Service, 1980]

Table 2. Average Iowa crop yields.

Crop	Average 1970-1975 State yields	Average 1978-1980* State yields
	(bushels/acre)	
Corn, for grain	93.8	116.7
Oats	54.2	60.7
Sorghum	73.2	69.7
Soybeans	32.3	37.5
Wheat	34.4	34.7
Hay**	2.6	3.6

* 1980 yields are estimates

** Average state yield is in tons per acre

SOURCE: [Iowa Crop and Livestock Reporting Service, 1978-1980] and [English, Short, Heady, and Johnson, 1980]

Table 3. Number of farms, average size, and land in farms - Iowa and U.S.

Year	Iowa: Number of farms	Iowa: Average size	Iowa: Land in farms	United States: Number of farms	United States: Average size	United States: Land in farms
		acres	(1,000 acres)		acres	(1,000 acres)
1975	130,000	262	34,100	2,491,010	427	1,062,723
1976	127,000	269	34,100	2,454,220	432	1,059,148
1977	125,00	273	34,100	2,409,130	438	1,054,798
1978	123,000	276	34,000	2,370,050	444	1,052,018
1979	121,000	281	34,000	2,332,690	450	1,049,063
1980*	119,000	286	34,000	2,309,130	453	1,046,713

* Preliminary

Table 4. Average land operated, crop sales, livestock sales, and total horsepower hours used per farm by geographic region of Iowa.

Geographic region of Iowa	Land operated (acres)	Crop sales per farm (dollars)	Livestock sales per farm (dollars)	Total horsepower hours used per farm (thousand)
West	422	$114,392	$91,216	86
North Central and East	350	64,694	45,627	76
Northeast	341	69,964	31,649	70
South Central	438	55,770	31,055	56
State Average	376	62,940	50,773	NA

the state. Tractor horsepower hours used varied considerably by regions but not in direct proportion to average farm size. No significant regional differences were found in the age of farm operators, their years of experience, or level of formal education.

Forty-eight percent of the farm operators surveyed in Iowa had 12 years of formal education (a high school diploma) and 18 percent had some post-high school training, with the average for all Iowa farmers being 11.2 years of schooling. Education was positively correlated with most variables related to farm size.

Seventy-seven percent of the farmers surveyed in Iowa were between 35 and 64 years of age. Eighteen percent were younger than 35 and 5 percent were 65 years old or over. The mean age for the state was at the upper end of the 35-44 age group. Many variables related to farm size increased then decreased in magnitude with operator age.

The average number of tractors owned per farm was 3.3. Forty percent had four tractors and less than 3 percent had only one.

1.2. Major Resource Policy Issues in Iowa

Concern over the long run sustainability of agricultural production in Iowa is most evident by increased public attention over soil loss and land use. As English, Guernsey, and Heady maintain, "The soil loss process is now recognized as the most widespread and destructive agent involved in bringing about the rapid depletion of the fertility and productivity of our cultivated lands" (1980). The Iowa Water Quality Report states that soil loss in Iowa in 1974 was at the highest level in 25 years, with 4.5 million acres having gross loss of more than 10 tons per acre (Iowa Department of Environmental Quality, 1975). Gross loss of 40 to 50 tons per acre was not uncommon and reached levels as high as 200 tons per acre in some areas.

In order to alleviate the problem of soil loss, the Iowa Legislature has passed laws which impose limits and practices on land use (Iowa Cooperative Extension Service, 1972). The question exists of how the costs and benefits of these practices and land use limitations will be distributed if they are widely implemented, and the impact they may have upon U.S. total agricultural production.

Soil losses can be reduced by a variety of methods. Contouring and terracing with diversion structures are ones of long standing, along with strip-cropping and the use of legume- and meadow-based rotations. Additionally, various forms of reduced or conservation tillage practices have been developed and tried by researchers and farmers (Jacobsen, 1969).

Contouring and terracing have long been advocated as soil loss control measures; however, with increased use in recent years of large equipment and narrow rows, they have decreased in acceptability. Crop rotations using legumes and meadow for nitrogen and reduced soil loss are uneconomical from the view point of farmers given current commodity and input price relationships. Industrially produced fertilizer is less expensive than organic nitrogen, and the high value of cash grain crops makes it uneconomical to turn land into meadow. For reasons similar to those concerning the decline of contouring and the use of meadow-based crop rotations, the use of strip cropping has also been cut back in areas where it was once common (Palmini, Taylor and Swanson, 1977). However, changes in the availability and relative price of inputs and other economic factors could change the farmer's incentive to adopt soil-saving practices.

Closely associated with the problem of soil loss is the issue of nonpoint pollution. Sediment is a pollutant which "occupies space in reservoirs, lakes, and ponds; restricts streams and drainage-ways; reduces the recreational and consumptive use value of water through turbidity; and increases water treatment costs. Sediment also carries other water pollutants such as plant nutrients, chemicals, radioactive materials, and pathogens" (Johnson and Moldenhauer, 1970). For instance, suspended sediment concentrations found in the Iowa River have ranged from 9 to 4,700 mg. per m^3 in recent years (Iowa Department of Environmental Quality, 1975). It is important to identify and quantify the economic effects of attempts to reduce the sediment contribution from agricultural land use. Previous studies of soil erosion and conservation in Iowa provide a substantial background of information on which the present study benefits (Alt and Heady, 1977, and Nagadevara, Heady, and Nicol, 1975).

2. Regional Approaches to Agricultural Modeling

Several methods of analyzing regional economic behavior have been developed. This section briefly reviews common approaches to regional modeling and discusses the potential advantages of the Regional-National system.

2.1. Typical Forms of Regional Modeling

Regional models have typically been developed along one of three spatial delineations: single region, subnational multiregion, or national multiregion. Single region models, for example, models of a single state or political subdivision, are beneficial to economic planning and analysis, but have two significant limitations (Ballard and Wendling, 1980). First, single region models are often not applicable to specific site studies because the scope of the site studies will often determine the geographic configuration of the region. For example, national government policies usually transcend state boundaries, or, land and water resources are generally not restricted to individual regions. Second, single-region models do not provide information about the impact outside the region, such as, how state land use restrictions will affect total national production and commodity price levels.

The subnational multiregional approach (e.g., models of the Cornbelt in north central United States) allows the potential for spatial analysis; however, subnational models are limited, since they still operate in an "open" economic system. While an impact can be measured in an adjacent region within the model, the extraregional impact (rest of the nation) is often ignored.

National multiregional models have effectively closed the economic system by measuring impacts for all regions in the Nation. However, they tend to place little direct emphasis on individual regional production activity, but rather allocate shares of national production to each region. There is little or no feedback from the various regions of the Nation.

The appropriateness of the type of analysis (single-region, subnational or national multiregion) is dependent upon the assumptions and purpose which the researcher has in mind. Without adequate insight into the particular research problem under consideration and the limitations of each modeling technique, there is always a danger in applying the "wrong" model to the collected data. "If the only tool you have is a hammer, you tend to treat everything as though it were a nail".

2.2. The Regional-National Approach

Typically, econometric models are not applicable to situations of highly disaggregated regional models because they presuppose the availability of time series on both the endogenous and exogenous variables. Most of the time one has only one, or a small set of, regional cross section observations. Hence, linear programming models are best suited for detailed representation of regional agricultural production and environmental interactions. Regional production and resource use depends in part upon relative commodtiy and resource input prices, which are determined at an aggregate national level. Hence, an econometric model is useful in estimating these relationships in a consistent national market system.

If the constraints imposed by the underlying assumptions of both linear programming and econometric models could be offset, it would appear that a benefit would be realized in terms of opening up new areas of investigative research. The regional-national recursive modeling system is an attempt to accomplish such a task. A regional-national system benefits from the integration of information on the spatial pattern of regional supply, resource use, and technical structure of production (generated by a regional programming model) with the detailed information on market structure and prices of commodities and inputs (generated by a national econometric simulation model).

There are three basic approaches to linking a regional model to an aggregate national model: top-down (Jaske, 1977; Mathematica, 1963; Heady and Srivastava, 1975), bottom-up (Schaller, 1968; Baum, 1978); and mixed methods (Meister, Chen, and Heady, 1978; Huang, Weisz, and Heady, 1980). In a top-down approach regional variables (such as crop production) are determined as shares of nationally estimated variables (such as total demand and supply). In a bottom-up approach, national variables (such as total supply of commodities) are determined by summing the level of production for each delineated region. Finally, a mixed approach arises when on the one hand the national variable (supply) is determined by a regional variable (production) while on the other hand the regional variable (production) is dependent upon a national variable (commodity price). The particular method which should be used in formulating a regional-national model depends upon the causality structure of the system (Rietveld, 1981).

Advantages can be gained from linking a regional linear programming model with a national econometric simulation model within a regional-national recursive framework. Since a system can be formulated such that only one region is explicitly modeled within a national framework, a detailed site-specific evaluation of the impacts of state and federal government policies or environmental interactions becomes practical. Problems such as soil erosion vary in intensity and concentration even across a single state. The region under study can be broken down into as many subregions as necessary to evaluate the impacts of conservation practices in different parts of the region. In general, it can be stated that the lower the level of aggregation, i.e., the smaller the average size of the regions considered (whatever the size indicator chosen), the higher the probability that explanatory variables will be located "elsewhere". The econometric component aids in estimating the variables which are not regionally determined. Also, the model can be expanded to a multiregional model of the entire Nation as resources become available and such a model is needed (e.g., Huang, et al., 1980; Langley and Heady, 1981).

A regional-national model requires the specification of three sets of data: regional variables, national variables, and linkage variables. Regional variables incorporate information determined within the regional model (e.g., production levels, input factor use, environmental variables, etc.) and can be thought of as regional responses or contributions to the national agricultural economy. Region-specific variables determine the intraregional economic activity over which the region has primary control.

National variables are those which are exogenous to particular regions, but are endogenous to the national model (e.g., aggregate commodity demand and supply, commodity and input factor prices, etc.). The level of national variables typically shows little or no variation across regions; however, the impact of these variables upon regional economic activity often varies considerably.

Linkage variables are the variables transfering information from the national model to the regional model, and vice versa. Linkage variables are selected from both regional and national variables. Regional variables frequently used for linkage are regional production and resource use, which transfers all regional production and resource use information to the national model to determine national and input factor prices. National commodity and input factor prices are frequently used as linkage variables to determine adjustment functions for regional input factor use, production response, production costs, and farm income.

The present application of the regional-national model is specified in regards to the U.S. economic system. However, changes in some underlying assumptions may allow a similar model to be specified for other economic systems as well.

3. Specification of the Iowa Regional-National Model

The regional-national recursive model developed for the Iowa Task 2 Case Study consists of three main components: a regional linear programming (LP) model for the State of Iowa, a national econometric simulation (ES) model for the United States excluding Iowa, and a linkage procedure which transfers information between the programming and econometric models. The purpose of the LP component is to determine crop production and input use occuring solely within the State of Iowa. The EM component estimates resource use and commodity output originating in the United States excluding Iowa. This section of the paper presents an overview of the regional-national recursive system, followed by a more detailed specification of the programming, econometric, and linkage components.

3.1. Overview and Logic of the Iowa Regional-National System

The potential linkages between the Iowa regional programming and U.S. national econometric simulation components which should be considered in formulating a regional-national recursive system for agricultural policy analysis is illustrated in Figure 2. The mixed approach to regional modeling is used. It is assumed that the impacts of any policy program can be translated into changes in costs of production and yields (A), or resource and institutional constraints (B). Policy instruments may be used to restrict inputs (e.g., nitrogen fertilizer) or outputs (e.g., soil loss) of the production process. Also, policy impacts upon relative price relationships may affect farmers' decisions to purchase certain inputs or to produce certain crops. Production costs and yields are adjusted (C) and used to determine the profitability of production (D). Relative price relationships among the endogenous crops are used to determine the range of regional production response through a flexibility constraint formulation (E), and to adjust the coefficients in the objective function of the regional LP model (F). The LP model then determines the regional production supply (G) and input factor demands (H). Soil loss is determined as a function of regional input

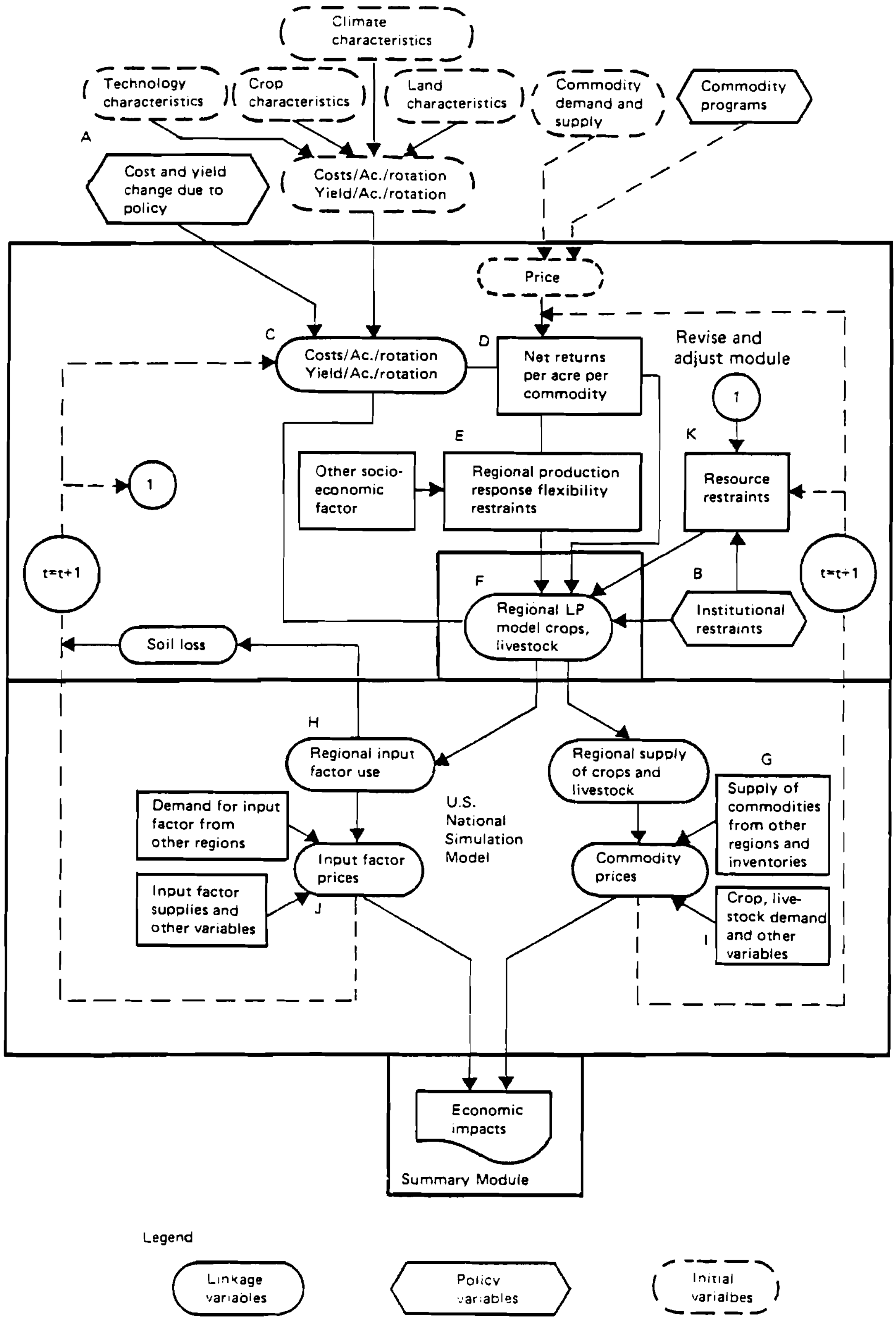

Figure 2. Structure of the Regional-National Model.

factor use (L). The production supply and factor demand subsequently determine the prices of commodities (I) and input factors (J). These prices are then used to determine production costs, yields, and net profits for the next time period (C) and resource constraint adjustments (K). The entire process is repeated until the predetermined number of simulations are completed.

Individual components of the Iowa regional-national system are discussed in more detail, beginning with the LP component. Attention will be focused upon the formulation of each component, and the role it plays in the overall modeling framework.

3.2. The Iowa Linear Programming Component

The linear programming (LP) component of the Iowa Task 2 Case Study model provides a relatively detailed representation of crop production and resource use occuring solely within the State of Iowa. The LP component may be divided into three sections: (1) an objective function which specifies the goals over which optimization is performed; (2) a coefficient matrix which maps the specified activity list into the set of constraints; and, (3) a right-hand-side (RHS) vector which sets the level of each constraint. A schematic diagram of these sections is illustrated in Figure 3.

Subregions within the State of Iowa are modeled on the basis of 12 spatially delineated producing areas (PA's), as shown in Figure 4. Each PA is an aggregation of contiguous counties within a specific soil conservancy district as defined by Iowa law (Iowa Cooperative Extension Service, 1972).

Any linear programming problem is only as accurate as its data inputs. The steps for setting up the initial Iowa LP matrix are presented in Figure 5. The primary sets of coefficients entering into the model are cost of production, nitrogen fertilizer use, crop yields, soil loss, and RHS constraint levels. The following review of the LP component presents a more complete derivation of these coefficients.

3.2.1. The Objective Function

The objective function of the Iowa model is defined to maximize the net returns from crop production subject to the availability of land and nitrogen fertilizer, and restrictions placed upon levels of soil erosion. Profit maximization is a valid assumption for the commercialized farming that predominates in Iowa. The objective function is of the form:

$$\max OBJ = \sum_{i}\sum_{n} P^{s}_{int}\, C^{s}_{int} - \sum_{i}\sum_{j}\sum_{k}\sum_{m} T_{ijkmt}\, L_{ijkmt} - \sum_{i} P^{N}\, Q^{NP}_{it} \qquad (1)$$

i = 1 to 12 for the producing areas;

j = 1 to 30 for the possible crop rotations defined for producing area (i);

k = 1 to 9 for the conservation-tillage practices;

m = 1 to 5 for the land groups;

n = 1 to 8 for the endogenous crops produced; and,

t = 1 to T for the time period in which optimization occurs.

where:

$P^{s}_{int}\, C^{s}_{int}$ = the gross return received for selling crop (C^{s}_{n}) at price (P^{s}_{n}) in producing area (i) in period (t);

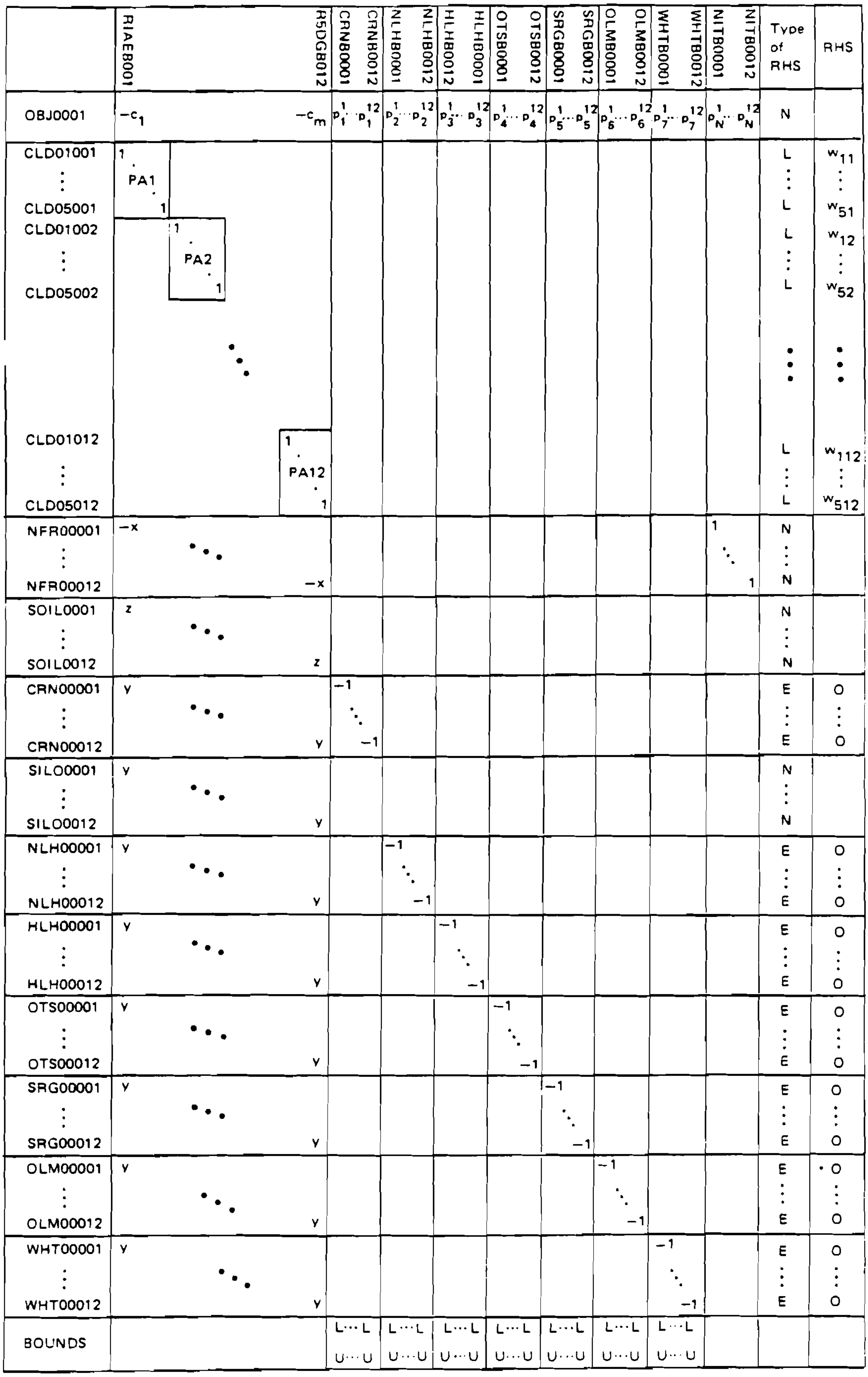

Figure 3. A schematic diagram of the Iowa linear programming component.

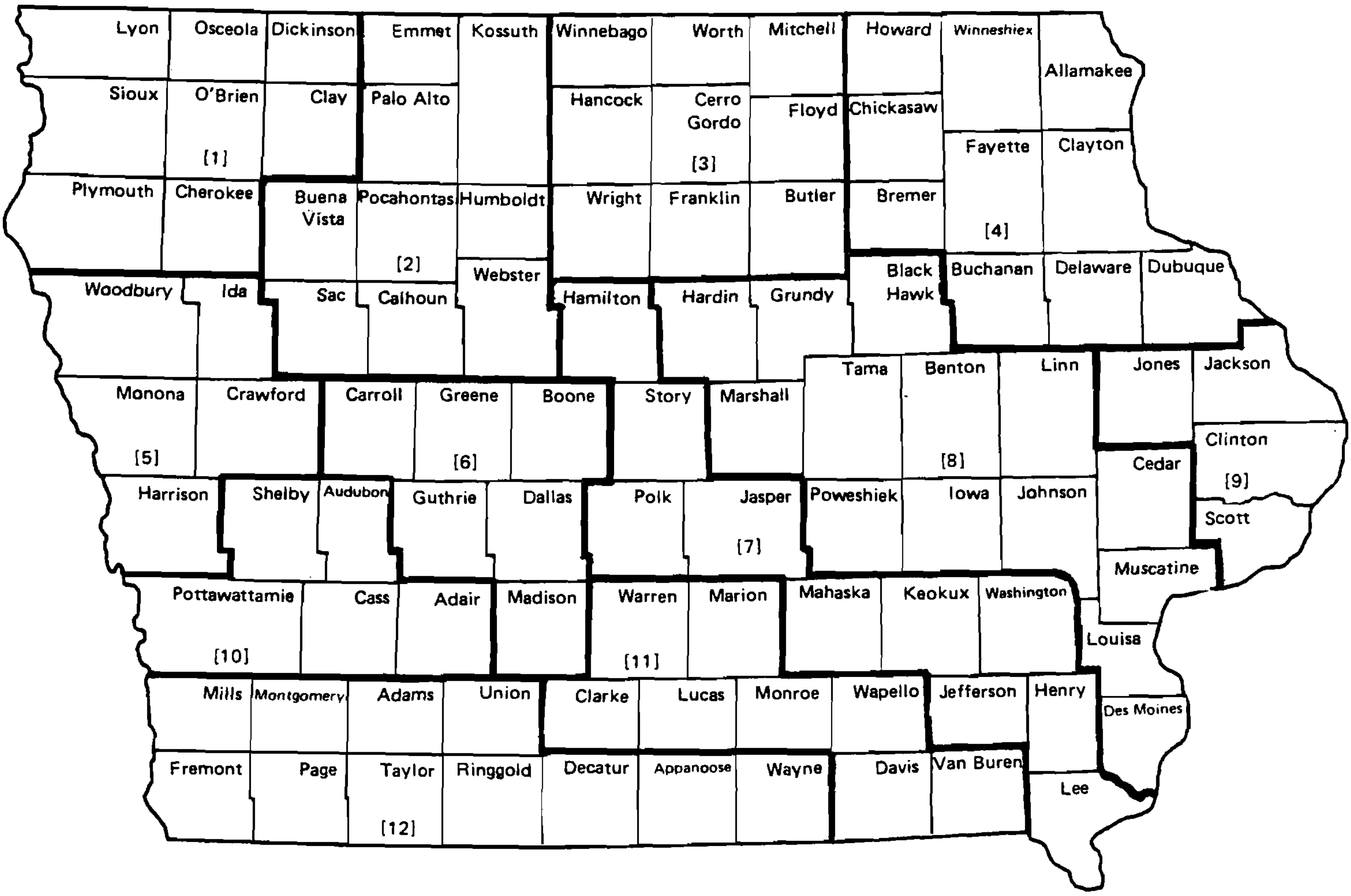

Figure 4. Iowa's 12 producing areas.

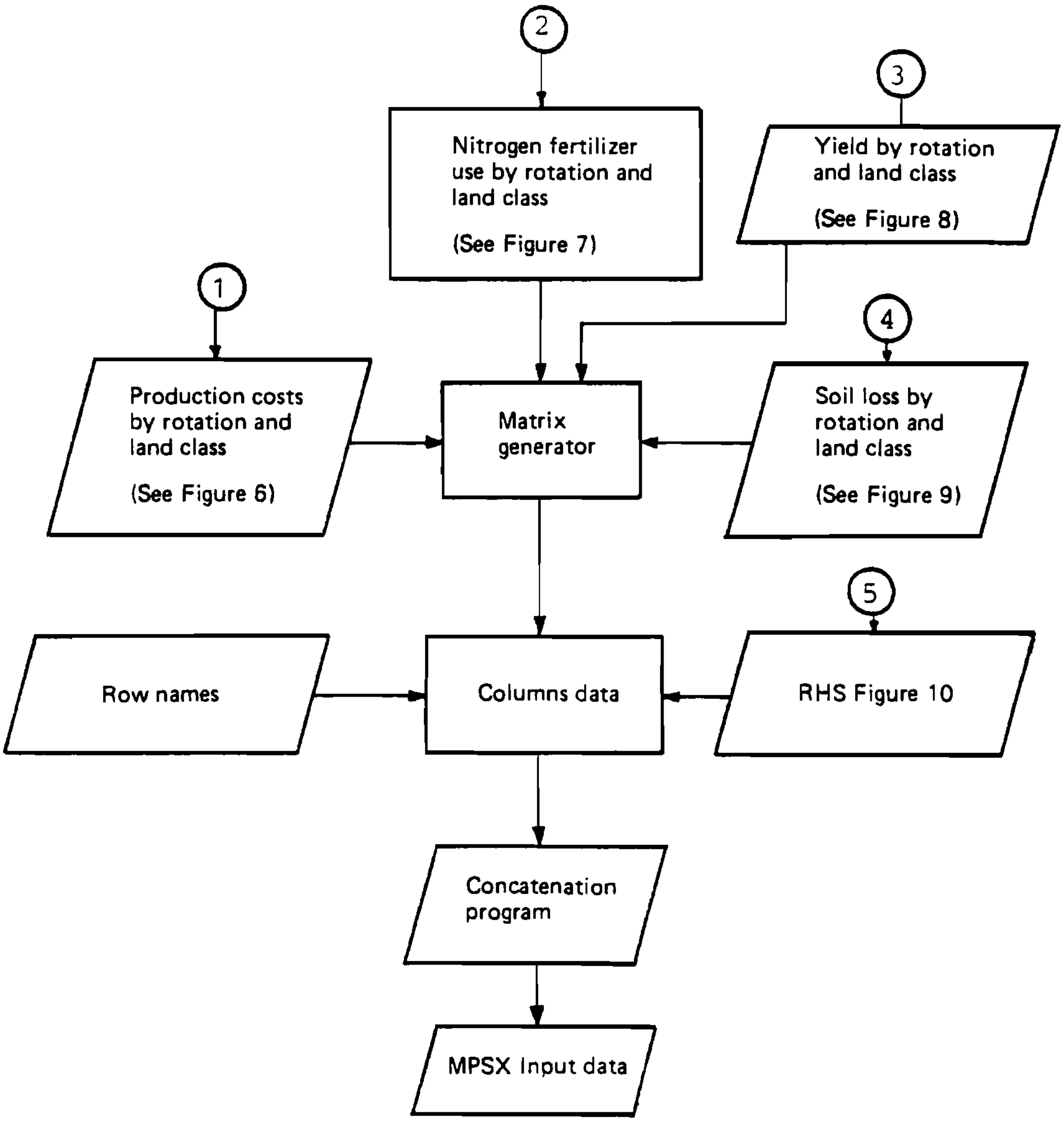

Figure 5. Steps for setting up initial LP matrix.

$T_{ijkmt} L_{ijkmt}$ = the cost of production (T) of rotation (j) with conservation-tillage practice (k) on land group (m) in producing area (i) in period (t), multiplied by the level of crop activity (L); and,

$P^N Q_{it}^{NB}$ = the price of nitrogen fertilizer (P^N) multiplied by the quantity of nitrogen fertilizer purchased (Q^{NB}) in producing area (i) in period (t).

units:

P_n^s in dollars per bushel for corn, oats, grain sorghum, and wheat, dollars per cwt. for soybeans (oilmeal equivalent), and dollars per short ton for leguminous hay, nonleguminous hay, and corn silage; T in dollars per acre; L in number of acres; P^N in cents per pound; and, Q^{NB} in number of pounds.

Commodity prices are estimated within the U.S. econometric simulation component. Costs of producing agricultural commodities include charges for labor, machinery, pesticides, and fertilizers other than nitrogen. Cost coefficients in the objective function, expressed in 1975 dollars, are derived from the Firm Enterprise Data System (FEDS) (U.S. Department of Agriculture, 1976b) and Iowa State Cooperative Extention Service budgets (1975). Costs are weighted to the 12 producing areas for each of the 8 endogenous crops using the acreage of the respective crop as weights. If a particular crop rotation is, for example, 50% corn and 50% soybeans, then the coefficient for the activity is determined by the sum of the cost of producing one-half acre each of corn and soybeans.

The cost coefficient for each activity is adjusted for land group and conservation-tillage practice based on information from the U.S. Soil Conservation Service (Figure 6). A base of straight-row cropping is used for conservation practices, and the adjustments are made in machinery and labor efficiency for contouring and strip cropping. Similarly, adjustments are made for the tillage practices where conventional tillage with no residue management serves as the base. Variations include conventional tillage with residue management and reduced tillage. Reduced tillage operations are further adjusted to reflect the tradeoff between tillage operations and the use of pesticides for weed control (Meister and Nicol, 1975).

3.2.2. Activities

Activities defined in the Iowa LP component are divided into crop production, crop sell, and nitrogen purchase activities. Crop production activities simulate rotations producing corn grain, corn silage, oats, grain sorghum, legume and nonlegume hay, soybeans, and wheat, in crop management systems incorporating rotations of one to four crops (Table 5). Rotations are defined for three conservation methods: straight- row, strip cropping, and contour plowing. Each conservation method is associated with three tillage practices: conventional tillage, residue manag ment, and reduced tillage. Each combination of crop rotation, conservation method, and tillage practice is defined on the land class to which they would apply (Table 6). Hence, each rotation combined with a specific conservation-tillage practice defines a unique crop management system.

The rotations specified in Table 5 allow for the substitution of crops in response to changes in relative input and output prices, and for the use of legume crops as an alternative source of nitrogen. Furthermore, the rotations allow for an increased use of small grains and hay in the land-use plan as a way of meeting potential soil-conservation requirements. Not all 30 rotations are

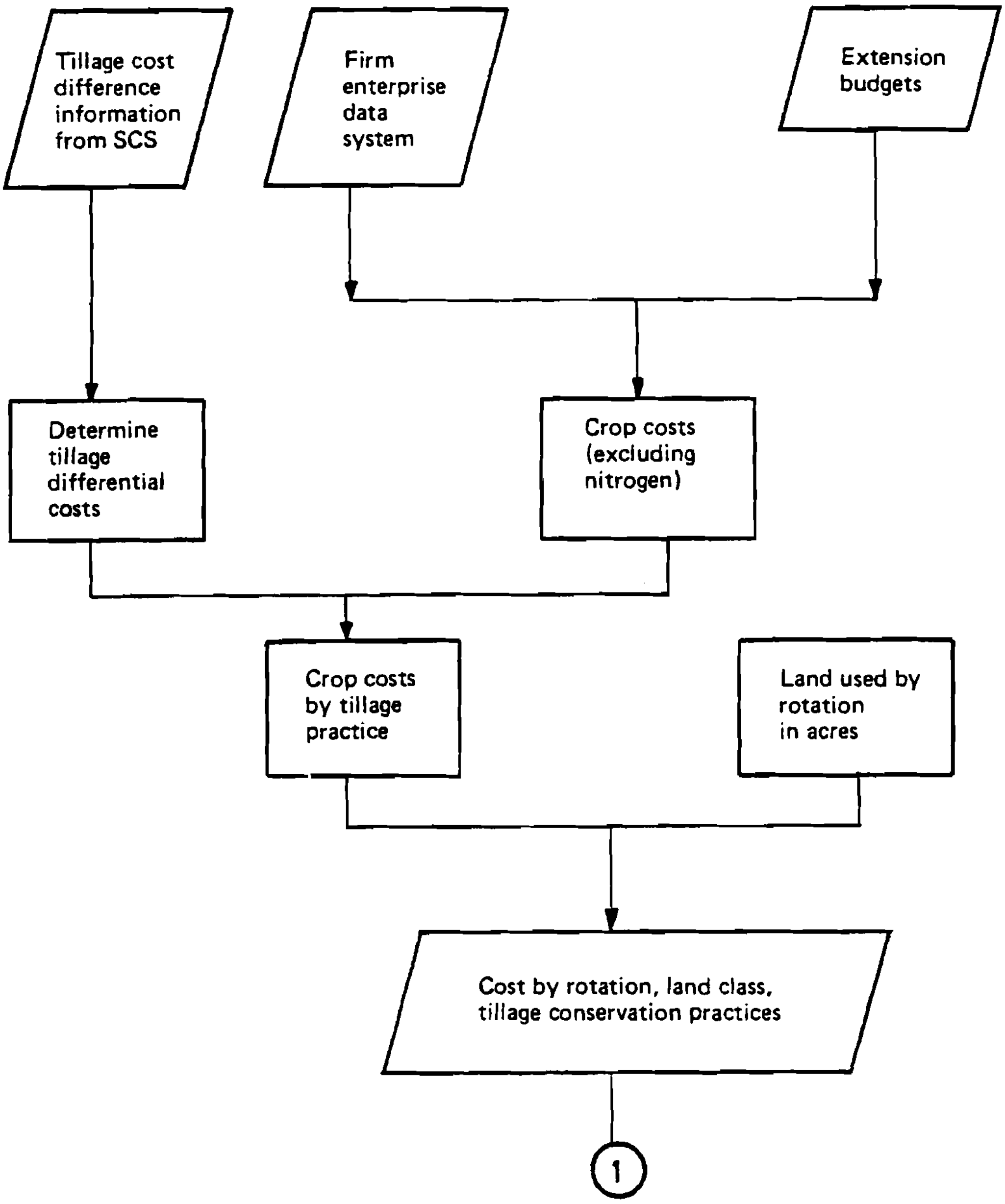

Figure 6. Schematic diagram illustrating steps taken to derive production costs.

Table 5. Crop rotations defined in the Iowa LP component.

Rotation	Corn	Oats	Grain Sorghum	Leguminous Hay	Non-Leguminous Hay	Soybeans	Wheat
			(Percent)[a]				
ae	0	0	100	0	0	0	0
ao	50	0	0	0	0	0	50
br	60	20	0	0	20	0	0
bs	50	25	0	0	25	0	0
bt	40	20	0	20	0	0	0
bv	34	33	0	0	33	0	0
bx	20	20	0	60	0	0	0
cd	17	16	0	0	67	0	0
ch	50	0	0	0	0	25	25
cj	50	0	0	0	0	50	0
cl	50	0	0	0	25	0	25
cm	25	25	0	0	50	0	0
cn	20	0	0	0	60	0	20
cs	67	0	0	0	0	33	0
cu	34	33	33	0	0	0	0
cz	20	20	0	0	60	0	0
db	17	16	0	50	0	17	0
dc	40	20	0	0	20	20	0
df	0	14	28	44	0	14	0
dg	0	0	0	100	0	0	0
dh	40	0	0	0	20	20	20
dl	34	0	0	0	33	0	33
dy	0	0	0	0	25	50	25
hn	50	25	0	0	0	25	0
ho	40	20	0	20	0	20	0
hq	28	0	0	30	0	14	28
hs	28	28	0	44	0	0	0
kf	0	0	67	0	0	33	0
kg	0	20	40	0	40	0	0
Ot	100	0	0	0	0	0	0

[a] Numbers indicate the percentage of each rotation made up of the particular crop. For example, ae is 100% grain sorghum, cj is 50% corn - 50% soybeans (i.e., a corn-soybean rotation), etc.

Table 6. Conservation-tillage practices defined in the Iowa LP component.

Land Group	Conservation-Tillage Practice[a]								
	a	b	c	d	e	f	g	h	i
1	*	*	*	-	-	-	-	-	-
2	*	*	-	*	*	*	-	-	-
3	*	*	*	-	-	-	*	-	*
4	*	*	*	-	-	-	*	*	*
5	*	*	*	-	-	-	-	-	-

[a] Conservation-tillage practices defined as:
a = straight row, residue removed;
b = straight row, residue left;
c = straight row, reduced tillage;
d = contour, residue removed;
e = contour, residue left;
f = contour, reduced tillage;
g = strip cropping, residue removed;
h = strip cropping, residue removed; and
i = strip cropping, reduced tillage.
A "*" indicates that the conservation-tillage practice is defined for the particular land group.

defined for each PA. An attempt has been made to specify crop activities in keeping with the specific geography-topography of the individual producing areas; i.e., allow more small grains and hay in hilly areas, etc.

Coefficients defined for each activity include the cost of production, land use, the quantity of nitrogen applied, the yield adjusted for conservation-tillage practice, and the average level of gross soil-loss leaving the field during a one-year period. Cost coefficients have already been discussed. Land use is assumed to be one acre for each crop activity. Hence a rotation composed of more than one crop, such as cj (50% corn-50% soybeans), is assumed to use one-half acre for corn and one-half acre for soybeans.

Each rotation requires nitrogen as an input in the production process. Nitrogen is available either from direct purchase and from legume crops. The commercial nitrogen fertilizer coefficients are derived from a combination of sources (Figure 7). Total 1974 Iowa and county acreage, by crop, and the percentage of land fertilized, by crop, is derived from the 1974 Census of Agriculture (U.S. Department of Commerce, 1977). The 1974 state quantities of commercial nitrogen, phosphorus, and potassium applied per acre by crop, is found in Energy and U.S. Agriculture (U.S. Department of Agriculture, 1976 a).

Average state and producing area fertilizer ratios are derived by dividing the quantity of fertilizer applied to a given crop by the state total harvested acres, as in equations (2) and (3).

$$SRATIO_n = SFERT_n * 2000 / SACRE_n \quad (2)$$

$$PARATIO_{in} = FERT_{in} * 2000 / ACRE_{in} \quad (3)$$

where:

$SRATIO_n$ = average fertilizer ratio applied for crop (n) for the State of Iowa (pounds per acre);

$SFERT_n$ = state total quantity of fertilizer applied in 1974 on crop (n) (tons);

$SACRE_n$ = state total acreage on which fertilizer was applied in 1974 on crop (n) (acres);

$PARATIO_{in}$ = average fertilizer ratio applied for crop (n) in PA (i) (pounds per acre);

$FERT_{in}$ = quantity of fertilizer applied in 1974 on crop (n) in PA (i) (tons); and,

$ACRE_{in}$ = number of acres on which fertilizer was applied on crop (n) in PA (i) (acres).

A weight is derived for each PA and crop using equation (4).

$$TRATIO_{in} = PARATIO_{in} / SRATIO_n \quad (4)$$

The 1974 state per acre average for nitrogen, phosphorus, and potassium are found for each crop and weighted by the TRATIO's to give per acre averages for each PA (English et al., 1980).

Crop yields are estimated using 1970 to 1975 average county yields (Iowa Crop and Livestock Reporting Service, 1978-80). These yields are then weighted by average production to obtain PA yields for each crop. With the exception of hay, yields are adjusted for land class and conservation-tillage practice (Figure 8). Hay yields are derived from the 1974 Census of Agriculture (U.S. Department of Commerce, 1977). The data obtained in a Soil Conservation Service questionnaire (Meister and Nicol, 1975) includes a set of ratios giving the relative land class yields of each crop category as compared to the most productive land

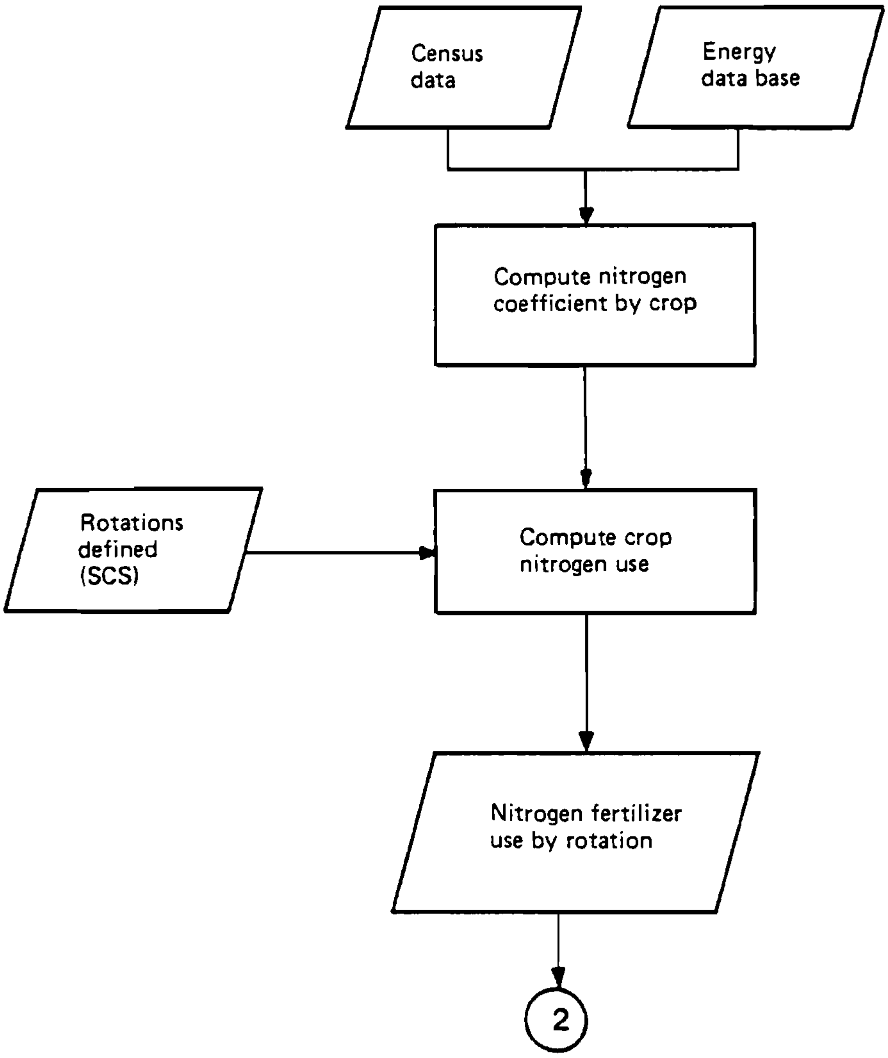

Figure 7. Schematic Diagram illustrating steps taken to derive crop Nitrogen Fertilizer use.

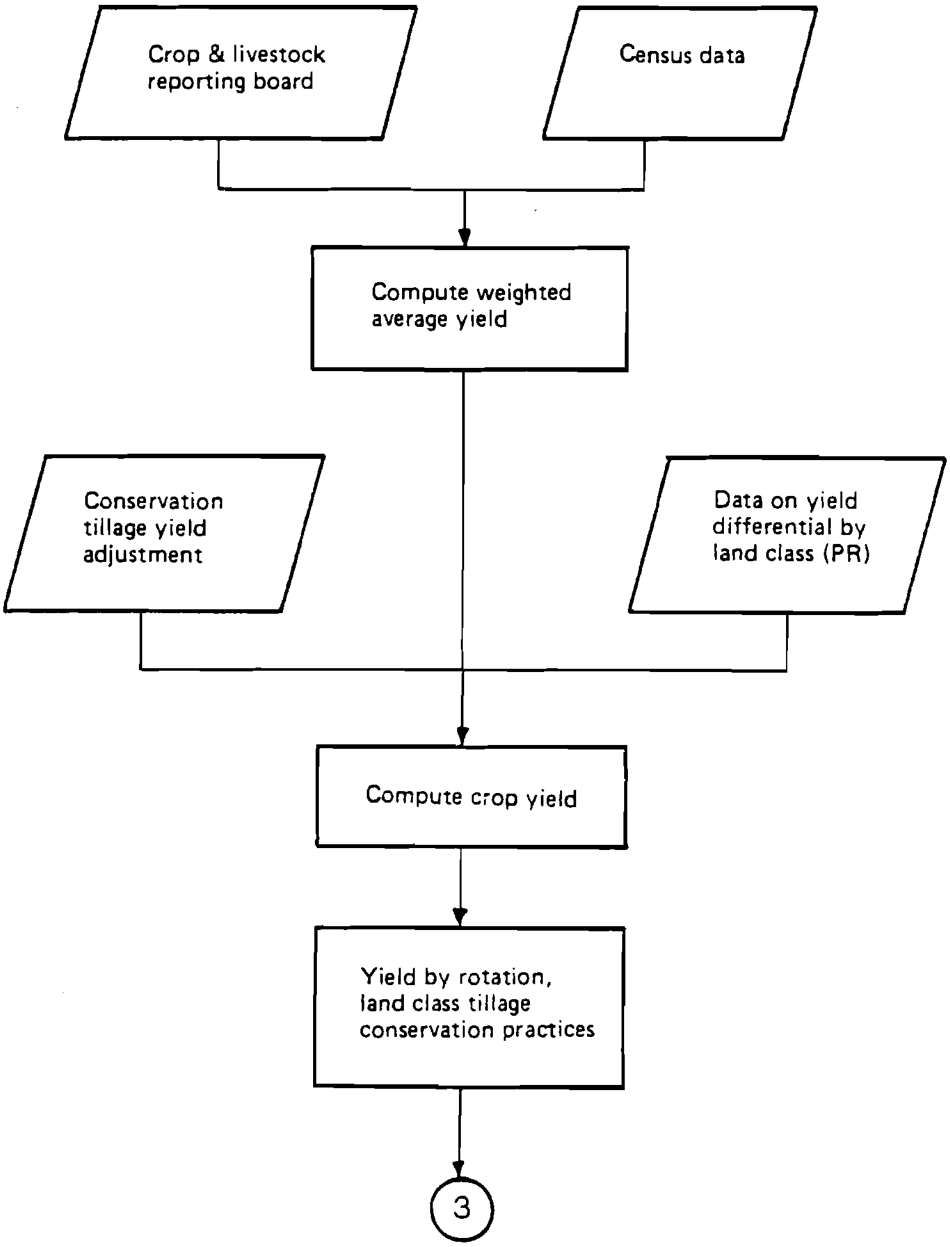

Figure 8. Schematic diagram illustrating steps taken to derive crops yield.

class of the area. These ratios initially are weighted to the five land groups and are adjusted such that land group I has a relative yield value of 1.0. The conservation-tillage yield ratios are used equally on each land group to adjust yields of each crop (except hay) for both conservation and tillage effects. The contil yield ratios are scaled such that a representative "composite" contil practice in each producing area equals 1.0.

Gross soil loss for the major land resource areas in Iowa is determined using the Universal Soil Loss Equation developed by Wischmeier and Smith (1965). Soil loss data are then weighted to the producing areas and attached to the appropriate crop management system, as shown in Figure 9.

Calculated gross soil loss represents the average annual tons of soil leaving the field. The soil loss equations is represented by:

$$A = R * K * L * S * C * P \tag{5}$$

where:

A is computed soil loss per unit area,

R, the rainfall factor, is the number of erosion-index units in a normal year's rain. The erosion index is a measure of the erosive force of specific rainfall.

K, the soil-erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9-percent slope 72.6 feet long.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6 foot length on the same soil type and gradient.

S, the slope-gradient factor, is the ratio of soil loss from the field gradient to that from a 9-percent slope.

C, the cropping-management factor, is the ratio of soil loss from a field with specified cropping and management to that from the fallow on which the factor K is evaluated.

P, the erosion-control practice factor, is the ratio of soil loss with contouring, strip cropping, or terracing to that with straight-row farming, up-and-down slope.

Numerical values for each of the six factors have been determined from research data (Wischmeir and Smith, 1965).

The variables in the Universal Soil Loss Equation are defined as the dominant value existing on each soil class and subclass in each reporting area. Soil loss is then computed by Land Resource Area for each feasible combination of crop rotation, conservation-tillage practice, and soil class defined by the Soil Conservation Service (Meister and Nicol, 1975).

The soil loss defined above for the relevant 29 soil class- subclasses is aggregated using weighting functions to get soil loss by the five land groups defined in the Iowa LP component. These coefficients are attached to the appropriate crop production activity and reflect the severity of erosion for the conditions on which the crop management system is specified

3.2.3. Constraints

Constraints are incorporated at both the producing area (PA) and state level. Constraints defined at the PA level include land and crop transfer rows, while those at the state level include nitrogen and soil loss from crop production.

The land base represents the major constraint on the productive capacity

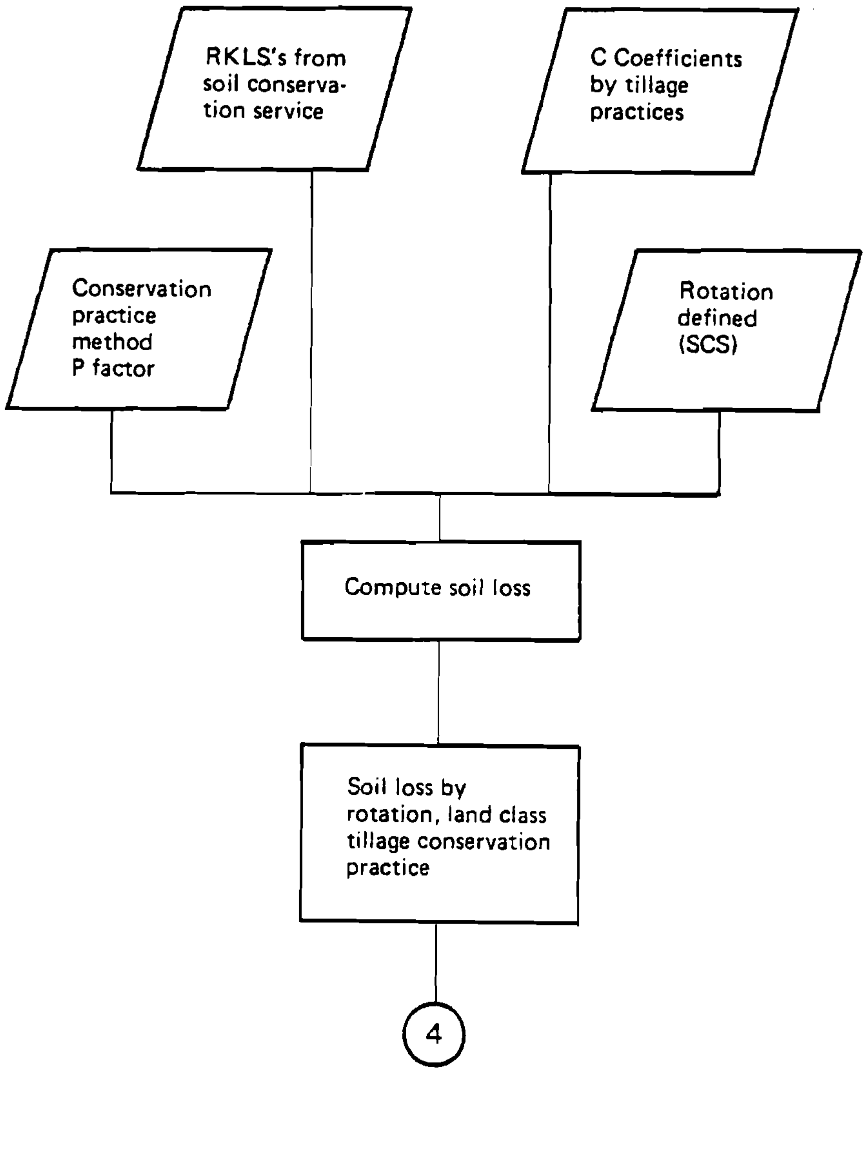

Figure 9. Schematic diagram illustrating steps to derive soil loss due to crop production

of the system. Land in the Iowa model is used solely for dryland cropping activities defined for the endogenous crops and non-rotation pasture. Five land groups, representing an aggregation of the 29 class-subclasses in the National Inventory of Soil and Conservation Needs, 1967 (Conservation Need Inventory Committee, 1971) are specified for each of the 12 producing areas (Table 7 and Figure 10). The 1967 Inventory base is updated to 1975 using data developed by Paul Rosenberry.*

The Conservation Needs Inventory (CNI) places all soils in eight capability classes. The risks of soil damage or limitations in use become progressively more severe from class I (few limitations) to class VIII (no beneficial agricultural uses). Soils in the first four classes under good management are capable of producing common cultivated field crops and pasture plants. Soils in classes V, VI, and VII may be suited for field crops under highly intensive management involving elaborate soil and water conservation practices. Soils in class VIII do not return on-site benefits for inputs of management for crops without major reclamation (Klingebiel and Montgomery, 1966).

Four land capability subclasses are defined according to the general kinds of limitations upon agricultural use. Subclass e (erosion) is made up of soils where the susceptibility to water or wind erosion is the dominant problem or limitation in their use. Subclass w (excess water) is made up of soils in areas with poor soil drainage, wetness, or high water table. Subclass s (soil limitations within the rooting zone) include soils with shallow rooting zones, low moisture-holding capacity, or low fertilizty difficult to correct. Finally, subclass c (climatic conditions) is made up of soils where temperature or lack of moisture is the only major hazard or limitation in their use.

The second type of constraints incorporated at the producing area level are the commodity transfer rows. These rows represent the marketplace for the 8 endogenous crops: corn grain, corn silage, legume hay, nonlegume hay, oats, grain sorghum, and wheat. The producing areas supply these commodities directly to the crop purchase activities. Commodity transfer rows for each endogenous crop are of the form:

$$\sum_{k} \sum_{n} Y_{ikmnt} L_{ikmnt} - \sum_{n} C^{s}_{int} = 0 \qquad (6)$$

where:

Y_{ikmnt} = the per acre yield of crop activity (n) with conservation-tillage practice (k) on land group (m) in PA (i) in period (t);

L_{ikmnt} = the level of crop (n) using conservation-tillage practice (k) on land group (m) in PA (i) in period (t); and,

C^{s}_{int} = the quantity of crop (n) sold from PA (i) in period (t).

units:

Y in bushels per acre for corn, oats, grain sorghum, and wheat, cwt per acre for soybeans (oilmeal equivalent), and short tons per acre for leguminous and nonleguminous hay and corn silage; L in number of acres; and, C^{s} in number of bushels for corn, oats, grain sorghum, and wheat, number of cwt for soybeans, and, number of short tons for hays.

Hence, total production of each crop must be sold in the market at the prevailing price.

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* Communications with Paul Rosenberry, ESS, Iowa State University

Table 7. Organization of land capability class-subclasses into the land groups defined for the Iowa model.

Land Group In Iowa Model	Land Capability Class-Subclasses[a]
I	I
II	II e,w,s,c; III w,s,c; IV w,s,c; V e,w,s,c
III	III e
IV	IV e
V	VI e,w,s,c; VII e,w,s,c; VIII e,w,s,c

[a] As included in the National Inventory of Soil and Conservation Needs, 1967 (Conservation Needs Inventory Committee, 1971). Land Capability Classes are indicated by Roman numerals I-VIII; Subclasses by letters e (erosion hazard), w (wetness), s (rooting-zone limitations), and, c (climate). No general types of limitations or hazards are defined for Land Class I.

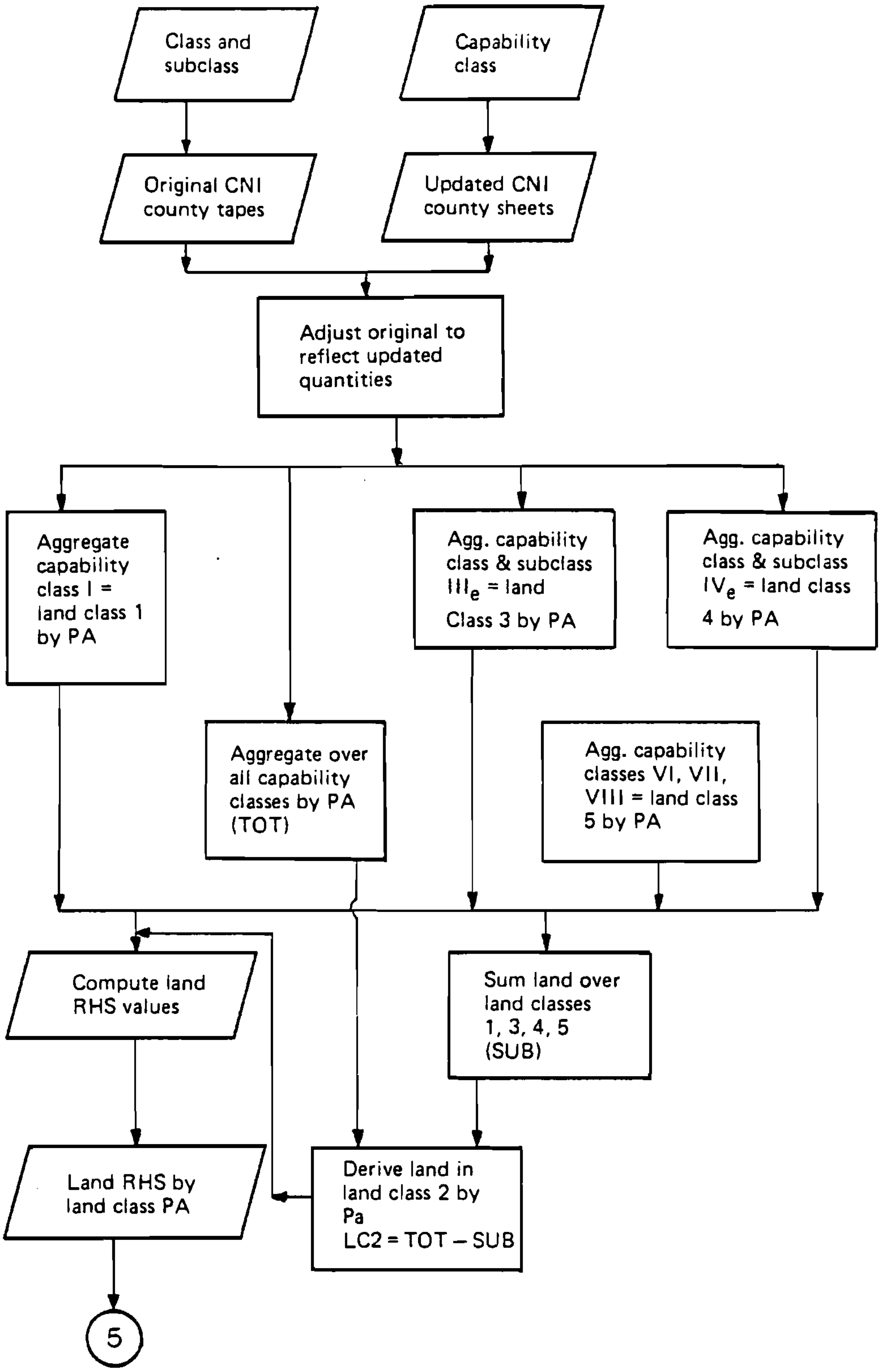

Figure 10. Schematic diagram illustrating steps to derive right-hand-side constraint coefficients for land.

The two statewide constraints in the model are nitrogen use and soil loss through production of crops. The nitrogen fertilizer constraint acts as a market place for the supply and demand of commercial fertilizers used for crop production. The general form of the nitrogen constraint at the state level is:

$$Q_{it}^{NB} - \sum_{i} \sum_{j} \sum_{k} N_{ijkmt} \, L_{ijkmt} \geq 0 \qquad (7)$$

where:

Q_{it}^{NB} = the quantity of commercial nitrogen purchased in PA (i) in period (t);

N_{ijkmt} = the quantity of commercial nitrogen required for crop rotation (j) with conservation-tillage practice (k) in land group (m) in PA (i) in period (t); and,

L_{ijkmt} = the level of crop rotation (j) using conservation-tillage practice (k) in land group (m) in PA (i) in period (t).

units: Q^{NB} in pounds; N in pounds per acre; and, L in number of acres.

An upper limit for nitrogen purchases and, hence, nitrogen use in crop production, is not defined. However, policy alternatives which specify constraints on nitrogen use or availability can be analyzed with this model by imposing an upper limit in the right-hand-side of the state nitrogen fertilizer constraint.

The statewide soil loss constraint is an accounting row to determine the level of gross soil loss occuring from the production of crop commodities. The general form of the state soil loss constraint is:

$$\sum_{i} \sum_{j} \sum_{k} \sum_{m} S_{ijkmt} \, L_{ijkmt} \leq SSL \qquad (8)$$

where:

S_{ijkmt} = the level of gross soil loss for crop activity (j) with conservation-tillage practice (k) in land group (m) in PA (i) in period (t);

L_{ijkmt} = the level of crop activity (j) with conservation-tillage practice (k) in land group (m) in PA (i) in period (t); and,

SSL = the total state soil loss allowed.

units: S in tons per acre; L in number of acres; and, SSL in tons.

SSL is not currently defined; thus, the soil loss row does not act in a constraining manner. The level of soil loss can be controlled in the Iowa LP component either by specifying an upper limit for SSL, or by prohibiting the use of crop rotations which result in a quantity of soil loss per acre above a desired level.

Constraints on nitrogen use and soil loss are specified at the state level; however, information on nitrogen input and total soil loss is available for each producing area. It is believed that any policy controls of these variables would likely be imposed at the state, and not substate, level.

Selected coefficients in the Iowa LP component are revised periodically through the Linkage Component based on information estimated in the U.S. Simulation Component. A presentation of these components follow.

3.3. The U.S. Econometric Simulation Component

The purpose of the U.S. econometric simulation component of the Iowa regional-national recursive programming system is to estimate resource use and commodity output originating in the United States other than Iowa. These estimates are summed with those originating solely within the State of Iowa (from the programming component) to determine changes in input factor costs and prices received by farmers for commodities.

The econometric component is based upon the CARD-National Agricultural Econometric Simulation model (CARD-NAES) originally specified by Schatzer, et al (1981), and Roberts, and Heady (1979, 1980), with some restructuring being done for this study. CARD-NAES depicts farmers' behavior in the purchase of major inputs and can be used to characterize the response of farmers to many changing variables which relate to production and investment decisions.

Major categories of agricultural production are included in the simulation sector by five crop submodels--feed grains (corn, sorghum, oats, and barley), wheat, soybeans, cotton, and tobacco; five livestock submodels--beef, pork, lamb and mutton, chicken, and turkey; and, a submodel which aggregates components from each of the other ten and sums those results with the exogenously determined variables for the rest of the U.S. agricultural sector. The submodels can be described in general terms as follows: a) resource demands in the current year depend directly or indirectly on lagged commodity and resource prices, lagged resource demands, and other variables; (b) current production depends upon the current quantity of resources demanded; c) supply in the current year depends on current production, carryover, and imports; d) average current year commodity prices depend on current supply, exports, and other variables; e) commodity demand in the current year depends on current price, and other variables; f) gross income in the current year depends on current price and production, and, h) quantity supplied is required to equal quantity demanded primarily through inventory adjustments.

Each crop submodel is divided into three stages corresponding to the pre-input (planning), input (planting), and output (harvesting and marketing) decisions in a sequential production cycle for one year at a time. Hence, the time path for each endogenous variable (i.e., variables whose values are determined within the model) to be generated by interating the model for each year in the projection period, subject to a set of assumptions on the exogenous variables (i.e., variables whose values are determined outside the model). The livestock submodels are aggregated into a single commodity group for the pre-input and input stages, but are disaggregated in the output stage.

The pre-input stage determines the level of physical assets committed to the production of farm commodities. Acreage intended for harvest, machinery purchases, machinery stocks, on-farm commodity stocks, value of land and buildings per harvested acre, average machinery and commodity stocks, total land and building value, and stocks of physical assets, are determined in the pre-input stage for each endogenous crop and for aggregate livestock.

The level of variable inputs needed to produce each endogenous crop are estimated in the input sector of each commodity submodel based on the level of fixed resources from the pre-input sector and other variables. The variable inputs considered in this model include real estate taxes and expenditures, fertilizer, seed, fuel, oil, and repairs, machinery, man-hours of labor, interest on commodity stocks, and miscellaneous inputs.

Estimates of prices received by farmers, commercial demand, supply, end-of-year stocks, and gross farm income resulting from resources committed in the pre-input and input stages are determined in the output sector of each commodity submodel. Livestock is also disaggregated into beef, pork, lamb and mutton, chicken, and turkey in the output stage of the livestock submodels.

Crop yields per harvested acre are incorporated into the output sector of each crop submodel using either of two approaches. First, crop yields are projected exogenously as linear functions of time using 1949-76 as a sample period.

Then, year-to-year deviations from those trend yields are determined from a production function which uses estimated elasticities of production for six inputs from the input sector. The production function used is

$$Y_t = YB_t * \left[1.0 + \sum_{i=1}^{6}\left\{E_i * \left(\frac{I_{it} - B_{it}}{B_{it}}\right)\right\}\right] \tag{9}$$

where: Y_t is the yield per harvested acre; YB_t is the Base Run yield; E_i is the elasticity of production of the i th input (i = fertilizer, seed, labor, machinery, fuel, oil, and repairs, and miscellaneous expenses); and B_{it} is the Base Run level of the i th input, all for each crop in year t. The input elasticities of production are estimated from factor share data using Tyner and Tweeten's methdology (1965).

In the second approach crop yields are estimated endogenously as a function of the ratio of nitrogen price in year t(NP_t) and the commodity prices in period t−1(P_{t-1}), i.e., NP_t / P_{t-1}, a time trend variable to account for technological factors, and a proxy variable for weather (percentage deviation from normal pasture conditions). At the time of planning, the price of nitrogen (NP_t) is known to the farmer, while P_{t-1} is used as the expected price to be received for the crop when harvested. The ratio NP_t / P_{t-1} is assumed to be negatively related to yield in that when the nitrogen price increases relative to the expected commodity price, farmers tend to apply less nitrogen and, hence, receive a relatively lower yield.

A more detailed presentation of a typical crop submodel (e.g., feed grains) is illustrated in Figures 11.a, 11.b, 11.c. A typical livestock submodel (e.g. beef) is illustrated in Figure 12. The endogenous and exogenous variables included in CARD-NAES are listed in Table 8. Data sources for each variable are found in Schatzer, et al (1981) and Roberts and Heady (1980).

CARD-NAES consists of 210 equations (151 for crops and 59 for livestock) formulated primarily in a recursive framework. If a system of equations is recursive, then (1) each endogenous variable can be determined sequentially, i.e., the solution of the n th endogenous variable involves only the first n equations of the model, and (2) the error terms across equations are not correlated among themselves (Johnston, 1972). Portions of the output section are block recursive. A block-recursive system is a group of equations which can be broken up into blocks of equations in such a way that equations within each block are simultaneous, but groups of equations across blocks are recursive, i.e., knowledge of the endogenous variables in the first block permit the determination of the endogenous variables in the second block, etc. (Pindyck and Rubinfeld, 1976).

Annual time series data are used to estimate the structural parameters of the model using appropriate statistical estimation techniques, including ordinary and autoregressive least squares, two-stage and three-stage least squares (Roberts and Heady, 1979). Most equations are estimated from 1949-76 data with portions of the livestock submodels using 1953-76 da a.

The CARD-NAES model must be adapted to the Iowa regional-national system so that estimates of certain resource input and commodity output levels originating in the United States excluding Iowa can be obtained. In the current version of the Iowa Task 2 Case Study model, a distinction is made between Iowa and the rest of the United States only for harvested acreage, nitrogen fertilizer expense, and the quantity of each endogenous crop produced, because these values can be determined solely for the State of Iowa from the programming component. As the Iowa regional programming component is expanded in future

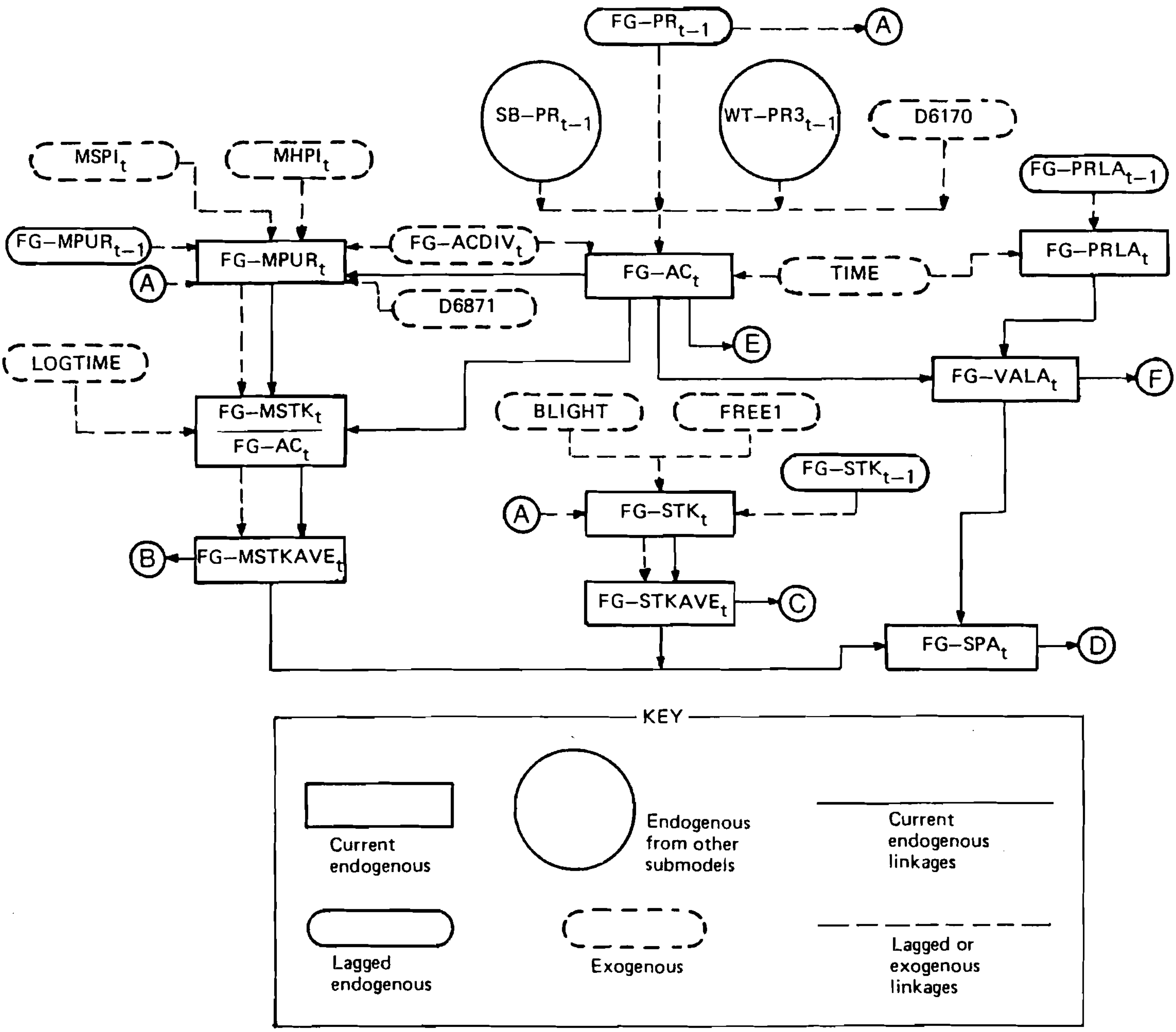

Figure 11.a. Schematic diagram of the feed grain pre-input sector

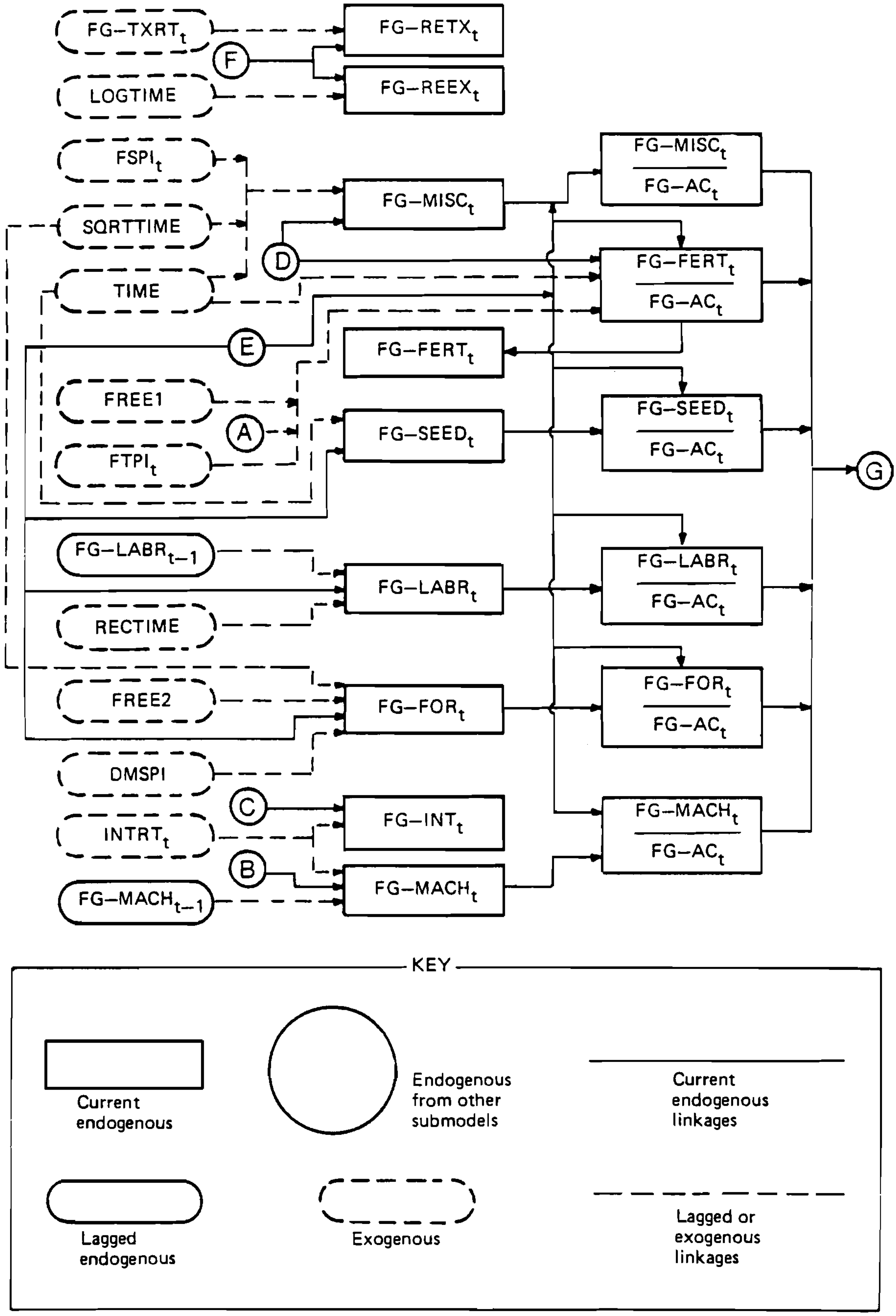

Figure 11.b. Schematic diagram of the feed grain input sector

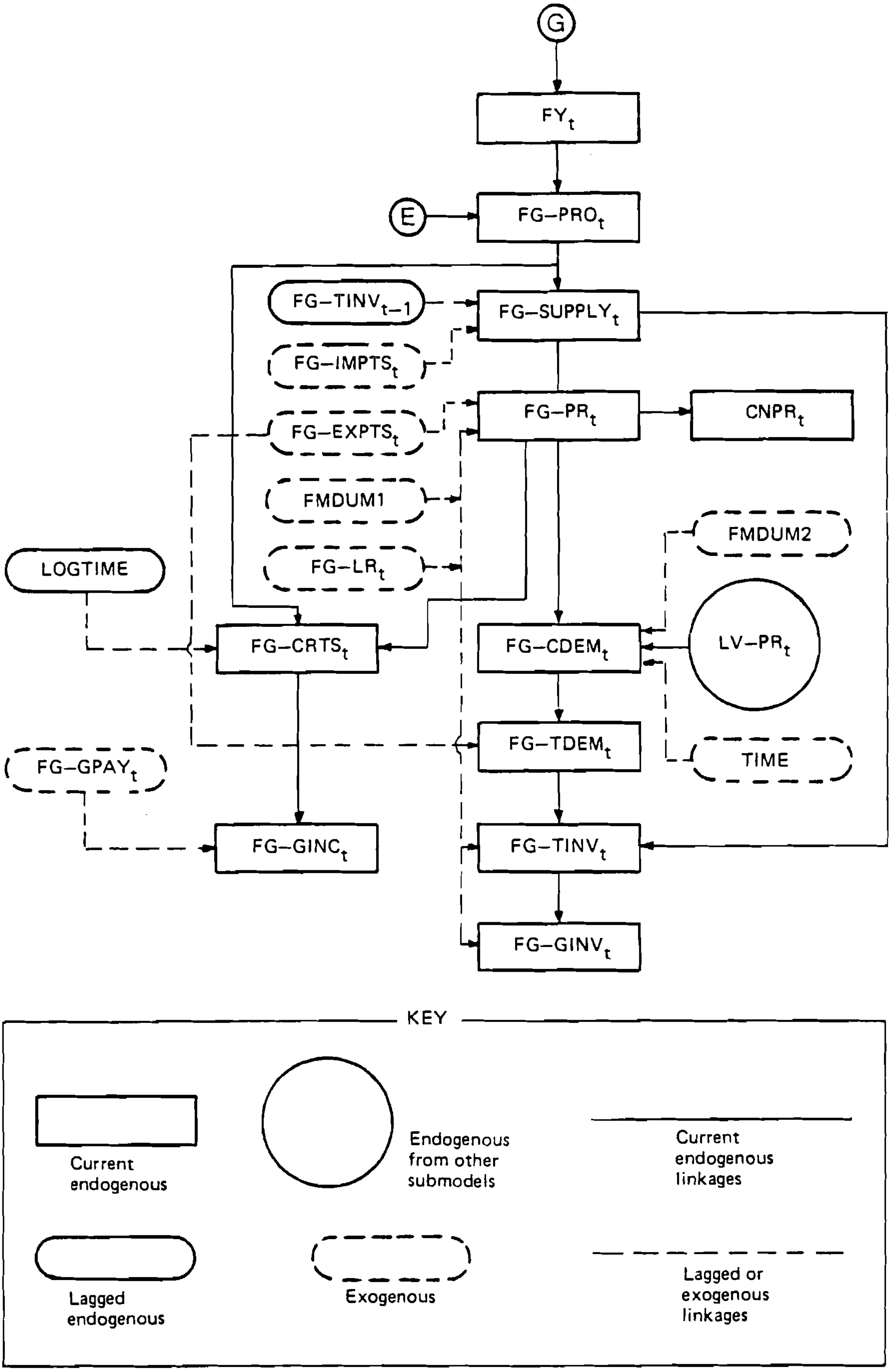

Figure 11.c. Schematic diagram of the feed grain output sector.

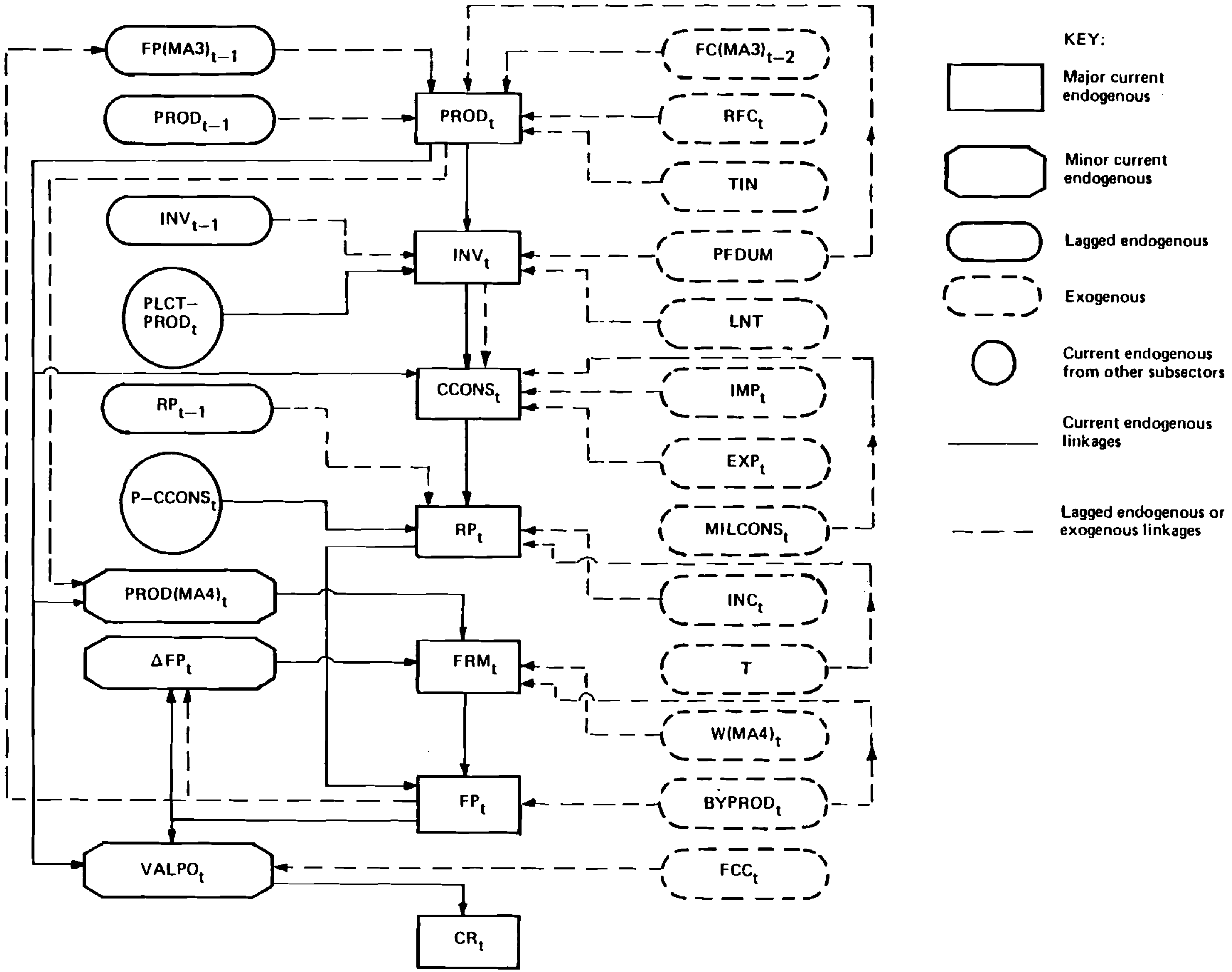

Figure 12. Schematic diagram of the beef submodel

Table 8. Definition of endogenous and exogenous variables included in the econometric component.

Variable Code Name	Definition
AC	Harvested acreage (million acres).
ACALL	Tobacco acreage allotment (million acres).
ACATDUMY	Acreage allotment dummy with 1.0's in years allotments were in effect.
ACDIV	Acres diverted from production under crop commodity programs (million acres).
BLCT-PROD	The sum of the production of beef, lamb and mutton, chicken, and turkey in millions of pounds.
BLIGHT	Dummy variable for corn blight in 1970.
BPCT-PROD	The sum of the production of beef, pork, chicken, and turkey in millions of pounds.
BMKQUOTA	Market quota of burley tobacco production (in millions of pounds) 1971-1976.
BYPROD	Amount paid to farmers in cents per pound for byproducts not sold as meat at the ratail level deflated by the Consumer Price Index 1967= 100.
CCONS	Civilian consumption in millions of pounds of carcass weight or ready-to-cook weight meat.
CDEM	Total domestic crop year demand for all uses, except wheat which excludes food demand (same units as production)
CINV	Privately owned ending crop year inventory (same units as production).
CNPR	Average crop year price received by farmers for corn (dollars per bushel)
CPI	The Consumer Price Index with 1967 = 100.
CR	Cash receipts in thousands of dollars from the sale of a livestock commodity deflated by the Consumer Price Index 1967=100.
CRPTS	Cash receipts from the sale of crops (million dollars) deflated by CPI.
CS-PR	Price of cotton seed deflated by index of prices paid by farmers.
CT-CDEMP	Domestic demand for cotton per capita multiplied by 100 (bales).
D6170	Feed grain base dummy with 1961-1970 = 1 and 0 otherwise.
D6771	Dummy variable = 1.0 for years 1967-1971.
D6871	Dummy variable = 1.0 for years 1968-1971.
D6872	Dummy variable = 1.0 for years 1968-1972.
DALLOT	Dummy variable for wheat allotment program with 1.0's for 1971-1973.
DMSPI	Change in index of motor supplies price.
EXP	Exports in millions of pounds of carcass weight meat.
EXPTS	Crop year exports (same units as production).
FC	A weighted average feed grain and soybean price per hundred pounds of feed for the commodity deflated by the index of prices paid by farmers with 1967 = 100. These variables are taken as proxies for feed costs.
FEED	Purchased livestock feed (million 1967 dollars).
FERT	Fertilizer and lime expense (million 1967 dollars).
FOOD	Crop year demand for wheat as food (million bushels).
FOR	Machinery fuel, oil and repairs expense (million 1967 dollars).

Table 8. (continued)

Variable Code Name	Definition
FP	Gross farm value for beef (choice), pork and lamb (choice), and farm value for chicken and turkey deflated by the index of prices paid by farmers with 1967 = 100. Gross farm value and farm value are prices paid to farmers for a quantity of live animal or bird equivalent to one pound of retail cuts or ready-to-cook bird.
FREE1	Free market dummy variable with 1.0's for 1973-76.
FREE2	Free market dummy variable with 1.0's for 1974-1976.
FRM	The farm-retail margin in cents per pound of meat sold at the retail level for the ith commodity deflated by the Consumer Price Index 1967 = 100.
FSIZE	Average number of acres per farm.
FSPI	Index of farm supplies price deflated by GNP deflator (1967 = 100).
FTPI	Index of fertilizer price deflated by GNP deflator (1967 = 100).
GINC	Cash receipts plus government payments (million dollars).
GINV	Government owned ending crop year inventory (same units as production).
GPAY	Government payments to farmers under crop programs (million dollars).
GNP	Gross National Product deflator index (1967 = 100).
IMP	Imports in millions of pounds of carcass weight meat.
IMPTS	Crop year imports (same units as production).
INC	Personal disposable Income (billion dollars).
INV	End-of-year stocks in millions of pounds of carcass weight for beef, pork, and lamb and mutton and ready-to-cook weight for chicken and turkey.
INTRT	Interest rate paid by farmers on new farm loans.
IPPBF	The index of prices paid by farmers with 1967 = 100.
LABR	Man-hour requirements (million man-hours).
LLRDUM	Dummy accounting for low wheat loan rates with 1964-76 = 1 and 0 otherwise.
LOGTIME	Natural log of TIME variable.
LPRDUM	Soybean low price dummy with 1975 = 1 and 0 otherwise.
LPUR	Livestock purchased by farmers (million 1967 dollars).
LR	Crop government program loan rate (same units as price except FG which is the corn loan rate in dollars per bushel).
LV-PR	Weighted average livestock and poultry farm price (formed by weighting the farm prices for beef, pork, lamb, chicken, and turkey by their respective productions in millions of pounds).
(MA2)	A two-year equally-weighted moving average of the accompanying variable.
(MA3)	A three-year equally-weighted moving average of the accompanying variable.
(MA4)	A three-year, weighted, moving average of the accompanying variable where the weights are 1/4, 1/2, and 1/4.
MACH	Machinery interest and depreciation (million 1967 dollars).
MC	Payment by wheat processors for marketing certificates (dollars per bushel).
MHPI	Index of machinery price deflated by GNP deflator (1967 = 100).

Table 8. (continued)

Variable Code Name	Definition
MILCONS	Military consumption in millions of pounds of carcass weight or ready-to-cook weight meat.
MISC	Miscellaneous expenses including pesticides, small hand tools, binding materials, electricity, telephone, etc. (million 1967 dollars).
MPUR	Machinery purchased (million 1967 dollars).
MSPI	Index of motor supplies price deflated by GNP deflator (1967 = 100).
MSTK	Ending callendar year stock of machinery on farms (million 1967 dollars).
MSTKAVE	Average of beginning and ending calendar year stock of machinery on farms (million 1967 dollars).
NEXP	Net exports in millions of pounds of ready-to-cook meat.
PFDUM	A dummy variable with 1973 = 1 and 0 otherwise to account for the effects of the 1973 price freeze.
PINC	Per capita disposable income (dollars).
PLCT-PROD	The sum of the production of pork, lamb and mutton, chicken, and turkey in millions of pounds.
POLYPR	Polyester price (cents per pound).
POP	U.S. civilian population (million).
PR	Average crop year price received by farmers deflated by the implicit GNP deflator (LV, dollars per hundred weight; FG, dollars per ton; WT and SB, dollars per bushel; and TB, cents per pound). All prices and incomes are deflated by the Consumer Price Index 1967 = 100 when used in the output sector.
PR2	PR variable deflated by index of prices paid by farmers instead of GNP.
PRDUM	Dummy with 1973 = 1 and 0 otherwise.
PRLA	Index of price of land and buildings per acre (index 1967 = 1.0).
PRO	Crop production (FG, million short tons; W and SB, million bushels; CT, million bales; and CS, million short tons).
PROD	Production in millions of pounds of carcass or ready-to-cook weight meat.
RECTIME	Reciprocal of TIME variable.
REEX	Real estate expense including interest on land and farm buildings and depreciation repairs and maintenance on farm buildings (million 1967 dollars).
RETX	Real estate taxes (million 1967 dollars).
RFC	An index of range feed conditions in 17 western states. RFC ranges from 49 or below indicating very bad to 100 and over indicating excellent range feed conditions.
RP	The retail price in cents per pound of the commodity deflated by the Consumer Price Index 1967 = 100.
SBAR	Acreage withheld from production under the Soil Bank Acreage Reserve program (million acres).
SEED	Purchased plus home-grown seed for individual crops (million 1967 dollars).

Table 8. (continued)

Variable Code Name	Definition
SDPI	Index of seed prices deflated by the implicit GNP deflator (1967 = 100).
SQRTIME	Square root of the TIME variable.
SPA	Stock of physical assets defined as the sum of STKAVE, MSTKAVE, and VALA (million 1967 dollars).
SPPR	Average support price levels deflated by the implicit GNP deflator (same units as price).
STK	End of year commodity stock on farms (million 1967 dollars).
STKAVE	Average of beginning and end of year commodity stock on farms (million 1967 dollars).
SUPPLY	Beginning crop year supply defined as the sum of production, carry-in stocks, and imports (same units as production).
t	Current year.
TDEM	Total domestic crop year demand for all uses plus exports (same units as production).
TIME	Time trend with 1949 = 1, 1950 = 2, 1951 = 3, ... 1976 = 28.
TINV	Ending crop year inventory (same units as production)
TXRT	Tax rate per dollar value of land and buildings.
VALA	Value of farmland and buildings (million 1967 dollars).
VOLPG	Dummy variable for voluntary wheat programs with 1.0's for 1965-1970.
W	The wage rate in dollars per hour for meat manufacturing employees deflated by the Consumer Price Index 1967 = 100.
WAR1	Post war dummy variable for World War II with 1.0's for 1949-1951.
WAR2	Post war dummy variable for World War II with 1.0's for 1949-1952.
WPRD1	Wheat price dummy, PR, with price equal to zero for 1953-1963.
WPRD2	Wheat price dummy, PR, with price equal to zero for 1949-1972.
WPRD3	Wheat price dummy, PR2, with price equal to zero for 1949, 1953-1962.
Y	Crop yield per harvested acre (FG and CS, short tons; W and SB, bushels; and CT, bales).

List of Prefixes

B	Beef
C	Chicken
CS	Cottonseed
CT	Cotton Lint or Cotton Total
FG	Feed Grain
L	Lamb and Mutton
LV	Livestock Total
P	Pork
SB	Soybean
T	Turkey
TB	Tobacco
WT	Wheat
US	United States Total

versions of the Iowa model, other categories of resource inputs and commodity outputs can be differentiated within the regional-national system.

Acreage of feed grains, wheat, and soybeans intended for harvest for the U.S. excluding Iowa is determined in the current version of the model by a historical share method based upon the following regression equation

$$AC47_i = \beta_i * AC48_i \tag{10}$$

where $AC47_i$ is the estimated harvested acreage of crop i (i = feed grains, wheat, soybeans) for the United States excluding Iowa, $AC48_i$ is the estimated harvested acreage for the United States including Iowa, and β_i is the estimated share of total U.S. acreage for crop i not harvested in Iowa, $0 \leq \beta_i \leq 1$. (Note: There are 48 states in the continental United States). No cotton or tobacco are grown in Iowa; hence, β_i=1.0 for these crops. The national harvested acreage for each endogenous crop is then determined by equation (11), where $AC47_i$ is found from equation (10) and

$$AC48_i = AC47_i + AC01_i \tag{11}$$

AC01 is the acreage of crop i harvested in Iowa (dervied by the summation of production activity levels for each crop in the regional programming component).

Nitrogen fertilizer expense for the U.S. excluding Iowa is found by the product of the estimated fertilizer expense per acre and the summation of the acreage estimates for each crop for the U.S less Iowa (dervied in the pre-input stage). Aggregate nitrogen purchases in Iowa are found within the programming component by a summation of nitrogen buying activities for each producing area, and then added with the econometric estimates for the rest of the U.S. to obtain a national fertilizer expense level.

Production of each crop for the United States excluding Iowa is found by multiplying the harvested acreage of each crop by the estimated yield. Crop production for Iowa is found by summing activity levels for each crop in the programming component.

Changes in input factor costs and commodity prices are found within the econometric component for subsequent use in revising the programming component. A discussion of this procedure is presented in relation to the Linkage Component.

3.4. The Linkage Component

The purpose of the linkage component of the Iowa regional-national system is to retrieve and transfer information between the programming and econometric components, and to revise and adjust selected variables between time periods to simulate the recursive sequence of agricultural production and its interaction with the environment.

The basic solution procedure for the Iowa model is shown in Figure 13. The regional LP component is first solved for the profit maximizing level of crop production and resource use for the State of Iowa. These values are summed with estimates of production and input use occuring in the United States excluding Iowa (estimated from the national econometric simulation component) to obtain national totals. Commodity and input factor prices and crop yields are then estimated in the ES component and used to determine the range of production response and the adjustment of input factor costs and crop yields. These data are used to revise the LP coefficient matrix, and the programming component is solved for the next time period, thus repeating the entire process again until the

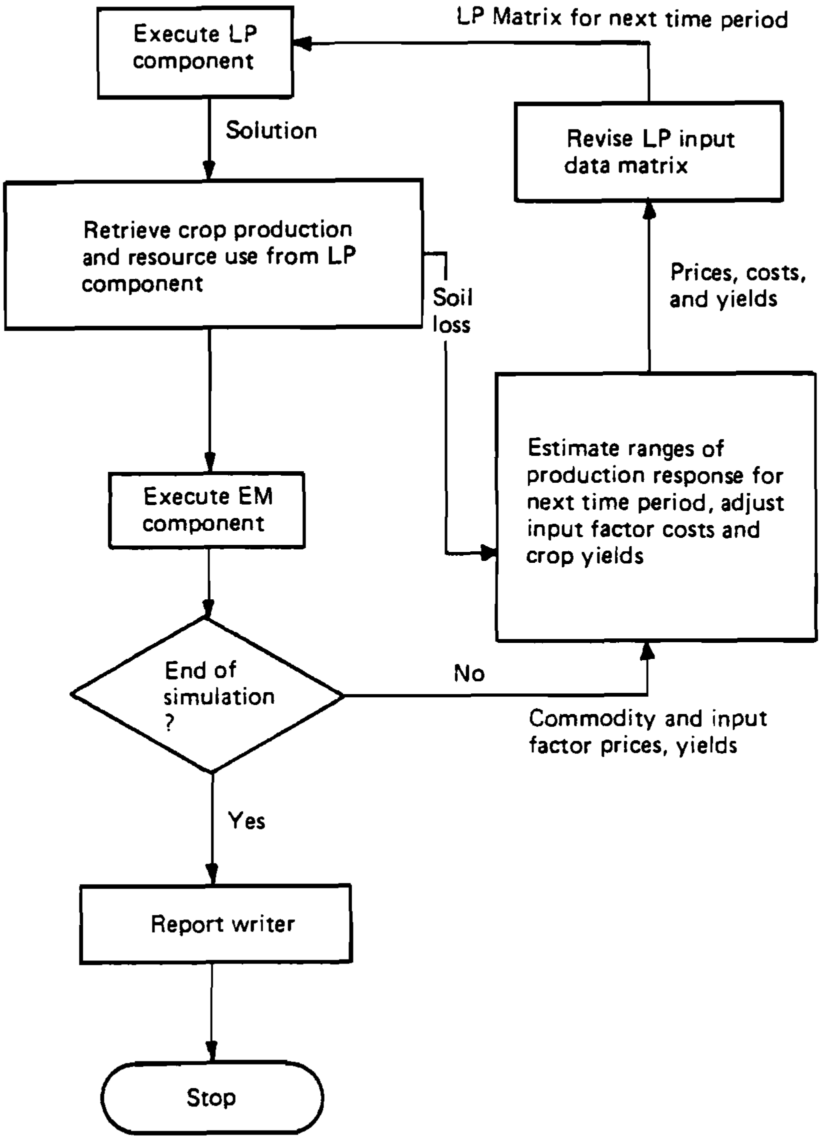

Figure 13. Basic solution procedure for the Iowa Model.

predetermined number of simulations are completed.

The linkage component can be decomposed into three subsectors: Retrieval, Adjustment, and Revision. Linkage variables, defined as variables providng information from the regional model to the national model, and vice versa, must be specified for these three subsectors. In the current version of the Iowa model, information retrieved from the Iowa LP component includes production levels of endogenous crops, soil loss, nitrogen fertilizer use, and land use in each of 5 land groups for each of 12 producing regions. Crop production and fertilizer use are inputs to the econometric component, while soil loss and land use are inputs to the Adjustment and Revision subsectors of the linkage component.

The purpose of the Adjustment subsector is to adjust the estimated crop yields and costs of production which are affected by the level of soil loss. The adjustment procedures, illustrated in Figures 14 and 15, are adapted from "Soil Depletion Study Reference Report: Southern Iowa Rivers Basin" (U.S. Department of Agriculture, 1980). The tonnage of soil loss from each soil mapping unit, estimated by the Universal Soil Loss Equation, is converted to inches of soil loss using equation (12):

$$ISL_{it} = \frac{TSL_{it}}{SBD_{it} * TACRE_{it}} \qquad (12)$$

where:

ISL_{it} = the estimated inches of soil lost in producing area (i) in period (t);

TSL_{it} = total soil loss in producing area (i) in period (t);

SBD_{it} = the average bulk density of the soil in producing area (i) in period (t); and

$TACRE_{it}$ = total cropland acres in producing area (i) in period (t).

units: ISL in inches; TSL in short tons; SBD in tons per acre-inch; and, TACRE in number of acres.

Inches of soil lost from crop production is used to reclassify the severity of erosion for a given soil depth. Three phases of erosion are defined for each soil type in Iowa (U.S. Department of Agriculture, 1980). Erosion phase 1 includes those soils with only slight erosion and no mixing of surface and subsoils in the plow layer. Erosion phase 2 (moderately eroded) includes those soils that have some sub-soil mixing into the plow layer. Erosion phase 3 (severely eroded) includes soils where the plow layer is predominantly subsoil material.

The degree of severity of erosion is then used to determine the effect on yield change and costs of producing using equation (13):

$$R_{it} = \frac{S_{it-1} - S_{it}}{S_{it-1}} \qquad (13)$$

where:

R_{it} = the ratio of the change in average soil depth in producing area (i) between periods (t-1) and (t); and,

S_{it} = the average depth of the topsoil in producing area (i) in period (t), in inches.

An improved procedure for adjusting crop yields and production costs due to changes in erosion phase is being developed.

The Revise subsector of the Linkage Component takes information from the Retrieval and Adjust subsectors and revises the LP component for the next time period. The revision reflects the expected yield and cost change, expected

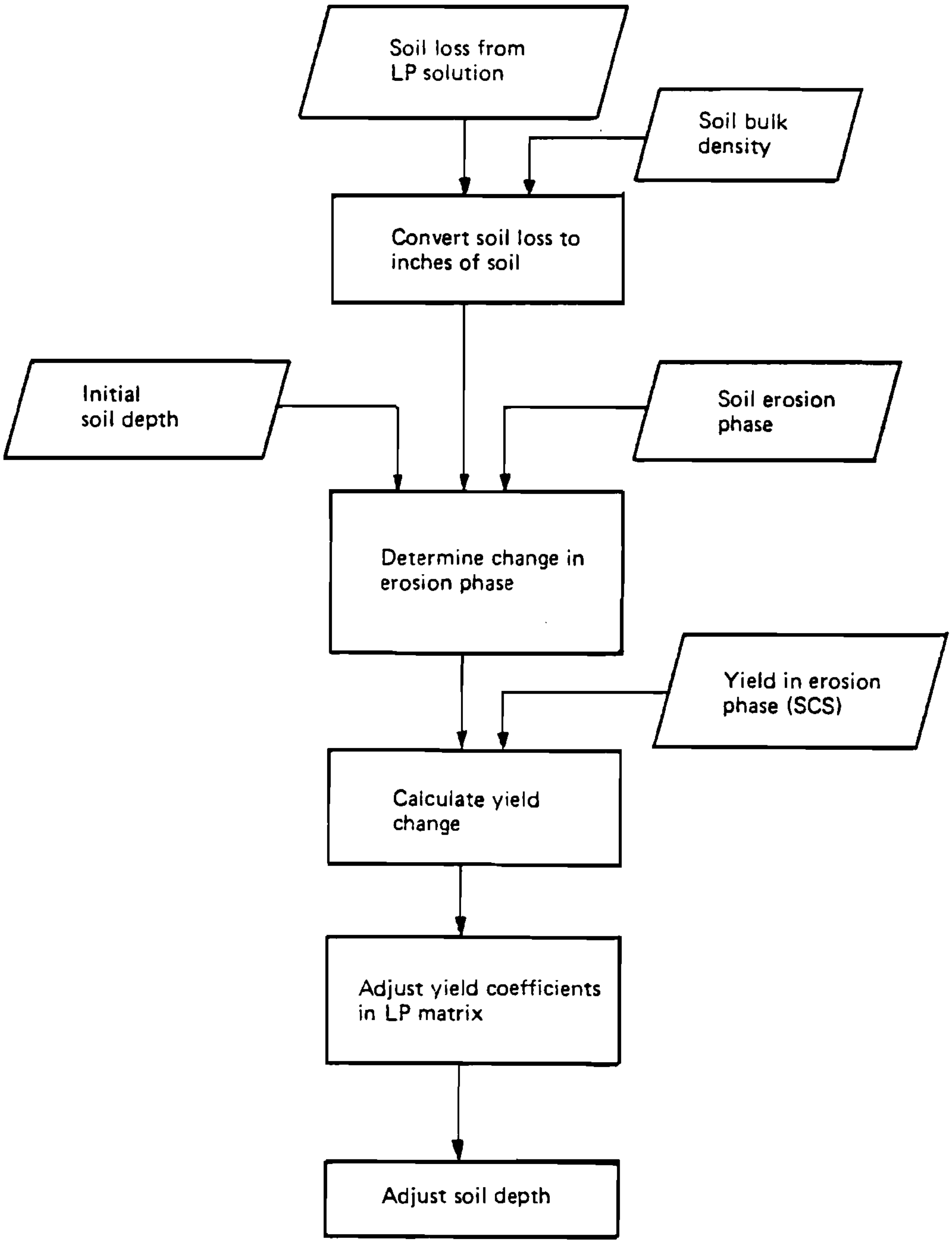

Figure 14. Schematic diagram illustrating yield adjustment for soil loss.

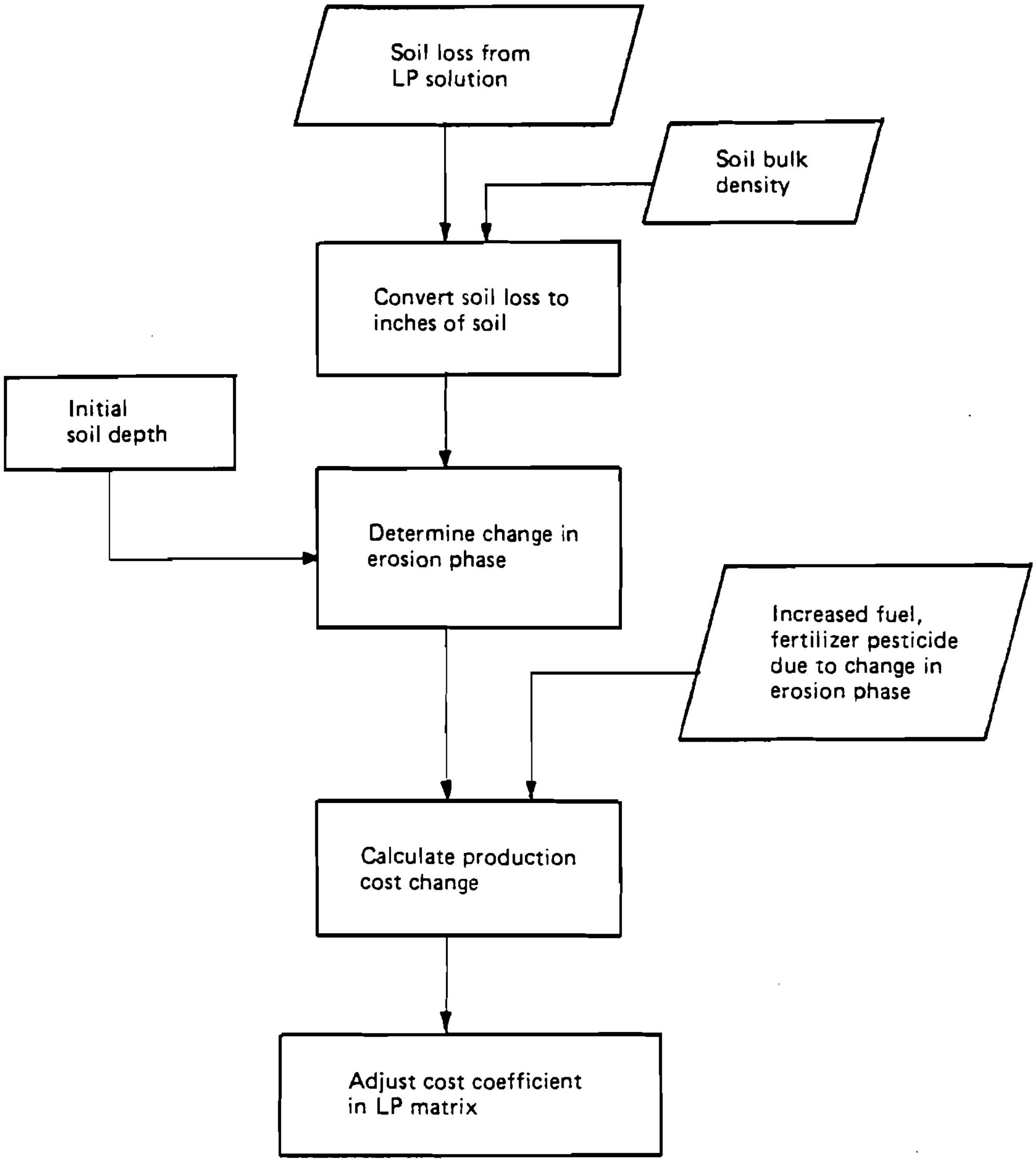

Figure 15. Schematic diagram illustrating increased costs due to soil depletion.

price, and the range of regional production response for the next year's production.

3.5. Computer Software Considerations

A complication arises because the linear programming and econometric simulation components are developed with different computer software systems, i.e., the LP component is set up on MINOS (Murtagh and Saunders, 1977) and the ES component is written in FORTRAN77 (International Business Machines, 1978). Computer software trials for linking separate programs together in a recursive process have been investigated by Huang, Short and Langley (1981). A comprehensive guide to using the Iowa model on IIASA's computer system is forthcoming.

Once the Iowa regional-national system is specified, the model can be used to examine a variety of policy alternatives directed towards the interrelationships between agricultural production and resource use and the physical and economic environment. A brief review of potential applications of the Iowa model is presented in the following section.

4. Potential Applications of the Iowa Model.

The model specified in Part 3 may be applied to the analysis of alternative scenarios concerning the interrelationships between agricultural production and the surrounding environment. Potential scenarios include the following:

1) Restrictions on selected outputs from the production process, such as alternative soil loss limits. To achieve this, one may run a Base Solution (no limit) and a set of alternatives where a limit is imposed. Restrictions on crop technologies that result in soil loss on a give land group in excess of pre-determined tolerance levels could be modeled by removing those activities from the linear programming component. By comparing the Base with alternative soil loss limits one can examine the changes in cropping patterns, the spatial allocation of crop production, and the prices of the commodities.
2) Restrictions on selected inputs into the production process, e.g., the amount of nitrogen fertilizer applied per acre. Such a limit could be modeled in the LP component by defining a right-hand-side value for the nitrogen row, or by placing an upper bound on the nitrogen buying activities
3) The impact on production patterns in Iowa due to changes in relative input and output prices.

Changes in certain exogenous variables and policy instruments in the econometric component will have various impacts upon relative prices paid for inputs and received for commodities, and, subsequently, upon agricultural production practices in Iowa. After such a change, the impacts on soil loss, production levels, patterns, and costs, and commodity prices can be evaluated.

The above presents only a brief overview of the types of analysis which may be performed using the Iowa regional-national model in its current stage of development. A study of these and other scenarios is currently in progress and will be reported in a later paper.

5. Shortcomings of the Iowa Model and Suggested Extensions.

Various components of the Iowa model have been developed somewhat independently of the Food and Agriculture Program's Task 2, "Technological Transformations in Agriculture: Resource Limitations and Environmental Consequences." This section of the paper presents a discussion of the objectives of Task 2, the correspondence of the Iowa model to those objectives, and suggested extensions of the current model.

5.1. Review of Task 2 Objectives

The premises behind Task 2 are that the basic agricultural resources - land, water, and fertilizer - will, over a long run time horizon, become more scarce and expensive, that changes in the availability and relative prices of factor inputs will lead to changes in techniques of production, and that explicit account must be made for environmental consequences and feedbacks in land productivity occuring as a result of these changes. A conclusion drawn is that,

> "... over the coming decades a technological transformation of agriculture will take place which will be constrained by resource limitations and whose environmental implications pose questions regarding the sustainability of adequate production to feed mankind in the future (Parikh, 1981)."

In order to identify the broad dimensions of the problem and to obtain general policy guidelines, a series of case studies, formulated in a general methodological framework, have been proposed (Reneau, van Asseldonk, and Frohberg, 1981). Countries or regions within countries being considered for case studies are: U.S.A. (Iowa), Hungary, C.S.S.R., U.S.S.R., Italy, Japan, Kenya, and Thailand.

Implementation of FAP's objectives for Task 2 requires a quantitative description of crop and livestock production processes, including the associated environmental effects which occur as joint products with agricultural production. Environmental effects need to be translated into their impacts on the quality of the resource base for the next period. For example, how soil erosion changes fertility of soil from one period to the next would have to be quantified (Parikh, 1981).

5.2. Correspondence of the Iowa Model to Task 2 Objectives.

The linear programming component of the Iowa regional-national model incorporates a relatively detailed quantitative description of crop production within the State of Iowa. Costs of production, nitrogen requirements, crop yields, and resulting soil loss are specified for 8 crops combined into 30 possible rotations using up to 9 different conservation-tillage practices and 5 land groups in 12 spatially delineated regions of the state of Iowa. The LP component provides an indication of the profit maximizing level of crop production and resource use occuring within Iowa in any particular time period given specified exogenous conditions.

Relative prices paid for input factors of production and relative prices received for the commodities produced are estimated within an econometric simulation component consisting of 210 equations formulated into 11 commodity submodels. The econometric component estimates short-run (annual) changes in market conditions affecting farmers' behavior in the purchase of major inputs, and can be used to characterize the response of farmers at the national level of aggregation to many changing variables which relate to production and investment decisions.

The linkage component allows the profit maximizing level of output within the State of Iowa (in the LP component) to reflect changes in the market conditions estimated within the econometric component. Also, crop yields and costs of production are adjusted between time periods to reflect the severity of soil erosion.

5.3 Possible Extensions of the Iowa Model

Many of the components perceived to be necessary for a long-term model of agricultural transformation subject to input restrictions and changes in input factor prices are incorporated in the Iowa regional-national system. Discussions with FAP staff have suggested possible extensions of the current Iowa case study model. These extensions may be divided into physical linkages and economic linkages.

Physical linkages include: 1) an improved soil loss adjustment sector whereby crop yields are adjusted by changes in soil depth and erosion phase; and, 2) chemical loss as associated with soil loss and leaching. Economic linkages include: 1) differentiating changes in cost of production between machinery and labor expenses and nitrogen use, and updating the cost coefficients in the objective function of the linear programming component by the appropriate rate of change for each cost; and, 2) improved government policy variable interactions with market incentives.

Livestock and energy sectors need to be added to the LP component to form a more complete representation of the agricultural production practices occuring in Iowa. Additional extensions and refinements may be included during continued interactions with FAP staff.

APPENDIX 1: LIST OF FIGURES

APPENDIX 2: LIST OF TABLES

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