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# The Economics of Soil and Water Conservation Practices in Iowa: Model and Data Documentation

the center for agricultural and rural development
iowa state university | ames, iowa 50011

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# THE ECONOMICS OF SOIL AND WATER
# CONSERVATION PRACTICES IN IOWA:
## MODEL AND DATA DOCUMENTATION

by

C. Arden Pope III
Shashanka Bhide
and
Earl O. Heady

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The Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011

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# PREFACE

Because of the magnitude of the soil erosion problem and because of the important role that economic factors play in the adoption of conservation practices, an extensive research effort to examine the economics of soil and water conservation practices in Iowa has been conducted. It was conducted by the Center for Agricultural and Rural Development (CARD) in the Iowa Agricultural and Home Economics Experiment Station in cooperation with the Iowa Department of Soil Conservation and the Cooperative Extension Service in order to provide guidance in planning and implementing cost-effective control for Iowa's soil erosion and nonpoint water pollution problems. Because of the scope of this effort, various related studies have been completed and various related reports have been written. These are being published as series of five CARD Reports. These reports are listed as follows:

I. The Economics of Soil and Water Conservation Practices in Iowa: Model and Data Documentation (Pope, Bhide and Heady, 1982).

II. The Economics of Soil and Water Conservation Practices In Iowa: Results and Discussion (Pope, Bhide and Heady, 1982).

III. A Dynamic Analysis of Economics of Soil Conservation: An Application of Optimal Control Theory (Bhide, Pope and Heady, 1982).

IV. Effects of Tenure Arrangements, Capital Constraints, and Farm Size on the Economics of Soil and Water Conservation Practices in Iowa (Banks, Bhide, Pope and Heady, 1982).

V. Effects of Livestock Enterprises on the Economics of Soil and Water Conservation Practices in Iowa (Krog, Bhide, Pope and Heady, 1982).

The first report of this series describes and documents the basic methodology, data and assumptions used in these related studies. Methodology, data, and assumptions specific to an individual study are given in the corresponding report.

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high land prices, high interest rates, growing expenses, etc., many farmers believe that they must concentrate on short-run profits and cash flows or be forced out of farming. Because soil and water conservation often requires long-term investments such as terraces and conservation tillage equipment and because many of the benefits of soil and water conservation practices may not be realized for many years, there are few obvious incentives for farmers to aggressively seek and use conservation practices. Finally, economic circumstances of individual farmers, such as tenure, total capital and equity, can alter the use of conservation practices.

## Objectives

Some soil erosion from water movement is inevitable. However, when the level of erosion exceeds the rate at which new soil can be created, soil erosion becomes a threat to long-term productivity. On most soils in Iowa, a tolerance level of about four or five tons of annual soil loss per acre is regarded as acceptable because at this level the soil can replace itself through natural processes. However, in Iowa average annual soil loss from cropland is estimated as being at least twice what is acceptable (U.S. Department of Agriculture, 1981a). In some parts of the state it is even much higher. As a result of this erosion and the high levels of sediment that concurrently enter streams, rivers, lakes, and reservoirs, water quality is greatly reduced.

Therefore, the following questions are raised: What practices are available to help control this erosion? Which practices are more effective and more efficient across differing soil characteristics and farming situations? What policies can be implemented to promote the use of these practices? How would a farmer's profits be affected if soil erosion is held to acceptable levels? This study attempts to address these and other similar questions.

In general, the objective of this study is to evaluate soil and water conservation practices in Iowa under various economic environments and across various farm situations with differing soil resources and economic characteristics. The objective of this particular report is to explain the general methodology and to document the data collection and model building activities of the study.

## Steps for Reaching the Objectives

The six following steps are needed to achieve the objectives of the study:

1. Define representative farms in terms of soil resources such that the farms and soil situations will represent typical and extreme conditions with respect to soils and erosion in Iowa and will range over enough conditions so that the major problems in attaining reduced soil loss and application of soil and water conservation practices can be studied.
2. Choose the relevant soil and water conservation practices that will be evaluated by first choosing and defining the

crop rotations, the tillage systems, and the supporting practices that should be considered, and then determine which combinations of them are practical and/or probable in Iowa.

3. Develop the framework for a linear programming (LP) model for each farm in terms of the activities, constraints, and objective function that will be needed.

4. Gather the data needed to estimate yields, costs, prices, constraints, etc. This includes collecting all data needed to estimate the coefficients and other values needed in the models for all of the farms.

5. Utilize the models under different scenarios and use the results to help evaluate the various soil and water conservation practices across the different farms and different scenarios.

6. Conduct various special studies that further modify, expand, and/or use the models and data to look at specific problems in more depth.

It is noted that any model building of this sort is subject to many chances of misspecification of both the physical and economic relationships. This can occur because some of the data used in building the models may be inaccurate or because the basic underlying assumptions and framework of the models are not totally correct. These problems occur to some degree in all model-building attempts.

In order to successfully study the economics of soil and water conservation practices in Iowa, information dealing with livestock feeding, integrated pest management, soil fertility, soil distribution, soil topograpgy, soil erodibility, rural sociology, farm engineering and other related subjects is needed. It would be difficult to incorporate all the relevant information from all of these areas in order to study conservation practices without developing some sort of models. Such attempts can quickly become disjointed and cumbersome. The mathematical models developed in this study attempt to incorporate the best data possible from all fields of agriculture, in a format that can be easily used.

An advisory committee of experts has been organized to help provide accurate and relevant data, and to help develop the basic underlying assumptions and framework of the models. These experts also provide help in evaluating the results of these models. The members of this committee are listed below:

Min Amemiya, Agronomy, Iowa State University (ISU)
Mark Berkland, Soil Conservation Service
Robert Dahlgren, Animal Ecology, ISU
Jerry DeWitt, Integrated Pest Management, ISU
Richard Fawcett, Weed Science, ISU
Tom Fenton, Agronomy, ISU
Clay Herman, Information Service, ISU
Bob Jolly, Economics, ISU
Stewart Melvin, Ag. Engineering, ISU
Bruce Menzel, Animal Ecology, ISU
Gerald Miller, Agronomy, ISU
Peter Nowak, Sociology, ISU
Paul Rosenberry, Ag Economics, USDA
Gene Rouse, Animal Science, ISU

Help and advice was also sought from many other experts who are not on this advisory committee. For example, much help was received from Dan Lindquist and Bill Nicholas, Iowa Department of Soil Conservation (IDSC); Ubbo Agena, Iowa Department of Environmental Quality; and Vivan Jennings, Iowa State University Cooperative Extension Service.

## II. DEFINITION OF REPRESENTATIVE FARMS

### General Location Selection

It is estimated that 18 representative farms can adequately represent the major resource situations and still be manageable in terms of the constraints of this study. In order to identify and define 18 farms that are representative of the various types of farm situations in Iowa, the general locations of the farms are first determined. In doing this, the following criteria are used: 1) the full range of erosiveness should be represented, 2) the principal soil association areas should be included, and 3) the six major land resource areas in Iowa should be well represented.

The selection of these 18 general farm locations is a subjective process that is not easily documented. However by using a map showing the principal soil association areas of Iowa (Oschwald, et al., 1964), a map showing soil association areas of Iowa (Iowa Agriculture and Home Economics Experiment Station, 1978), a map that shows the erosiveness of different areas of Iowa on a scale from one to ten (Iowa Department of Environmental Quality, 1979), and a map that outlines the land resource area of Iowa (Iowa Agriculture and Home Economics Experiment Station, 1978), general locations that meet the above criteria are selected. These locations were subsequently adjusted slightly after consultation with Tom Fenton (Agronomist, Iowa State University, Ames, Iowa), Min Amemiya, and Gerald Miller (extension agronomists, Iowa State University,

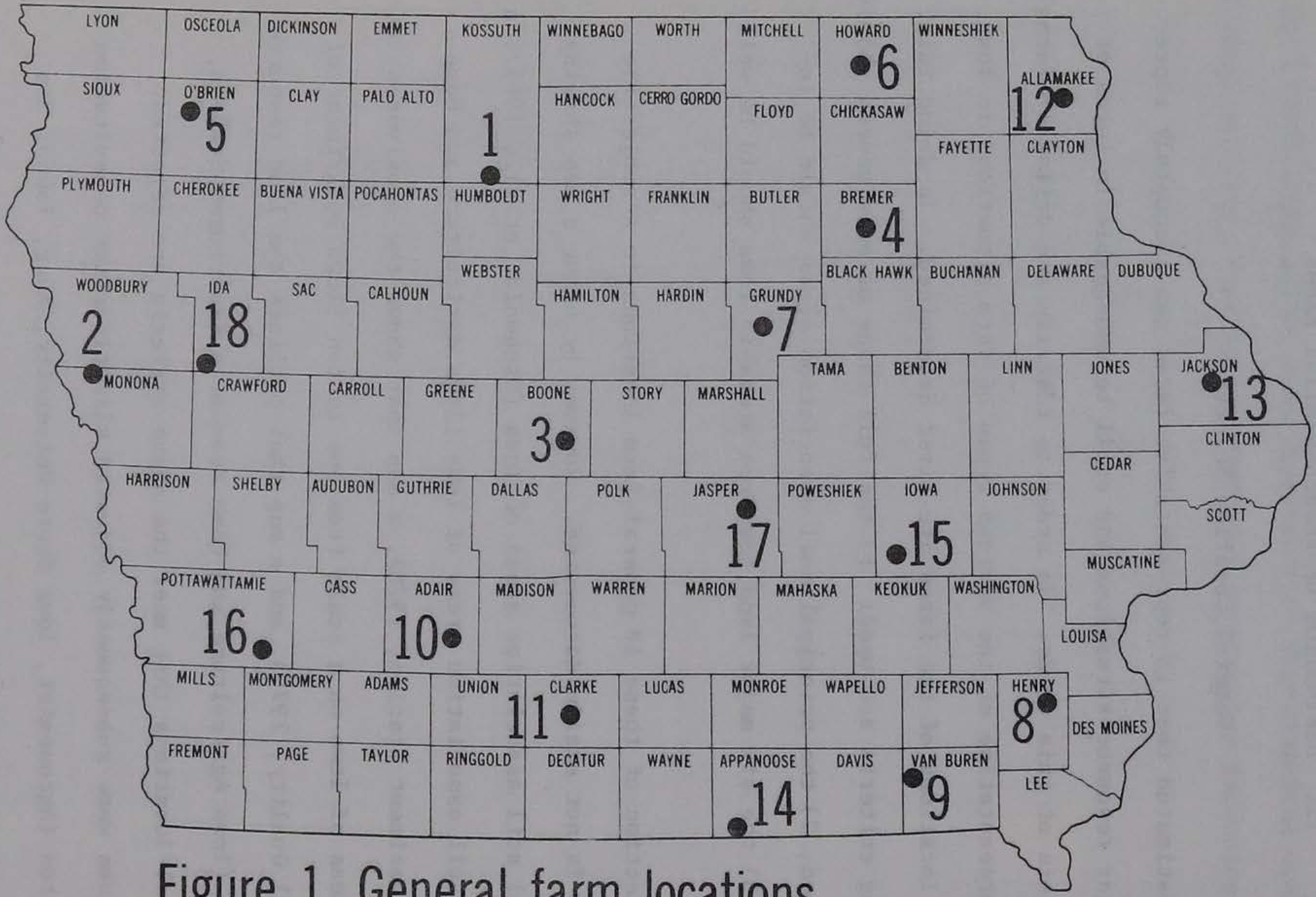

Figure 1. General farm locations

Ames, Iowa). The selected general locations of the 18 representative farms are shown in Figure 1.

## Farm Description

Actual farms are not used in this study for various reasons. It is difficult if even possible to find an actual farm that can be viewed as typical or representative of a given area and level of erosiveness. For example, in order to even try and find a representative farm, one must first synthesize one by using soil surveys, farm surveys, farm budgets, etc., to determine how a representative farm should be constructed. Also, because no actual farm includes all the rotations, tillage systems, supporting practices, livestock enterprises, etc., that are included in this study, an actual farm can provide only a small amount of the data needed to build the LP models. Even the data that an actual farm can provide often can be acquired from more reliable sources. Therefore, representative farms are constructed for use in this study.

The size of the 18 representative farms are determined for each farm based on information in "Number and Size of Farms in Iowa" (Iowa Crops and Livestock Reporting Service, 1979) and in "1978 Farm Business Summary" (Edwards and Stoneberg, 1978a, 1978b, 1978c, 1978d, 1978e, 1978f, 1978g, and 1978h). The farm sizes are chosen to reflect the average size of commercial farms in the area. Gross farm size equals the total size of the farm. Net farm size equals gross farm size minus 30 acres of land assumed to be used for the homestead, roads, drainage ways, etc.

The soils in each farm are delineated by soil mapping units (SMUs). These units describe the soil type, the slope class, and the erosion phase (see Oschwald, et al., 1964, p. 10-15). For example, one soil mapping unit may be Clarion loam, 2-5 percent slope with only slight erosion (greater than 7 inches of A horizon with no mixing of surface soil and subsoils in the plow layer). The soil type legend for Clarion loam, is 138 (Highland, et al., 1973), the slope class is B, and the erosion phase is 1. Therefore, the code used in this study for this soil is 138B1.

A land capability class and subclass (see Oschwald, et al., 1964, p. 16) is assigned to each SMU. These are obtained from County Soil Survey reports (Andrews, 1977; Andrews and Dederiksen, 1981; Buckner, 1967; Buckner and Highland, 1974; Dankert, Hanson, and Reckner, 1981; Dietz, and Hidlebaugh, 1962; Highland and Dederiksen, 1967; Kovar, Dederiksen, and Fisher, 1973; Lockridge, 1977; Nestrud and Worster, 1979; Scholtes, Swenson, Mogen, and Kittleson, 1958; and Sherwood, 1980).

Upon consultation with Thomas Fenton (agronomist, Iowa State University, Ames, Iowa) and Paul Rosenberry (agricultural economist, Economics, Statistics, and Cooperatives Service, USDA, Ames, Iowa) and based on information obtained form the National Inventory of Soil and Water Conservation Needs (Conservation Needs Inventory Committee, 1979), the Iowa Soil Association Map (Iowa Agricultural and Home Economics

Experiment Station, 1978), and from the County Soil Survey reports (the same reports referenced above), the 18 farms are tentatively defined in terms of soil composition. These farms are defined such that a reasonable combination of SMUs, representative of the area, is included. Each farm is assigned an erosiveness class based on the erosiveness of the general area in which it is found. In conjunction with this research effort, and in an attempt to get farmer and other input into this study, trips were taken by the research team to the different general farm locations in Iowa and visits were made with farmers, area extension personnel, and local Soil Conservation Service personnel. Information obtained from these trips is used to either adjust or confirm the size and soil delineation of each farm.

The final farm descriptions utilized in this study are summarized in Table 1-18.

Table 1. Farm 1

Principal Soil Association: Clarion-Nicollet-Webster,
Location: South Central Kossuth, Land Resource Area: 103,
River Basin: Des Moines River, Erosiveness Class: #1,
Gross farm size: 380 acres, Net farm size: 350 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Webster sicl | 107 | A | 1 | IIw-1 | 60 | 210 |
| Nicollet l | 55 | A | 1 | I-1 | 33 | 116 |
| Clarion l | 138 | B | 1 | IIe-1 | 7 | 24 |

Table 2. Farm 2

Principal Soil Association: Luton-Onawa-Salix,
Location: Northwest Monona, Land Resource Area: 107,
River Basin: Western Iowa, Erosiveness Class: #1,
Gross farm size: 550 acres, Net farm size: 520 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Luton sic | 66 | A | 1 | IIIw | 66 | 343 |
| Salix sicl | 36 | A | 1 | I-1 | 27 | 140 |
| Blencoe sic | 44 | A | 1 | II-w | 7 | 37 |

Table 3. Farm 3

Principal Soil Association: Clarion-Nicollet-Webster,
Location: East Central Boone, Land Resource Area: 103,
River Basin: Des Moines River, Erosiveness Class: #2,
Gross farm size: 350, Net farm size: 320.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Webster sicl | 107 | A | 1 | IIw-1 | 45 | 144 |
| Nicollet l | 55 | A | 1 | I-1 | 25 | 80 |
| Clarion l | 138 | B | 1 | IIe-1 | 23 | 74 |
| Clarion l | 138 | C | 2 | IIIe-1 | 7 | 22 |

Table 4. Farm 4

Principal Soil Association: Kenyon-Floyd-Clyde,
Location: Central Bremer, Land Resource Area: 104,
River Basin: Northeast Iowa, Erosiveness Class: #2,
Gross farm size: 380 acres, Net farm size: 350 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Kenyon l | 83 | B | 1 | IIIe-1 | 28 | 98 |
| Readlyn l | 399 | A | 1 | I-2 | 26 | 90 |
| Floyd l | 198 | B | 1 | IIw-1 | 23 | 81 |
| Clyde cl | 84 | A | 1 | IIw-1 | 23 | 81 |

Table 5. Farm 5

Principal Soil Association: Galva-Primghar-Sac,
Location: Northwest O'Brien, Land Resource Area: 107,
River Basin: Western Iowa, Erosiveness Class: #3,
Gross farm size: 360 acres, Net farm size: 330 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Galva sicl | 310 | B | 1 | I-2 | 27 | 86 |
| Galva sicl | 310 | C | 1 | IIe-2 | 15 | 48 |
| Sac sicl | 77 | B | 1 | IIe-1 | 34 | 109 |
| Primghar sicl | 91 | A | 1 | I-1 | 24 | 77 |

Table 6. Farm 6

Principal Soil Association: Cresco-Lourdes-Clyde,
Location: Central Howard, Land Resource Area: 104,
River Basin: Northeastern, Erosiveness Class: #3,
Gross farm size: 200 acres, Net farm size: 180 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Cresco l | 783 | B | 1 | IIe-2 | 25 | 45 |
| Clyde sicl | 84 | A | 1 | IIw-1 | 50 | 90 |
| Riceville l | 784 | B | 1 | IIw-3 | 25 | 45 |

Table 7. Farm 7

Principal Soil Association: Dinsdale-Tama,
Location: Central Grundy, Land Resource Area: 108,
River Basin: Iowa-Cedar River, Erosiveness Class: #4,
Gross farm size: 350 acres, Net farm size: 320.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Tama sicl | 120 | B | 1 | IIe-1 | 50 | 160 |
| Tama sicl | 120 | C | 2 | IIIe-1 | 25 | 80 |
| Dinsdale sicl | 377 | B | 1 | IIe-1 | 25 | 80 |

Table 8. Farm 8

Principal Soil Association: Otley-Mahaska-Taintor,
Location: Northeast Henry, Land Resource Area: 108,
River Basin: Skunk River, Erosiveness Class: #5,
Gross farm size: 340 acres, Net farm size: 310 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Mahaska sicl | 280 | B | 1 | I-1 | 45 | 140 |
| Clinton sicl | 80 | C | 2 | IIIe | 15 | 47 |
| Taintor sicl | 279 | A | 1 | IIw-2 | 15 | 47 |
| Otley sicl | 281 | C | 1 | IIIe-1 | 24 | 76 |

Table 9. Farm 9

Principal Soil Association: Lindley-Keswick-Weller,
Location: Northwest VanBuren, Land Resource Area: 109,
River Basin: Des Moines River, Erosiveness Class: #6,
Gross farm size: 390 acres, Net farm size: 360 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Lindley 1 | 65 | E | 2 | VIe | 40 | 144 |
| Pershing sil | 131 | B | 1 | IIe | 30 | 108 |
| Weller sil | 132 | C | 2 | IIIe | 30 | 108 |

Table 10. Farm 10

Principal Soil Association: Shelby-Sharpsburg-Macksburg,
Location: East Central Adair, Land Resource Area: 108,
River Basin: Southern Iowa, Erosiveness Class: #7,
Gross farm size: 380 acres, Net farm size: 350 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Sharpsburg sicl | 370 | B | 1 | IIe | 16 | 56 |
| Sharpsburg sicl | 370 | C | 2 | IIIe | 24 | 84 |
| Shelby-Adair cpx | 93 | D | 2 | IVe | 46 | 161 |
| Colo-Ely cpx | 11 | B | 1 | IIw | 14 | 49 |

Table 11. Farm 11

Principal Soil Association: Adair-Grundy-Haig,
Location: Central Clarke, Land Resource Area: 109,
River Basin: Des Moines River, Erosiveness Class: #7,
Gross farm size: 480 acres, Net farm size: 450 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Shelby-Adair cpx | 93 | D | 2 | IVe | 55 | 248 |
| Haig sil | 362 | A | 1 | IIw | 25 | 112 |
| Grundy sil | 364 | C | 2 | IIIe | 20 | 90 |

Table 12. Farm 12

Principal Soil Association: Fayette-Dubuque-Stonyland,
Location: Central Allamakee, Land Resource Area: 105,
River Basin: Northeast Iowa, Erosiveness Class: #8,
Gross farm size: 430 acres, Net farm size: 400 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Fayette sil | 163 | C | 1 | IIIe-1 | 10 | 40 |
| Fayette sil | 163 | D | 2 | IIIe-3 | 25 | 100 |
| Fayette sil | 163 | E | 2 | IVe-1 | 7 | 28 |
| Steep Rock | 478 | G | 1 | VIIs-1 | 28 | 112 |
| Downs sil | 162 | C | 1 | IIIe-1 | 30 | 120 |

Table 13. Farm 13

Principal Soil Association: Fayette,
Location: North Central Jackson, Land Resource Area: 105,
River Basin: Northeast Iowa, Erosiveness Class: #8,
Gross farm size: 240 acres, Net farm size: 210 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Fayette sil | 163 | C | 2 | IIIe-1 | 28 | 59 |
| Fayette sil | 163 | D | 2 | IIIe-3 | 32 | 67 |
| Fayette sil | 163 | E | 2 | IVe-1 | 25 | 52 |
| Steep Rock | 478 | G | 1 | VIIs-1 | 8 | 17 |
| Downs sil | 162 | C | 1 | IIIe-1 | 7 | 15 |

Table 14. Farm 14

Principal Soil Association: Adair-Seymour-Edina,
Location: Southwest Appanoose, Land Resource Area: 109,
River Basin: Southern Iowa, Erosiveness Class: #8,
Gross farm size: 330 acres, Net farm size: 300 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Shelby-Adair cpx | 93 | D | 2 | IVe-5 | 20 | 60 |
| Shelby loam | 24 | E | 2 | IVe-1 | 25 | 75 |
| Adair clay l | 192 | C | 2 | IVe-2 | 25 | 75 |
| Seymour sil | 312 | B | 1 | IIIe-3 | 30 | 90 |

Table 15. Farm 15

Principal Soil Association: Clinton-Keswick-Lindley,
Location: Southwest Iowa, Land Resource Area: 108,
River Basin: Iowa-Cedar River, Erosiveness Class: #9.
Gross farm size: 420 acres, Net farm size: 390 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Otley sicl | 281 | C | 2 | IIIe-1 | 48 | 187 |
| Ladoga sil | 76 | C | 2 | IIIe-1 | 14 | 55 |
| Ladoga sil | 76 | D | 2 | IIIe-3 | 14 | 55 |
| Mahaska sicl | 280 | B | 1 | I-1 | 24 | 93 |

Table 16. Farm 16

Principal Soil Association: Marshall,
Location: Eastern Pottawattamie, Land Resource Area: 107,
River Basin: Southern Iowa, Erosiveness Class: #9,
Gross farm size: 350 acres, Net farm size: 320 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Marshall sicl | 9 | B | 1 | IIe-1 | 19 | 61 |
| Marshall sicl | 9 | C | 2 | IIIe-1 | 19 | 61 |
| Marshall sicl | 9 | D | 2 | IIIe-2 | 37 | 118 |
| Colo-Ely cpx | 11 | B | 1 | IIw | 18 | 58 |
| Shelby l | 24 | D | 2 | IIIe | 7 | 22 |

Table 17. Farm 17

Principal Soil Association: Tama-Muscatine,
Location: Northeast Jasper, Land Resource Area: 108,
River Basin: Skunk River, Erosiveness Class: #10,
Gross farm size: 370 acres, Net farm size: 340 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Tama sicl | 120 | C | 2 | IIIe-1 | 60 | 204 |
| Downs sil | 162 | D | 2 | IIIe-3 | 20 | 68 |
| Muscatine sicl | 119 | A | 1 | I-1 | 10 | 34 |
| Shelby l | 24 | E | 2 | IVe-1 | 10 | 34 |

Table 18. Farm 18

Principal Soil Association: Monona-Ida-Hamburg,
Location: Southwestern Ida, Land Resource Area: 107,
River Basin: Western Iowa, Erosiveness Class: #10,
Gross farm size: 340 acres, Net farm size: 310 acres.

| Soil Type Name | Soil Type Legend | Slope Class | Erosion Phase | Capability Class | % Net Farm Acres | Acres of SMU |
|---|---|---|---|---|---|---|
| Ida sil | 1 | D | 3 | IIIe | 15 | 47 |
| Ida sil | 1 | E | 3 | IVe | 30 | 93 |
| Monona sil | 10 | C | 2 | IIe | 18 | 56 |
| Monona sil | 10 | D | 2 | IIIe | 17 | 52 |
| Napier sil | 12 | C | 1 | IIIe | 20 | 62 |

# III. IDENTIFICATION OF CONSERVATION PRACTICES

To identify which soil and water conservation practices should be included in this study, it is necessary to define exactly what practices are available and classify them so they can fit into a linear programming framework and can be evaluated in terms of their effects on soil erosion and farm profits. Soil and water conservation practices are divided into three categories: 1) less intensive crop rotations, 2) conservation tillage systems, and 3) supporting practices. For the purposes of this study the terms and definitions given in Table 19 are used.

## Defining the Crop Rotations

Considering the large number of crops that grow well in Iowa, there are almost countless possible crop rotations in the state. The following seven criteria are used to limit the number of rotations included in the models of this study:

1. The only crops that should be included in the rotations are corn grain, corn silage, soybeans, oats, meadow, and pasture. This is because these crops make up approximately 99 percent of the total crop acres harvested in Iowa (corn grain about 48 percent, corn silage about 2.5 percent, soybeans about 30 percent, oats about 4 percent, and meadow about 15 percent, see Iowa Crop and Livestock Reporting Service, 1981). Crops such as sorghum, rye, popcorn,

Table 19. Recommended Terminology

| | |
|---|---|
| Field operations: | Operations such as shredding stalks, applying fertilizers or pesticides, moldboard plowing, disking, chisel plowing, planting, etc., that are performed on the field in order to till, plant, cultivate, or harvest crops. |
| Tillage systems: | Combinations of field operations, distinguished by different levels, types, or degrees of tillage and remaining crop residue. Five different tillage systems might be conventional, chisel plow, spring disk, till-plant, and slot-plant. |
| Supporting practices: | Practices that help reduce soil erosion and water pollution that can be used in combination with the tillage systems, such as contour planting, strip cropping, and terracing. |
| Crop rotations: | Different sequences of crops over one or more years such as continuous corn, corn-soybeans, corn-oats-meadow, etc. |
| Soil and water conservation practices: | Sometimes called "Best management practices" are practices of tilling, cultivating, or harvesting crops that help reduce soil erosion and water pollution. These include conservation tillage systems, supporting practices, less intensive crop rotations, and/or combinations of each. |
| Management systems: | Combinations of different tillage systems, supporting practices and crop rotations that can be used on a given field. |

potatoes, and others can be and are grown on a small scale in Iowa, and could be brought into great production as more emphasis is placed on soil and water conservation. However, there is no real evidence that this is happening or will happen to any significant degree. Even on farms in Iowa where there is, and has been much emphasis on soil and water conservation, there has been no clear trend or evidence to show that crops other than corn, soybeans, oats, meadow, and pasture will be grown to any greater extent than they are currently. Furthermore, yield data and other needed data on other crops are often sketchy at best.

2. No continuous soybeans should be used because of disease and weed control problems.

3. No rotations with soybeans after meadow should be used because corn will normally follow to utilize the nitrogen carried over from the meadow.

4. No continuous oat rotations should be used because they are rarely, if ever, economically optimal in Iowa given prevailing relative prices. Oats are used in a meadow rotation and interseeded with a legume hay.

5. All major crops in Iowa should be well represented.

6. The full range of row cropping intensities or erosiveness for all practical combinations should be well represented.

7. More widely used rotations should be considered more strongly than less used rotations.

Based on these criteria and upon personal consultation with Min Amemiya and Garren Benson (Extension Agronomists, Iowa State University, Ames, Iowa), 15 crop rotations are chosen to be included in this study. These rotations are identified as follows:

1. C
2. CCCOM
3. CCOMM
4. COMMM
5. S
6. SSSOM
7. SSOMM
8. SOMMM
9. CB
10. CCB
11. SB
12. SSB
13. CBCOMM
14. SBSOMM
15. P

where:

C = corn grain;
S = corn silage;
B = soybeans;
O = oats;
M = meadow (leguminous hay);
P = permanent pasture.

## Defining the Tillage Systems

As with the crop rotations, there is a very large number of tillage systems that can be used by farmers. Therefore, the following criteria are used to limit the number of tillage systems included in this study:

1. The full range of tillage systems in terms of erosiveness should be represented.
2. Only systems that have been or are currently being used or experimented with to the extent that reasonably accurate data can be obtained should be used.
3. The chosen systems should be distinctly different from each other and not redundant in terms of their contribution to the study.

Based on these criteria, and upon consultation with John Laflen, Thomas Colvin, Donald Erback, and Stewart Melvin (agricultural engineers, Iowa State University, Ames, Iowa), five tillage systems are chosen and defined. The five tillage systems chosen are called conventional, fall chisel, spring disk, till-plant, and slot-plant. These systems are defined in terms of their field operations in Tables 20-25.

## Defining the Supporting Practices

There are many different supporting practices that could be included in this study. For example, contouring, strip cropping, terracing, grassed waterways, sediment control basins, field border planting, etc. are soil and water management practices that could be used as supporting practices. Only contouring, strip cropping, and terracing are

Table 20. Description of tillage systems for corn (or silage) following corn (or silage)

| Field operation | Conventional | Chisel | Disk | Till-Plant | Slot-Plant |
|---|---|---|---|---|---|
| Broadcast granular P & K | X | X | X | X | X |
| Shred stalks (Fall) | | X[a] | | | |
| Disk stalks (Fall) | X[a] | | | | |
| Moldboard plow (Fall) | X | | | | |
| Chisel plow (Fall) | | X | | | |
| Anhydrous Ammonia and/or spread manure[b] | X[1] | X[c,1] | X[c,2] | X[c,2] | X[c,2] |
| Disk-harrow (Spring) | X | X | | | |
| Field cultivator (Spring) | X | | | | |
| Offset disk (Spring) | | | X | | |
| Plant, double disk openers | X | | | | |
| Plant, slot planter/coulters | | X | X | | X |
| Plant, till-planter | | | | X | |
| Preemergence herbicide[d] | X | X | X | X | X |
| Corn borer/rootworm insecticide[f] | X | X | X | X | X |
| Sweep cultivation | 2X | | | | |
| Rolling cultivation | | 2X | 2X | 2X | X |
| Harvest[e] | X | X | X | X | X |

[a] Not done on silage.

[b] The Anhydrous Ammonia is applied in the fall, the manure is spread in the spring.

[c] Must have coulters on applicator.

[d] Depends on herbicide program.

[e] Combine corn, chop silage.

[f] Applied at planting.

[1] Fall.

[2] Spring.

Table 21. Description of tillage systems for corn (or silage) following beans

| Field operation | Conventional | Chisel | Disk | Till-Plant | Slot-Plant |
|---|---|---|---|---|---|
| Broadcast granular P & K | X | X | X | X | X |
| Chisel plow (Fall) | X | X | | | |
| Anhydrous Ammonia and/or spread manure[a] | $X^{1}$ | $X^{b,1}$ | $X^{b,2}$ | $X^{b,2}$ | $X^{2}$ |
| Disk-harrow (Spring) | X | | | | |
| Field cultivator | X | X | | | |
| Offset disk (Spring) | | | X | | |
| Plant, double disk openers | X | X | | | |
| Plant, slot planter w/coulters | | | X | | X |
| Plant, till-plant | | | | X | |
| Preemergence herbicide[c] | X | X | X | X | X |
| Sweep cultivation | 2X | | | | |
| Rolling cultivation | | 2X | 2X | 2X | 1.5X |
| Harvest | X | X | X | X | X |

[a] The Anhydrous Ammonia is applied in the fall, the manure in the spring.

[b] Must have rolling coulters on applicator.

[c] Depends on herbicide program.

[1] Fall.

[2] Spring.

Table 22. Description of tillage systems for corn (or silage) following meadow

| Field operation | Conventional | Chisel | Disk | Till-Plant | Slot-Plant |
|---|---|---|---|---|---|
| Broadcast N P & K (Fall) | X | X | X | X | X |
| Chisel | | X | | | |
| Disk | | | X | | |
| Moldboard plow (Fall) | X | | | | |
| Offset disk (Spring) | X | | 2X | | |
| Disk harrow (Spring) | X | 2X | | | |
| Plant double disk openers | X | X | X | | |
| Plant, slot planter/w/coulter | | | | X | X |
| Preemergence herbicide | X | X | X | X | X |
| Post emergence herbicide | | | | X | X |
| Sweep cultivation | 2X | | | | |
| Rolling cultivation | | 2X | 2X | 2X | |
| Harvest | X | X | X | X | X |

Table 23. Description of tillage systems for beans following corn

| Field operation | Conventional | Chisel | Disk | Till-Plant | Slot-Plant |
|---|---|---|---|---|---|
| Shred stalks (Fall) | | X[a] | | | |
| Disk stalks (Fall) | X[a] | | | | |
| Moldboard plow (Fall) | X | | | | |
| Chisel plow (Fall) | | X | | | |
| Disk-harrow (Spring) | X | X | | | |
| Field cultivator (Spring) | X | | | | |
| Offset disk (Spring) | | | X | | |
| Plant, double disk openers | X | | | | |
| Plant, slot planter/w/coulters | | X | X | | X |
| Plant, till-planter | | | | X | |
| Preemergence herbicide[b] | X | X | X | X | X |
| Sweep cultivation | 2X | | | | |
| Rolling cultivation | | 2X | 2X | 2X | 1.5X |
| Harvest | X | X | X | X | X |

[a] Not done following silage.

[b] Depends on herbicide program.

Table 24. Description of tillage systems for meadow following meadow or oats

| Field operation | Conventional | Chisel | Disk | Till-Plant | Slot-Plant |
|---|---|---|---|---|---|
| Broadcast P & K[a] | X | X | X | X | X |
| Harvest: | | | | | |
| Swath | 3X | 3X | 3X | 3X | 3X |
| Bale | 3X | 3X | 3X | 3X | 3X |
| Haul | 3X | 3X | 3X | 3X | 3X |

[a] Broadcast P & K on 3rd year meadow only.

Table 25. Description of tillage systems for oats following corn (or silage)

| Field operation | Conventional | Chisel | Disk | Till-Plant | Slot-Plant |
|---|---|---|---|---|---|
| Disk-harrow (Spring) | 2X | 2X | 2X[a] | 2X | 2X |
| Drill seed and broadcast alfalfa | X | X | X | X | X |
| Harvest | X | X | X | X | X |

[a] Offset disk in spring comes before disk-harrow.

actually modeled as separate supporting practices in this study because these are the three major practices that directly affect soil erosion as measured by the universal soil loss equation.

Although grassed waterways are not modeled as a separate supporting practice, in developing the model it is assumed grassed waterways are used when needed. For example, the costs of terracing also include the cost of the grassed waterways needed for those terraces. Therefore, grassed waterways are included in the study but only where they are needed in conjunction with another supporting practice.

## Defining the Management Systems

The management systems included in the study are all the combinations of crop rotations, tillage systems, and supporting practices previously identified and defined with the following exceptions. Strip cropping is used for only the following rotations: CCOMM, COMMM, SSOMM, and SOMMM. Only the conventional tillage system is used on pasture and pasture cannot be strip cropped or contoured. The till-plant and slot-plant systems are done on the contour on soil mapping units with slope classes C or steeper. Also, the till-plant tillage system is not used on rotations COMMM or SOMMM.

# IV. CONSTRUCTING THE LINEAR PROGRAMMING MODELS

A linear programming (LP) model ~~was~~ built for each of the 18 representative farms. A discussion of the theoretical basis for linear programming and its applications to agricultural and economic problems can be complex and lengthy and is, therefore, left to several qualified texts (Agrawal and Heady, 1972; Beneke and Winterboer, 1973, and Pfaffenberger and Walker, 1976). Succinctly, a linear programming model maximizes (or minimizes) a linear objective function subject to a simultaneous system of linear constraints.

## Mathematical Representation of the Models

A general mathematical representation of the models used in this study is presented as follows:

$$\text{Maximize:}\quad Z = \sum_i Q_i^c P_i^c + \sum_j Q_j^L P_j^L - \sum_k \sum_l \sum_m \sum_n X_{klmn}^c C_{klmn}^c - \sum_p X_p^L C_p^L - \sum_q F_q C_q^F$$

$$- \sum_r H_r C_r^H - \sum_s L_s C_s^L - \sum_w E_w C_w^E - \sum_u K_u C_u^k - SC^s - TC^T - \sum_v V_v C^v \qquad (4.1)$$

subject to:

$$\sum_k \sum_l \sum_m X_{klmn}^c \leq AA_n \qquad (4.2)$$

$$\sum_k \sum_l \sum_m \sum_n X_{klmn}^c LR_{klmns}^c + \sum_p X_p^L LR_{ps}^L - L_s \leq LA_s \qquad (4.3)$$

$$\sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, HR_{klmnr} - H_{r} \leq 0 \qquad (4.4)$$

$$\sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, ER^{c}_{klmnt} + \sum_{p} X^{L}_{p} ER^{L}_{pw} - E_{w} \leq 0 \qquad (4.5)$$

$$\sum_{k}\sum_{l}\sum_{n} X^{c}_{kl4n}\, TC_{n} - T \leq 0 \qquad (4.6)$$

$$\sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, KR^{c}_{klmnu} + \sum_{p} X^{L}_{p} KR^{L}_{pu} + \sum_{q} F_{q} KR^{F}_{qu} + \sum_{r} H_{r} KR^{H}_{ru}$$

$$+ \sum_{s} L_{s} KR^{L}_{su} + \sum_{w} E_{w} KR^{E}_{wu} + \Sigma T_{n} KR^{T}_{nu} + \sum_{v} V_{v} KR^{A}_{vu} - K_{u} \leq 0 \qquad (4.7)$$

$$\sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, SLA_{klmn} - S = 0 \qquad (4.8)$$

$$\sum_{k}\sum_{l}\sum_{m} X^{c}_{klmn}\, SLA_{klmn} \leq SLA_{n} \qquad (4.9)$$

$$\sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, DR_{klmn} \leq DRA \qquad (4.10)$$

$$\sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, FR_{klmnq} - \sum_{p} X^{L}_{p} FO_{pq} - F_{q} \leq 0 \qquad (4.11)$$

$$Q^{c}_{i} + \sum_{p} X^{L}_{p} QR^{c}_{pi} - \sum_{k}\sum_{l}\sum_{m}\sum_{n} X^{c}_{klmn}\, QO^{c}_{klmni} \leq 0 \qquad (4.12)$$

$$Q^{L}_{j} - \sum_{p} X^{L}_{p} QO^{L}_{pj} \leq 0 \qquad (4.13)$$

where:

$i$ = 1,...I for the crop products sold,

$j$ = 1,...J for the livestock products sold,

$k = 1, \ldots 15$ for the crop rotations,

$l = 1, \ldots 5$ for the tillage systems,

$m = 1, \ldots 4$ for the supporting practices,

$n = 1, \ldots N$ for the SMUs,

$p = 1, \ldots P$ for the livestock activities,

$q = 1, \ldots 3$ for the fertilizers (N, P, and K),

$r = 1, 2$ for herbicides and insecticides,

$s = 1, 2, 3$ for spring, fall, and other time periods,

$w = 1, 2, 3$ for the sources of energy (diesel, LP gas, and electricity),

$u = 1, 2, 3$ for short-, medium-, and long-term capital costs,

$v = 1, 2$ for feeder livestock bought (feeder pigs, or feeder calves).

and where:

$Q_i^c$ = the number of units of crop i sold,

$P_i^c$ = the price of one unit of crop i,

$Q_j^L$ = the number of units of livestock output j sold,

$P_j^L$ = the price of one unit of livestock output j,

$X_{klmn}^c$ = the number of acres of rotation k with tillage system l and supporting practice m on SMU n,

$C_{klmn}^c$ = the cost per acre of rotation k with tillage system l and supporting practice m on SMU n (excluding fertilizer, herbicide, fuel, insecticide, hired labor, energy, capital, erosion tax, and terracing costs),

$X_p^L$ = the number of units of livestock activity p,

$C_p^L$ = the cost per unit of livestock activity p (excluding hired labor, energy, capital and feeder livestock costs),

$F_q$ = the number of pounds of fertilizer q purchased,

$C^F_q$ = the cost per pound of fertilizer q,

$H_r$ = the number of units of herbicide or insecticide r,

$C^H_r$ = the cost per unit of herbicide or insecticide r,

$L_s$ = the number of hours of hired labor required in time period s,

$C^L_s$ = the cost per hour of hired labor in time period s,

$E_w$ = the number of units of energy source w,

$C^E_w$ = the cost per unit of energy source w,

$K_u$ = the number of dollars of capital of term u required,

$C^k_u$ = the cost of one dollar of capital of term u,

$S$ = the number of tons of soil loss,

$C^S$ = the tax on one ton of soil loss (for use only when conservation taxes on soil loss are emposed),

$T$ = the total terracing costs in dollars,

$C^T$ = the fraction of total terracing costs paid by the farmer (i.e. the amount not subsidized or paid for by the government),

$V_v$ = the number of units of feeder livestock v,

$C^v_v$ = the cost of buying one unit of feeder livestock v,

$AA_n$ = the total acres of SMU n available,

$LR^c_{klmns}$ = the total hours of labor required in time period s to raise one acre of crop rotation k, using tillage system l, and supporting practice m, on SMU n,

$LR^L_{ps}$ = The hours of labor required in time period s to perform one unit of livestock activity p,

$LA_s$ = total hours of non-hired labor available in time period s,

$HR_{klmnr}$ = total units herbicide or insecticide r required to raise one acre of crop rotation k, using tillage system l and supporting practice m, on SMU n,

$ER^C_{klmnt}$ = the total units of energy source t required to raise one acre of crop rotation k, using tillage system l and supporting practice m, on SMU n,

$ER^L_{pw}$ = The total units of energy source w required to perform one unit of livestock activity p,

$TC_n$ = the total costs of terracing one acre of SMU n,

$KR^C_{klmnu}$ = the amount of capital of term u needed to raise one acre of crop rotation k with tillage system l, supporting practice m, on SMU n,

$KR^L_{pu}$ = The amount of capital of term u needed to perform one unit of livestock activity p,

$KR^F_{qu}$ = the amount of capital of term u needed to purchase one pound of fertilizer q,

$KR^H_{ru}$ = the amount of capital of term u needed to purchase one unit of herbicide or insecticide r,

$KR^L_{su}$ = the amount of capital of term u needed to buy one hour of labor in time period s,

$KR^E_{wu}$ = the amount of capital of term u needed to buy one unit of energy source w,

$KR^T_{nu}$ = the amount of capital of term u required to put terracing on one acre of SMU n,

$KR^{A}_{vu}$ = the amount of capital of term u needed to buy one unit of feeder livestock v,

$SLA_{klmn}$ = the amount of annual soil loss per acre under rotation k, using tillage system l and supporting practice m, on SMU n,

$SLA_{n}$ = the amount of soil loss that is acceptable on SMU n,

$DR_{klmn}$ = 1 when annual soil loss per acre under crop rotation k, using tillage system l and supporting practice m, on SMU n is greater than T-values,

= 0 otherwise,

DRA = 0 when annual per acre soil loss is constrained to t-values,

= $\infty$ otherwise,

$FR_{klmnq}$ = the amount of fertilizer q needed per acre of crop rotation k, using tillage system l and supporting practice m, on SMU n,

$FO_{pq}$ = the amount of fertilizer q furnished by one unit of livestock activity p,

$QR^{c}_{pi}$ = the amount of crop product i used per one unit of livestock activity p,

$QO^{c}_{klmni}$ = the amount of crop product i produced per acre of crop rotation k, using tillage system l and supporting practice m, on SMU n, and

$QO^{L}_{pj}$ = the amount of livestock product j produced per unit of livestock activity p.

## Explanation of the Equations of the Models

Equation (4.1) is the objective function used in this study. The objective of the models is to maximize the net returns to land, management, family labor, and permanent livestock facilities. With the exception of conservation taxes on soil loss, these are before-tax returns.

Therefore, equation (4.1) is maximized subject to the system of constraints represented by equations (4.2 - 4.13). Equation (4.2) states that the total acres of a given SMU used cannot exceed the acres owned. Equation (4.3) states that the total labor required for raising both crops and livestock cannot exceed the total amount of family labor plus the labor hired during the cropping seasons. Equations (4.4) states that the amount of herbicides and insecticides required cannot exceed the amount purchased. Equation (4.5) constrains the amount of energy used from different sources to be less than or equal to the amount purchased. Equation (4.6) constrains the total terracing costs to equal the total actual costs of terracing.

Equation (4.7) states that the total requirements of short-, medium-, and long-term capital cannot exceed the amount borrowed. Equation (4.8) constrains the sum of the soil loss from each SMU to equal the total soil loss for the whole farm. Equation (4.9) states that the level of soil loss on a given SMU cannot exceed a certain specified level.

In equation (4.10), when the dummy variable, DRA, is set to zero, soil loss for any given activity is constrained to be less than or equal to T-values.

Equation (4.11) constrains the total amount of fertilizers required to be equal to or less than the amount furnished by the livestock sector plus the amount purchased. Equation (4.12) constrains the amount of each crop product sold to be less than or equal to the amount raised minus the amount used in livestock production. Equation (4.13) constrains the amount of each livestock product sold to be less than or equal to the amount produced.

## Simplex Tableau of the Models

An alternative method of representing the basic model used for each of the farms is the simplex tableau as illustrated in Figure 2. In Figure 2 the rows represent the objective function (Z) and the constraints of the model. The columns represent the activities of the model. Note that only a small number of the cropping and livestock activities are actually represented in the tableau.

## Framework of Data Assimilation and Model Construction

The IBM MPSX linear programming package is used to solve the models. (For an explanation of this package and how to use it see Libbin, Moorhead, and Martin, 1973; and Benecke and Winterboer, 1973). In order to get the data gathered and in a format that can be used by the MPSX package to solve the LP models, several steps are taken: 1) four data files, the soil loss data file, the cost data file, the yields and fertilizer data file, and the prices data file are constructed; 2) information from these files are utilized to compile

| Activities | | | Cropping Activities | | | | Livestock Activities | | | | Miscellaneous Buy, Sell, Subsidize, and Soil Loss Activities | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rows | Row Type | RHS | XXRJJKL1 | XXRJJKL2 | ... | XXRJJKL5 | Livestock 1 | Livestock 2 | ... | Livestock P | Buy Spring Labor | Buy Fall Labor | Buy Other Labor | Buy Herbicide | Buy Insecticide | Buy Diesel | Buy LP Gas | Buy Electricity | Terracing Sub. | Buy St. Capital | Buy Mt. Capital | Buy Lt. Capital | Soil Loss Total | Soil Loss SMU1 | Soil Loss SMU2 | ... | Soil Loss SMU5 | Buy Nitrogen | Buy Phosphorous | Buy Potash | Buy Feeder Calves | Buy Feeder Pigs | Buy Straw | Sell Corn Grain | Sell Soybeans | Sell Oats | Sell Straw | Sell Alfalfa | Sell Pasture | Sell Feeder Pigs | Sell Cull Sows | Sell Finished Hogs | Sell Feeder Calves | Sell Cull Cows | Sell Finished Steers |
| Z | N | | -C | -C | -C | -C | -C | -C | -C | -C | -C | -C | -C | -1 | -1 | -C | -C | -C | -S | -C | -C | -C | -T | -T | -T | -T | -T | -C | -C | -C | -C | -C | -C | P | P | P | P | P | P | P | P | P | P | P | P |
| SMU1 | L | A | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SMU2 | L | A | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| : | L | A | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SMU5 | L | A | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spring Labor | L | H | h | h | h | h | h | h | h | h | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fall Labor | L | H | h | h | h | h | h | h | h | h | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Other Labor | L | H | h | h | h | h | h | h | h | h | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Herbicides | E | 0 | $ | $ | $ | $ | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Insecticides | E | 0 | $ | $ | $ | $ | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diesel | L | 0 | g | g | g | g | g | g | g | g | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| LP Gas | L | 0 | g | g | g | g | g | g | g | g | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Electricity | L | 0 | k | k | k | k | k | k | k | k | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Terracing | L | 0 | $ | $ | $ | $ | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| St. Capital | L | 0 | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ | -1 | | | | | | | | $ | $ | $ | $ | $ | $ | | | | | | | | | | | | |
| Mt. Capital | L | 0 | $ | $ | $ | $ | $ | $ | $ | $ | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Lt. Capital | L | 0 | | | | | $ | $ | $ | $ | | | | | | | | | $ | | | -1 | | | | | | | | | | | | | | | | | | | | | | | |
| T-Value Dummy | L | 0 | d | d | d | d | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Soil Loss | L | 0 | t | t | t | t | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | | |
| SMU1 Soil Loss | L | 0 | t | | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | | |
| SMU2 Soil Loss | L | 0 | | t | | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | | |
| : | L | 0 | | | t | | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | | |
| SMU5 Soil Loss | L | 0 | | | | t | | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | | |
| Nitrogen | E | 0 | p | p | p | p | -p | -p | -p | -p | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | | |
| Phosphorous | E | 0 | p | p | p | p | -p | -p | -p | -p | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | | | | |
| Potash | E | 0 | p | p | p | p | -p | -p | -p | -p | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | 1 | | |
| Feeder Calves | L | 0 | | | | | c | c | c | c | | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | 1 | | | | | |
| Feeder pigs | L | 0 | | | | | c | c | c | c | | | | | | | | | | | | | | | | | | | | | | -1 | | | | | | | | | | | | | |
| Corn Grain | L | 0 | -b | -b | -b | -b | b | b | b | b | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| Soybeans | L | 0 | -b | -b | -b | -b | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| Oats | L | 0 | -b | -b | -b | -b | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| Straw | L | 0 | -t | -t | -t | -t | t | t | t | t | | | | | | | | | | | | | | | | | | | | | | | -1 | | | | 1 | | | | | | | | |
| Alfalfa | L | 0 | -t | -t | -t | -t | t | t | t | t | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| Pasture | L | 0 | -a | -a | -s | -s | t | t | t | t | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| Cull Sows | L | 0 | | | | | -c | -c | -c | -c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| Finished Hogs | L | 0 | | | | | -c | -c | -c | -c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| Cull Cows | L | 0 | | | | | -c | -c | -c | -c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| Finished Steers | L | 0 | | | | | -c | -c | -c | -c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |

Figure 2. LP simplex tableau.

a larger data file called a MID (Matrix Input Data) set; 3) the data in the MID set is used to generate crop columns; 4) the crop columns are concatenated with the row names and other miscellaneous columns needed; 5) these columns and row names, along with the right hand sides (or constraints), livestock columns, and activity bounds are entered into an MPSX program; and 6) the models are utilized (see Figure 3).

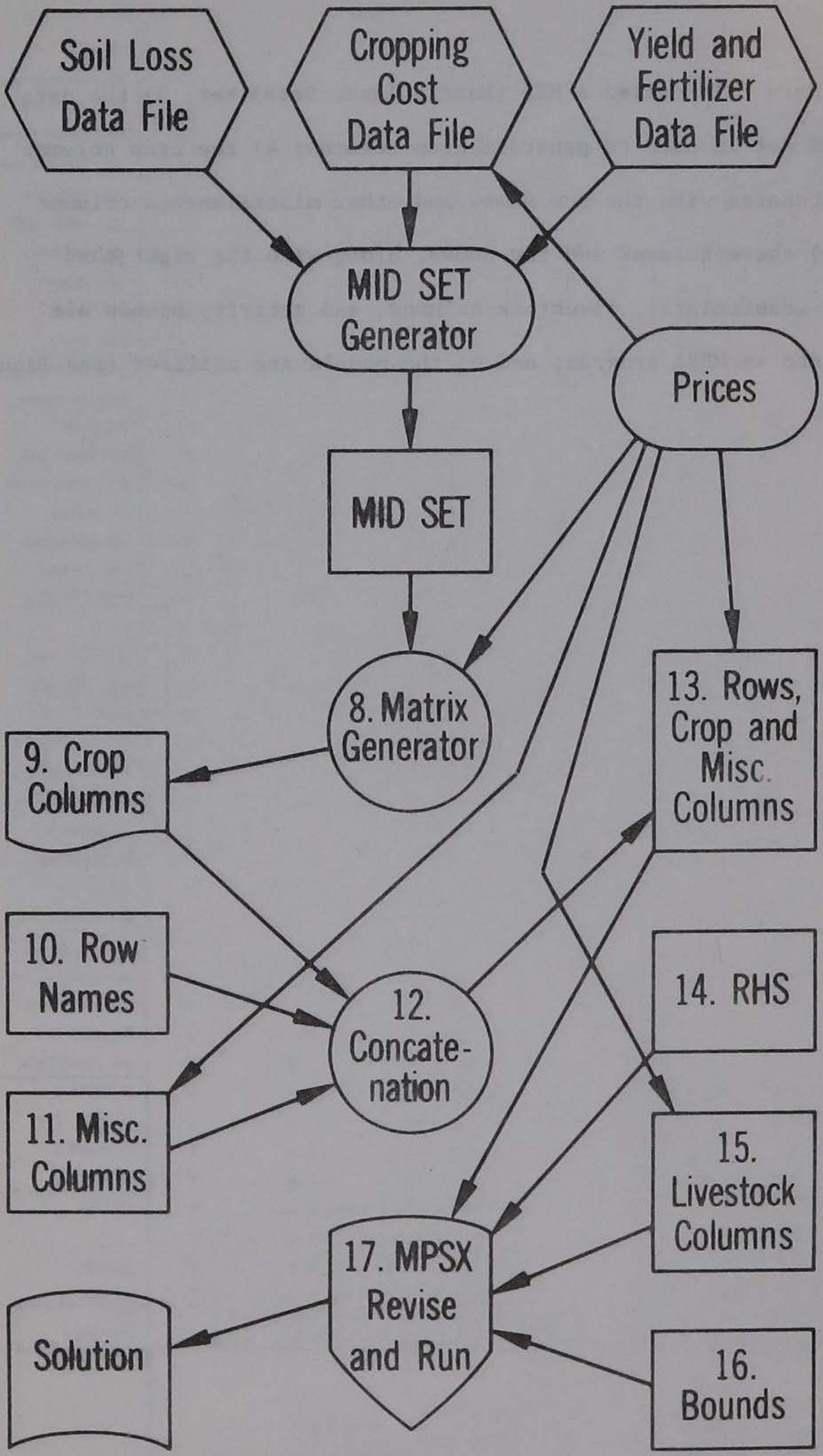

Figure 3. Data assimilation.

## V. DATA COLLECTION

### Soil Loss Data

Soil loss on a given SMU under a given management system is approximated by using the Universal Soil Loss Equation (USLE). The equation is formulated as follows:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

where:

A = the computed soil loss (or soil movement) in tons per acre,

R = the rainfall and runoff factor for the area where the soil is located,

K = the soil erodibility factor for the particular soil type,

L = the slope length factor for the SMU,

S = the slope gradient factor for the SMU,

C = the crop management factor which relates to a particular combination of the crop rotation and tillage system,

P = the erosion control practice factor which relates to the supporting practices.

For more information on these factors and how they are used and calculated see Wischmeier and Smith (1978).

In Table 26, the estimated RKLS and RKLST factors, the P factors for strip cropping under the CCOMM and COMMM rotations, the soil density, and the t-values for each SMU and for each farm are presented. The RKLS factor is simply the product of the estimated R, K, L, and S factors. The RKLST factor is also the product of the estimated R, K, L, and S

Table 26. Soil loss data

| Farm No. | Farm Soil No. | SMU Code | RKLS[a] Factor | RKLST[a] Factor | P-factor[b] for Contour | P-factor[b] Strip-Crop CCOMM | P-factor[b] Strip-Crop COMMM | Tons Per[a] Acre Inch | T-Values[a] |
|---|---|---|---|---|---|---|---|---|---|
| 01 | 1 | 107A1 | 0 | 0 | .65 | --- | --- | 159 | 4 |
| | 2 | 55A1 | 0 | 0 | .65 | --- | --- | 159 | 4 |
| | 3 | 138B1 | 14.37 | 14.37 | .54 | .3 | .2 | 159 | 4 |
| 02 | 1 | 66A1 | 0 | 0 | .65 | --- | --- | 151 | 4 |
| | 2 | 36A1 | 0 | 0 | .65 | --- | --- | 151 | 4 |
| | 3 | 44A1 | 0 | 0 | .65 | --- | --- | 151 | 4 |
| 03 | 1 | 107A1 | 0 | 0 | .65 | --- | --- | 159 | 4 |
| | 2 | 55A1 | 0 | 0 | .65 | --- | --- | 159 | 4 |
| | 3 | 138B1 | 14.37 | 14.37 | .54 | .3 | .2 | 159 | 4 |
| | 4 | 138C2 | 48.13 | 40.90 | .56 | .3 | .2 | 161 | 4 |
| 04 | 1 | 83B1 | 20.42 | 15.93 | 1.00 | .3 | .2 | 161 | 4 |
| | 2 | 399A1 | 0 | 0 | .65 | --- | --- | 161 | 4 |
| | 3 | 198B1 | 18.34 | 13.82 | 1.00 | .3 | .2 | 159 | 4 |
| | 4 | 84A1 | 0 | 0 | .65 | --- | --- | 159 | 4 |
| 05 | 1 | 310B1 | 21.72 | 16.95 | 1.00 | .3 | .2 | 147 | 5 |
| | 2 | 310C2 | 79.55 | 45.35 | 1.00 | .3 | .2 | 147 | 5 |
| | 3 | 77B1 | 21.42 | 16.72 | 1.00 | .3 | .2 | 147 | 4 |
| | 4 | 91A1 | 0 | 0 | .65 | --- | --- | 147 | 5 |
| 06 | 1 | 783B1 | 18.85 | 15.31 | 1.00 | .3 | .2 | 163 | 3 |
| | 2 | 84A1 | 0 | 0 | .65 | --- | --- | 159 | 4 |
| | 3 | 7S4B1 | 22.25 | 17.36 | 1.00 | .3 | .2 | 161 | 3 |
| 07 | 1 | 120B1 | 24.35 | 19.00 | 1.00 | .3 | .2 | 143 | 5 |
| | 2 | 120C2 | 92.03 | 52.47 | 1.00 | .3 | .2 | 145 | 5 |
| | 3 | 377B1 | 23.75 | 18.53 | 1.00 | .3 | .2 | 145 | 4 |

Table 26. (cont.).

| Farm No. | Farm Soil No. | SMU Code | RKLS[a] Factor | RKLST[a] Factor | P-factor[b] for Contour | P-factor[b] Strip-Crop CCOMM | P-factor[b] Strip-Crop COMMM | Tons Per[a] Acre Inch | T-Values[a] |
|---|---|---|---|---|---|---|---|---|---|
| 08 | 1 | 280B1 | 19.59 | 16.67 | .54 | .3 | .2 | 149 | 4 |
| | 2 | 80C2 | 88.26 | 60.68 | 1.00 | .3 | .2 | 152 | 4 |
| | 3 | 279A1 | 0 | 0 | .65 | --- | --- | 149 | 4 |
| | 4 | 281C1 | 77.09 | 53.00 | 1.00 | .3 | .2 | 149 | 4 |
| 09 | 1 | 65E2 | 329.81 | 172.95 | 1.00 | --- | --- | 168 | 3 |
| | 2 | 131B1 | 23.42 | 23.22 | .54 | .3 | .2 | 149 | 3 |
| | 3 | 132C2 | 104.17 | 73.66 | 1.00 | .3 | .2 | 154 | 3 |
| 10 | 1 | 370B1 | 19.34 | 18.58 | .54 | .3 | .2 | 149 | 4 |
| | 2 | 370C2 | 74.84 | 51.46 | 1.00 | .3 | .2 | 151 | 4 |
| | 3 | 93D2 | 154.10 | 84.40 | 1.00 | .4 | .3 | 151 | 4 |
| | 4 | 11B1 | 20.59 | 16.07 | 1.00 | .3 | .2 | 147 | 4 |
| 11 | 1 | 93D2 | 154.10 | 84.40 | 1.00 | .4 | .3 | 168 | 4 |
| | 2 | 362A1 | 0 | 0 | .65 | --- | --- | 153 | 4 |
| | 3 | 364C2 | 87.17 | 61.64 | 1.00 | .3 | .2 | 153 | 4 |
| 12 | 1 | 163C1 | 89.81 | 59.12 | 1.00 | .3 | .2 | 143 | 4 |
| | 2 | 163D2 | 185.84 | 108.81 | 1.00 | .4 | .3 | 147 | 4 |
| | 3 | 163E2 | 319.33 | 193.37 | 1.00 | --- | --- | 147 | 4 |
| | 4 | 478G1 | 278.33 | 145.96 | 1.00 | --- | --- | 147 | 4 |
| | 5 | 162C1 | 89.69 | 51.13 | 1.00 | .3 | .2 | 143 | 4 |
| 13 | 1 | 163C2 | 89.81 | 59.12 | 1.00 | .3 | .2 | 147 | 4 |
| | 2 | 163D2 | 185.84 | 108.81 | 1.00 | .4 | .3 | 147 | 4 |
| | 3 | 163E2 | 319.33 | 193.37 | 1.00 | --- | --- | 147 | 4 |
| | 4 | 478G1 | 278.33 | 145.96 | 1.00 | --- | --- | 143 | 4 |
| | 5 | 162C1 | 89.69 | 51.13 | 1.00 | .3 | .2 | 147 | 4 |

Table 26. (cont.).

| Farm No. | Farm Soil No. | SMU Code | RKLS[a] Factor | RKLST[a] Factor | P-factor[b] for Contour | P-factor[b] Strip-Crop CCOMM | P-factor[b] Strip-Crop COMMM | Tons Per[a] Acre Inch | T-Values[a] |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 1 | 93D2 | 154.10 | 84.40 | 1.00 | .4 | .3 | 168 | 4 |
| | 2 | 24E2 | 269.29 | 141.22 | 1.00 | --- | --- | 168 | 4 |
| | 3 | 192C2 | 90.18 | 54.96 | 1.00 | .3 | .2 | 168 | 3 |
| | 4 | 312B1 | 22.71 | 23.79 | .54 | .3 | .2 | 147 | 3 |
| 15 | 1 | 281C2 | 76.58 | 52.65 | 1.00 | .3 | .2 | 151 | 4 |
| | 2 | 76C2 | 75.74 | 52.08 | 1.00 | .3 | .2 | 152 | 4 |
| | 3 | 76D2 | 150.38 | 95.11 | 1.00 | .4 | .3 | 152 | 4 |
| | 4 | 280B1 | 19.59 | 16.67 | .54 | .3 | .2 | 149 | 4 |
| 16 | 1 | 9B1 | 19.71 | 17.71 | .54 | .3 | .2 | 147 | 5 |
| | 2 | 9C2 | 74.62 | 49.12 | 1.00 | .3 | .2 | 147 | 5 |
| | 3 | 9D2 | 148.55 | 90.27 | 1.00 | .4 | .3 | 147 | 5 |
| | 4 | 11B1 | 20.59 | 16.07 | 1.00 | .3 | .2 | 147 | 4 |
| | 5 | 24D2 | 149.99 | 82.15 | 1.00 | .4 | .3 | 168 | 4 |
| 17 | 1 | 120C2 | 92.03 | 52.47 | 1.00 | .3 | .2 | 145 | 5 |
| | 2 | 162D2 | 160.72 | 94.11 | 1.00 | .4 | .3 | 145 | 4 |
| | 3 | 119A1 | 0 | 0 | .65 | --- | --- | 143 | 5 |
| | 4 | 24E2 | 269.29 | 141.22 | 1.00 | --- | --- | 168 | 4 |
| 18 | 1 | 1D3 | 177.56 | 117.29 | 1.00 | .4 | .3 | 142 | 5 |
| | 2 | 1E3 | 362.69 | 203.33 | 1.00 | --- | --- | 142 | 5 |
| | 3 | 10C2 | 75.70 | 47.87 | 1.00 | .3 | .2 | 142 | 5 |
| | 4 | 10D2 | 152.31 | 89.19 | 1.00 | .4 | .3 | 142 | 5 |
| | 5 | 12C1 | 84.80 | 48.34 | 1.00 | .3 | .2 | 142 | 5 |

[a] SOURCE: Paul Rosenberry, Russell Knutson, and Lacy Harmon, 1980b.

[b] SOURCE: W. H. Wishmeier, and D. D. Smith, 1978, and personal communication with Min Amemiya (Extension Agronomist, Iowa State University, Ames, Iowa).

factors where the L factor is adjusted to reflect the shorter slope lengths due to terraces. The T-values are defined as tolerance values or levels of soil loss, or the maximum soil loss that can be tolerated without reducing the productivity of the soil (Bender, 1962).

The crop management factors (C factor in the USLE) for the different combinations of tillage systems and crop rotations are presented in Table 27.

## Cost Data for Cropping Activities

In collecting the cost data for the cropping activities, the general aim is to find costs that reflect average crop production cost situations across all cropping activities and that are consistent with other sectors of the models. These costs reflect 1980 price levels. The specific objectives of this effort are:

1) to develop per acre requirements of seed, labor, fuel, lubrication, herbicides and insecticides of different crops used in the model (corn grain, corn silage, soybeans, oats, meadow and pasture) for the 5 different tillage systems;

2) to develop per acre cost of machinery use (ownership cost: depreciation, interest charges, taxes, insurance and housing; and repair costs) for all crops and tillage systems;

3) to adjust the above coefficients (under (1) and (2)) for different farms which are being modeled;

4) to adjust the above coefficients (under (1) and (2)) for supporting practices and obtain the cost of installing and maintaining terraces;

Table 27. Crop management factors

| Tillage systems<br>Crop rotations | Conventional | Fall chisel | Spring disk | Till-plant | Slot-plant |
|---|---|---|---|---|---|
| 1. C | .39 | .29 | .23 | .13 | .03 |
| 2. CCCOM | .19 | .16 | .13 | .07 | .03 |
| 3. CCOMM | .11 | .10 | .09 | .05 | .03 |
| 4. COMMM | .05 | .03 | .03 | --- | .017 |
| 5. S | .48 | .47 | .46 | .44 | .40 |
| 6. SSSOM | .27 | .26 | .25 | .23 | .21 |
| 7. SSOMM | .17 | .16 | .15 | .14 | .13 |
| 8. SOMMM | .08 | .07 | .06 | --- | .04 |
| 9. CB | .51 | .42 | .35 | .30 | .09 |
| 10. CCB | .47 | .37 | .30 | .23 | .08 |
| 11. SB | .56 | .53 | .51 | .40 | .32 |
| 12. SSB | .53 | .51 | .49 | .42 | .37 |
| 13. CBCOMM | .20 | .16 | .14 | .09 | .05 |
| 14. SBSOMM | .25 | .22 | .20 | .17 | .14 |
| 15. P | .02 | --- | --- | --- | --- |

SOURCE: Soil Conservation Service, U.S. Department of Agriculture, 1980, and personal communication with Min Amemiya (extension agronomist, Iowa State University, Ames, Iowa) and Mark Berkland (Soil Conservation Service, Des Moines, Iowa).

5) to adjust the above coefficients (under (1) and (2)) for different yield levels; and

6) to combine all of the above information to obtain coefficients for various cropping activities for the study.

The steps followed in fulfilling these objectives are outlined in more detail below:

I. Development of labor, fuel, herbicides, insecticides and seed requirements and machinery costs for crops under each of the 5 tillage systems:

   A. A list of various field operations for corn (or silage), corn (or silage), corn (or silage) after beans, corn (or silage) after meadow, beans after corn, oats after corn (or silage), and meadow after meadow (or oats) and pasture are developed for the five tillage systems. These lists of field operations are provided in Tables 20-25.

   B. A list of machinery and equipment required to carry out the field operations listed in Tables 20 through 25 is developed. In addition to the field operations listed in Tables 20-25, an additional operation for silage, blowing silage into an upright silo, is considered in preparing the machinery list. The machinery or equipment needed is listed later in Table 34.

   C. Labor, fuel and machinery cost data for different field operations with specified machinery are obtained. By defining field operations by time-period, labor requirement is obtained for 3 time-periods: fall, spring and other. These data are obtained from the following sources:

Machine time for a given field operation is obtained from Knott and Benson (1973) and William Edwards (extension economist, Iowa State University, Ames, Iowa). Labor time is assumed to be 100 percent of the machine time (Fulton, 1976; and Ayres and Boehlje, 1979).

Fuel requirements are obtained from data provided by William Edwards (extension economist, Iowa State University, Ames, Iowa). These data compare well with other estimates as well (see Ayres, 1976). Gasoline requirements for running a pickup truck are converted into diesel equivalents. Fuel required for drying corn (in terms of LP gas) is obtained from Ozkan (1980).

Depreciation, interest, taxes, insurance, and housing and repair costs are obtained on a per hour basis from William Edwards (extension economist, Iowa State University, Ames, Iowa). By using the machine time required per acre, these costs are converted to a per acre basis.

Lubrication costs are assumed to be 15 percent of the fuel cost for all machinery (Kletke, 1979).

Corn drying is assumed to have a non-fuel cost of $0.11 per bushel (Edwards, 1981).

D. Seed requirements are obtained from Benson (1977), Knott and Benson (1973), Shroyer (1978), and Edwards and Thompson (1981). It is assumed that seed rates do not differ across tillage systems.

E. The herbicide program is specified based on recommendations from Dick Fawcett (extension weed scientist, Iowa State University, Ames, Iowa):

Corn (or silage) for conventional chisel, disk, and till plant systems, pre-emergence aplication of Lasso (2-1/2 qts/ac) and Bladex (2 qts/ac); for the slot-plant system, pre-emergence application of Lasso (2-1/2 qts/ac), Bladex (2 qtz/ac) and paraquat (1/2 qt/ac). Soybeans for conventional tillage, chisel, disk and till plant systems, pre-emergence application of Lasso (2-1/2 qts/ac) and Sencor (3/4 pt/ac); for the slot-plant system, pre-emergence application of Lasso (2-1/2 qt/ac), Sencor (3/4 pt/ac) and paraquat (1/2 qt/ac).

F. The insecticide program is specified based on the recommendations of Jerry Dewitt (extension entomologist, Iowa State University, Ames, Iowa). On continuous corn (or silage) and corn (or silage) after meadow the application of 1 lb/ac. (active ingredients) of Counter at planting (banded or in furrow) is assumed. The application of insecticide is also assumed to increase planting time by five percent (Ayres and Williams, 1976). On other crop rotations, no insecticide program is specified.

II. Adjustment of coefficients for different farms which are being modeled:

A. Fuel. More power is required for operating tillage and planting implements on heavier soils than on lighter soils (Frisby and Summers, 1978, and Harmon, Knutson and Rosenberry, 1980). While power and time requirements may also vary for different slopes of land, it is assumed that the differences due to slope changes are negligible.

Table 28. (continued)

| Soil | County | Index with Ida silt loam = 1.0 | Index with Nicollet loam A1 = 1.0 |
|---|---|---|---|
| Shelby-Adair D2 | C Clarke | 1.4 | 1.08 |
| Haig sil A1 | | 1.2 | 0.92 |
| Grundy sicl C2 | | 1.2 | 0.92 |
| Gayette sil C1 | C Alamakee | 1.2 | 0.92 |
| Fayette sil D2 | | 1.3 | 1.0 |
| Fayette sil E2 | | 1.3 | 1.0 |
| Steep Rock G2 | | 1.2 | 0.92 |
| Downs sil C1 | | 1.2 | 0.92 |
| Fayette sil C2 | NC Jackson | 1.3 | 1.0 |
| Fayette sil D2 | | 1.3 | 1.0 |
| Fayette sil E2 | | 1.3 | 1.0 |
| Steep Rock G1 | | 1.2 | 0.92 |
| Downs sil C1 | | 1.2 | 0.92 |
| Shelby-Adair D2 | Sw Appanoose | 1.4 | 1.08 |
| Shelby loam E2 | | 1.4 | 1.08 |
| Adair C2 | | 1.5 | 1.15 |
| Seymour sil B1 | | 1.1 | 0.85 |
| Otley C1 C2 | SW Iowa | 1.3 | 1.0 |
| Ladoga sil C2 | | 1.4 | 1.08 |
| Ladoga sil D2 | | 1.4 | 1.08 |
| Mahaska sicl B1 | | 1.3 | 1.0 |
| Marshall sic B1 | E. Pottawattamie | 1.2 | 0.92 |
| Marshall sic C2 | | 1.3 | 1.0 |
| Marshall sic D2 | | 1.3 | 1.0 |
| Colo-Ely B1 | | 1.2 | 0.92 |
| Shelby loam D2 | | 1.4 | 1.08 |
| Tama sic l C2 | NE Jasper | 1.3 | 1.0 |
| Downs sil D2 | | 1.3 | 1.0 |
| Muscatine sicl A1 | | 1.2 | 0.92 |
| Shelby loam E2 | | 1.4 | 1.08 |
| Ida sil D3 | SW Ida | 1.1 | 0.85 |
| Ida sil E3 | | 1.1 | 0.85 |
| Monona sil C2 | | 1.15 | 0.89 |
| Monona sil D2 | | 1.15 | 0.89 |
| Napier sil C1 | | 1.10 | 0.85 |

Table 29. Seed rates

| Crop | Farm # | Rate/Acre |
|---|---|---|
| 1. Corn and Silage[a] | 1, 3 | 24,706 kernels |
| | 2,9,10,11,14, 16 and 18 | 23,529 kernels |
| | 5 | 21,176 kernels |
| | 4,6,7,8,12, 13,15 and 17 | 25,882 kernels |
| 2. Beans[b] | All farms | 1 bu |
| 3. Oats[c] | All farms | 3 bu |
| 4. Alfalfa[b] | All farms | 4 lbs |
| Bromegrass[b] | All farms | 5 lbs |
| 5. Pasture (Bromegrass)[b] | All farms | 10 lbs |

[a] Benson, 1977.

[b] Edwards and Thompson, 1981.

[c] Knott and Benson, 1973.

Table 30. Per acre terracing costs

| Farm No. | SMU Code | Installation[a] Cost | Annualized[b] Installation Cost | Annual[c] Maintenance Cost | Terrace[d] Type |
|---|---|---|---|---|---|
| 1 | 107A1 | --- | --- | --- | --- |
| | 55A1 | --- | --- | --- | --- |
| | 138B1 | 350 | 38.86 | 1.46 | GBS |
| 2 | 66A1 | --- | --- | --- | --- |
| | 36A1 | --- | --- | --- | --- |
| | 44A1 | --- | --- | --- | --- |
| 3 | 107A1 | --- | --- | --- | --- |
| | 55A1 | --- | --- | --- | --- |
| | 138B1 | 500 | 55.51 | 2.08 | TOT |
| | 138C2 | 800 | 88.81 | 3.33 | TOT |
| 4 | 83B1 | 100 | 11.01 | 0.42 | NB |
| | 399A1 | --- | --- | --- | --- |
| | 198B1 | 100 | 11.01 | 0.42 | NB |
| | 84A1 | --- | --- | --- | --- |
| 5 | 310B1 | 75 | 8.33 | 0.31 | BB |
| | 310C2 | 100 | 11.10 | 0.42 | BB |
| | 77B1 | 75 | 8.33 | 0.31 | BB |
| | 91A1 | --- | --- | --- | --- |
| 6 | 783B1 | 100 | 11.10 | 0.42 | NB |
| | 84A1 | --- | --- | --- | -- |
| | 784B1 | 100 | 11.10 | 0.42 | NB |
| 7 | 120B1 | 300 | 33.30 | 1.25 | GBS |
| | 120C2 | 500 | 55.51 | 2.08 | GBS |
| | 377B1 | 300 | 33.30 | 1.25 | GBS |
| 8 | 280B1 | 200 | 22.20 | 0.83 | GBS |
| | 80C2 | 400 | 44.41 | 1.67 | GBS |
| | 279A1 | --- | --- | --- | --- |
| | 281C1 | 400 | 44.41 | 1.67 | GBS |
| 9 | 65E2 | --- | --- | --- | --- |
| | 131B1 | 300 | 33.30 | 1.25 | GBS |
| | 132C2 | 500 | 55.51 | 2.08 | GBS |

Table 30. (continued)

| Farm No. | SMU Code | Installation[a] Cost | Annualized[b] Installation Cost | Annual[c] Maintenance Cost | Terrace[d] Type |
|---|---|---|---|---|---|
| 10 | 370B1 | 400 | 44.41 | 1.67 | GBS |
|  | 370C2 | 500 | 55.51 | 2.08 | GBS |
|  | 93D2 | 600 | 66.61 | 2.50 | GBS |
|  | 11B1 | 400 | 44.41 | 1.67 | GBS |
| 11 | 93D2 | 900 | 99.12 | 3.75 | GBS |
|  | 362A1 | --- | --- | --- | --- |
|  | 364C2 | 700 | 77.71 | 2.91 | GBS |
| 12 | 163C1 | 400 | 44.41 | 1.67 | GBS |
|  | 163D2 | 550 | 61.06 | 2.29 | GBS |
|  | 163E2 | 600 | 66.61 | 2.50 | GBS |
|  | 478G1 | --- | --- | --- | --- |
|  | 162C1 | 400 | 44.41 | 1.67 | GBS |
| 13 | 163C2 | 400 | 44.41 | 1.67 | GBS |
|  | 163DC | 450 | 49.96 | 1.87 | GBS |
|  | 163E2 | 550 | 61.06 | 2.29 | GBS |
|  | 478G1 | --- | --- | --- | --- |
|  | 162C1 | 400 | 44.41 | 1.67 | GBS |
| 14 | 93D2 | 700 | 77.71 | 2.91 | GBS |
|  | 24E2 | --- | --- | --- | --- |
|  | 192C2 | 500 | 55.51 | 2.08 | GBS |
|  | 312B1 | 300 | 33.30 | 1.25 | GBS |
| 15 | 281C2 | 450 | 49.96 | 1.87 | GBS |
|  | 76C2 | 450 | 49.96 | 1.87 | GBS |
|  | 76D2 | 650 | 72.16 | 2.71 | GBS |
|  | 280B1 | 350 | 38.86 | 1.46 | GBS |
| 16 | 9B1 | 250 | 27.75 | 1.04 | GBS |
|  | 9C2 | 275 | 30.53 | 1.15 | GBS |
|  | 9D2 | 275 | 30.53 | 1.15 | GBS |
|  | 11B1 | 250 | 27.75 | 1.04 | GBS |
|  | 24D2 | 275 | 30.53 | 1.15 | GBS |

Table 30. (continued)

| Farm No. | AMU Code | Installation Cost[a] | Annualized[b] Installation Cost | Annual[c] Maintenance Cost | Terrace[d] Type |
|---|---|---|---|---|---|
| 17 | 120C2 | 700 | 77.71 | 2.91 | GBS |
| | 162D2 | 800 | 88.81 | 3.33 | GBS |
| | 119A1 | --- | --- | --- | --- |
| | 24E2 | 900 | 99.91 | 3.75 | GBS |
| 18 | 1D3 | 700 | 77.71 | 2.91 | GBS |
| | 1E3 | 900 | 99.91 | 3.75 | GBS |
| | 10C2 | 650 | 72.16 | 2.71 | GBS |
| | 10D2 | 700 | 77.71 | 2.91 | GBS |
| | 12C1 | 650 | 72.16 | 2.71 | GBS |

[a] Obtained by personal communication with William J. Brune, State Conservationist, Des Moines, Iowa.

[b] Annualized installation costs are calculated using the following formula:

$$R = \frac{A}{\frac{1-(1+i)^{-T}}{i}}$$

where R = the annual installation cost ($/Ac/Yr);
A = the total installation cost ($/Ac);
i = the interest rate (assumed to be 11%);
T = the amortization period (assumed to be 45 years).

[c] Rosenberry, Knutson, and Harmon, 1980a. They estimate annual maintenance costs to be approximately 3.75 percent annualized installment costs.

[d] GBS = Grassed Backslope Terraces
TOT = Tile Outlet Terraces
NB = Narrow Base (Grassed) Terraces
BB = Broad Base Terraces

grain or other crops, and (ii) fuel and non-fuel cost of drying corn. The procedure used to adjust hauling cost is as follows:

> If we let labor requirements for hauling corn at 120 bu per acre yield be (x) hours, then for a yield level (y) higher than 120 bu per acre the labor requirement for hauling is, $x + (\frac{x}{120})\ (Y-120)$. Drying costs are calculated on a per bushel basis so a given increase in bushels of corn per acre simply means a corresponding increase in drying costs.

V. Developing Coefficients for cropping activities:

All the coefficients described previously are obtained for each crop individually. The cropping activities specified in the model are rotations combined with different tillage systems, and suggesting practices and defined on different soil phases. The information obtained so far is used to develop coefficients for cropping activities. For example, in order to obtain the fall labor required per acre for the COMMM crop rotation, using conventional tillage, with no supporting practice = [fall labor for corn after meadow + fall labor for oats after corn + (fall labor for meadow after meadow) x 3] ÷ 5.

VI. Pasture costs:

The production costs for pasture are developed upon consultation with Gerald Miller, Richard Fawcett, and Stewart Melvin (extension agronomist, weed scientist, and agricultural engineer respectively, Iowa State University, Ames, Iowa). Based on the Land Resource Area in which for pasture. Various coefficients (such as labor, machinery costs, and fuel) described with respect to other crops were also obtained for pasture in a similar manner.

## Yield and Fertilizer Data

Corn, soybean, oat, and meadow yields on each soil mapping unit are obtained from "Productivity Levels of Some Iowa Soils" (Fenton, Duncan, Shrader, and Dumenil, 1971) and "Soil Survey Interpretations" (Iowa Soil Survey Staff, 1971). Upon the recommendation of Tom Fenton (extension agronomist, Iowa State University, Ames, Iowa) soybean yields are assumed to be 36 percent of corn yields. Also, upon the recommendation of Tom Fenton, all yields are adjusted upward by 14 percent to reflect 1980 yields. Corn silage yields are calculated in tons per acre by using different factors of corn grain yields. These factors are given in Table 1 of "Crops for Silage" (Schaller, 1972).

In order to project 1985 and 2020 yields, time series data from 1950 to 1980 are collected and the following model is estimated using three state least squares regression (Pope, 1981):

$$
\begin{aligned}
\hat{N} = {} & \underset{(2.539)}{30.6366} - \underset{(1.374)}{0.0601*(\mathrm{PR})} - \underset{(1.783)}{2.9247*(\mathrm{Z1})} + \underset{(4.300)}{0.4419*(\mathrm{Z2})} \\
& + \underset{(8.270)}{3.3473*(\mathrm{Z3})} - \underset{(2.451)}{0.6692*(\mathrm{DPRESP})} - \underset{(2.545)}{0.1342*(\mathrm{DPRESP})^2}
\end{aligned}
$$

$$
\begin{aligned}
\hat{C} = {} & \underset{(12.235)}{46,3318} + \underset{(6.072)}{11.5886*(\ln T)} + \underset{(6.456)}{0.006973*(\hat{N}\mathrm{T})} \\
& + \underset{(4.395)}{1.1081*(\mathrm{DPRESP})} - \underset{(3.834)}{0.1711*(\mathrm{DPRESP})^2} + \underset{(3.154)}{1.2683*(\mathrm{DJUNET})} \\
& + \underset{(5.948)}{4.3992*\mathrm{DJULYR})} - \underset{(1.616)}{0.5765*(\mathrm{DJULYR})^2}
\end{aligned}
$$

$$\hat{S} = \underset{(9.540)}{0.1352*(\hat{C})} + \underset{(3.338)}{0.6609*(\ln\hat{C})} - \underset{(5.042)}{0.1844*(T)}$$

$$+ \underset{(2.625)}{0.7572*(\ln T)}$$

$$\hat{B} = \underset{(35.005)}{21.9871} + \underset{(16.434)}{0.546*(T)} + \underset{(2.808)}{0.1958*(DPRESP)}$$

$$- \underset{(4.883)}{0.0588*(DPRESP)^2} + \underset{(4.628)}{0.5001*(DJUNET)} + \underset{(5.762)}{1.2581*(DJULYR)}$$

$$+ \underset{(2.454)}{0.2888*(DJULYT)} + \underset{(4.009)}{0.6044*(DAUGR)} + \underset{(1.771)}{0.2126*(DAUGT)}$$

$$\hat{O} = \underset{(22.032)}{30.8683} + \underset{(15.809)}{1.0995*(T)} - \underset{(2.663)}{0.0621*(DPRESP)^2}$$

$$+ \underset{(1.730)}{0.6838*(DJULYR)} + \underset{(3.952)}{0.3057*(DJULYR)^2}$$

$$\hat{M} = \underset{(31.075)}{2.1215} + \underset{(16.383)}{0.05752*(T)} + \underset{(2.779)}{0.01698*(DPRESP)}$$

$$- \underset{(3.873)}{0.004609*(DPRESP)^2} + \underset{(4.605)}{0.09529*(DJULYR)}$$

$$- \underset{(3.661)}{0.03146*(DJULYR)^2} + \underset{(4.625)}{0.06619*(DAUGR)}$$

Where:

$\hat{N}$ = estimated nitrogen used per corn acre in Iowa;

$\hat{C}$ = average Iowa corn grain yields in bushels per acre;

$\hat{S}$ = average Iowa corn silage yields in tons per acre;

$\hat{B}$ = average Iowa soybean yields in bushels per acre;

$\hat{O}$ = average Iowa oat yields in bushels per acre;

$\hat{M}$ = average Iowa alfalfa hay yields in tons per acre;

$\hat{T}$ = time, where: 1951 = 1, 1952 = 2, 1953 = 3,...., 1980 = 30;

$\hat{Z}_1$ = T when $T \leq 18$, and $Z_1$ = 18 when $T > 18$;

$Z_2 = T^2$ when $T \leq 18$, and $Z_2 = 324$ when $T > 18$;

$Z_3 = 0$ when $T \leq 18$, and $Z_3 = T - 18$ when $T > 18$;

PR = the price ratio of the price of nitrogen over the price of corn;

DPRESP = departure from normal Sept.-June total precipitation (note: normal refers to the average between 1950 and 1980);

DJUNET = departure from normal June temperature;

DJULYR = departure from normal July rainfall;

DJULYT = departure from normal July temperature;

DAUGR = departure from normal August rainfall;

DAUGT = departure from normal August temperature; and the absolute t-values are reported in parentheses below the estimated regression coefficients.

The variables T, $Z_1$, $Z_2$, $Z_3$, PR, DPRESP, DJUNET, DJULYR, DJULYT, DAUGR, and DAUGT are treated as exogenous to the system. The weighted $R^2$ value for the system is .9902, and the weighted MSE for the system is 1.877. The model is tested for autocorrelation and there is no evidence of autocorrelation at the 10 percent level of probability.

Using the above model, it is projected that by 1985 the percentage increase in expected average yields in Iowa over 1980 yields will be 9.02 percent, 4.47 percent, 6.88 percent, 8.61 percent, and 7.14 percent for corn, silage, soybeans, oats, and meadow, respectively. Using the above model, it is projected that by the year 2020 the percentage increase in expected average yields in Iowa will be 95.15 percent, 56.53 percent, 55.10 percent, 68.87 percent, and 57.17 percent, for corn, silage, soybeans, oats, and meadow, respectively over 1980 yields. In making these projections, it must be assumed that the relative price of nitrogen and corn will remain the same, and technological progress will continue as it has done over the past three decades.

Yields for 1985, therefore, are obtained by adjusting the 1980 yields by the projected percentage increase in expected average yields in Iowa (Table 32). This is also done for 2020 yields.

### Yield adjustments for supporting practices and crop rotations

It is assumed that yields are not significantly affected by the supporting practices. It is also assumed that yields are the same across crop rotations with one exception. Using information from "Crop Rotations Effect on Yields and Response to Nitrogen" (Voss and Shrader, 1979) and upon personal communication with Regis Voss (extension agronomist, Iowa State University, Ames, Iowa) corn yields during the first year following meadow or soybeans are adjusted upward by 7 percent.

### Yield adjustment for tillage systems

Data on many experiments looking at yield differences between tillage systems have been collected from different soils from Iowa, Indiana, Illinois, Minnesota, Nebraska, Ohio, and Missouri. Trips have been taken to tillage shows and conferences. Visits have been made with local and area extension, and soil conservation personnel, and with farmers throughout the state of Iowa who have been using and studying various tillage systems. In short, much effort has been made in order to determine the differences in yields between the tillage systems. It

Table 32. Estimated 1985 and 2020 crop yields.for selected soils in Iowa

| | | | 1985 Crop Yields | | | | | | 2020 Crop Yields (unadjusted for erosion) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farm No. | Farm Soil No. | SMU No. | Corn (bu./A) | Silage (tons/A) | Soybeans (bu./A) | Oats (bu./A) | Meadow (tons/A) | Pasture (AUM) | Corn (bu./A) | Silage (tons/A) | Soybeans (bu./A) | Oats (bu./A) | Meadow (tons/A) | Pasture (AUM) |
| 01 | 1 | 107A1 | 136 | 18.2 | 48 | 102 | 5.4 | 7.6 | 244 | 27.2 | 70 | 159 | 7.9 | 9.4 |
| | 2 | 55A1 | 147 | 19.6 | 51 | 110 | 6.1 | 8.6 | 263 | 29.4 | 74 | 171 | 9.0 | 10.7 |
| | 3 | 138B1 | 136 | 18.2 | 48 | 102 | 5.7 | 7.9 | 244 | 27.2 | 70 | 159 | 8.3 | 9.8 |
| 02 | 1 | 66A1 | 81 | 11.9 | 29 | 56 | 3.0 | 4.5 | 144 | 17.8 | 42 | 88 | 4.4 | 5.5 |
| | 2 | 36A1 | 142 | 18.9 | 50 | 99 | 5.2 | 7.3 | 254 | 28.3 | 73 | 154 | 7.7 | 9.1 |
| | 3 | 44A1 | 119 | 16.1 | 42 | 83 | 4.4 | 6.2 | 212 | 24.1 | 60 | 128 | 6.4 | 7.7 |
| 03 | 1 | 107A1 | 136 | 18.2 | 48 | 96 | 5.4 | 7.6 | 244 | 27.2 | 70 | 149 | 7.9 | 9.4 |
| | 2 | 55A1 | 147 | 19.6 | 51 | 103 | 6.1 | 8.6 | 263 | 29.4 | 74 | 160 | 9.0 | 10.7 |
| | 3 | 138B1 | 136 | 18.2 | 48 | 96 | 5.7 | 7.9 | 244 | 27.2 | 70 | 149 | 8.3 | 9.8 |
| | 4 | 138C2 | 126 | 16.8 | 45 | 88 | 5.2 | 7.3 | 226 | 25.2 | 65 | 137 | 7.7 | 9.1 |
| 04 | 1 | 83B1 | 141 | 18.7 | 49 | 98 | 5.8 | 7.9 | 252 | 38.0 | 71 | 152 | 8.5 | 9.8 |
| | 2 | 399A1 | 143 | 19.0 | 50 | 100 | 5.9 | 8.3 | 256 | 28.4 | 73 | 155 | 8.6 | 10.3 |
| | 3 | 198B1 | 132 | 17.6 | 46 | 92 | 5.1 | 7.8 | 236 | 26.3 | 67 | 144 | 7.5 | 9.6 |
| | 4 | 84A1 | 126 | 16.8 | 45 | 88 | 4.9 | 6.8 | 226 | 25.2 | 65 | 137 | 7.2 | 8.5 |
| 05 | 1 | 310B1 | 118 | 15.9 | 42 | 100 | 4.4 | 6.2 | 211 | 23.8 | 60 | 155 | 6.4 | 7.7 |
| | 2 | 310C2 | 108 | 14.8 | 38 | 91 | 4.1 | 5.7 | 193 | 22.2 | 56 | 142 | 6.0 | 7.1 |
| | 3 | 77B1 | 110 | 14.8 | 38 | 93 | 4.1 | 5.8 | 197 | 22.2 | 56 | 145 | 6.0 | 7.2 |
| | 4 | 91A1 | 128 | 17.0 | 45 | 108 | 4.7 | 6.7 | 228 | 25.5 | 65 | 167 | 7.9 | 8.4 |
| 06 | 1 | 783B1 | 109 | 14.9 | 38 | 76 | 4.5 | 6.3 | 195 | 22.4 | 56 | 118 | 6.6 | 7.8 |
| | 2 | 84A1 | 126 | 16.8 | 45 | 88 | 4.9 | 6.8 | 226 | 25.2 | 65 | 137 | 7.2 | 8.5 |
| | 3 | 784B1 | 101 | 13.9 | 35 | 71 | 4.0 | 5.9 | 181 | 20.8 | 51 | 110 | 5.8 | 7.3 |
| 07 | 1 | 120B1 | 155 | 20.6 | 55 | 108 | 6.4 | 8.9 | 277 | 30.8 | 79 | 167 | 9.4 | 11.1 |
| | 2 | 120C2 | 145 | 19.3 | 50 | 101 | 6.0 | 8.4 | 260 | 29.0 | 72 | 157 | 8.8 | 10.4 |
| | 3 | 377B1 | 148 | 19.7 | 52 | 103 | 6.1 | 8.6 | 265 | 29.6 | 76 | 160 | 9.0 | 10.7 |

Table 32. (cont.)

| Farm No. | Farm Soil No. | SMU No. | 1985 Crop Yields Corn (bu./A) | Silage (tons/A) | Soybeans (bu./A) | Oats (bu./A) | Meadow (tons/A) | Pasture (AUM) | 2020 Crop Yields Corn (bu./A) | Silage (tons/A) | Soybeans (bu./A) | Oats (bu./A) | Meadow (tons/A) | Pasture (AUM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08 | 1 | 280B1 | 148 | 19.7 | 52 | 81 | 6.1 | 8.6 | 265 | 29.6 | 76 | 127 | 9.0 | 10.7 |
| | 2 | 80C2 | 123 | 16.4 | 44 | 67 | 5.0 | 7.2 | 221 | 24.6 | 64 | 105 | 7.4 | 9.0 |
| | 3 | 279A1 | 145 | 19.3 | 50 | 79 | 6.0 | 8.1 | 260 | 29.0 | 73 | 123 | 8.8 | 10.0 |
| | 4 | 281C1 | 142 | 18.9 | 50 | 78 | 5.8 | 8.3 | 258 | 28.3 | 73 | 122 | 8.5 | 10.3 |
| 09 | 1 | 65E2 | 0 | 0.0 | 0 | 0 | 2.5 | 2.6 | 0 | 0.0 | 0 | 0 | 3.6 | 3.2 |
| | 2 | 131B1 | 125 | 16.9 | 44 | 68 | 5.1 | 7.2 | 224 | 25.4 | 64 | 106 | 7.5 | 9.0 |
| | 3 | 132C2 | 106 | 14.5 | 37 | 58 | 4.4 | 5.7 | 189 | 21.8 | 54 | 90 | 6.4 | 7.1 |
| 10 | 1 | 370B1 | 141 | 18.7 | 49 | 71 | 5.8 | 8.1 | 252 | 28.0 | 71 | 110 | 8.5 | 10.0 |
| | 2 | 370C2 | 131 | 17.4 | 46 | 75 | 5.4 | 7.6 | 234 | 26.1 | 67 | 101 | 7.9 | 9.4 |
| | 3 | 93D2 | 86 | 12.7 | 30 | 43 | 3.5 | 5.2 | 154 | 19.1 | 43 | 68 | 5.2 | 6.4 |
| | 4 | 11B1 | 124 | 16.5 | 44 | 62 | 4.9 | 7.0 | 222 | 24.7 | 64 | 96 | 7.2 | 8.7 |
| 11 | 1 | 93D2 | 86 | 12.7 | 30 | 47 | 3.5 | 5.2 | 154 | 19.1 | 43 | 73 | 5.2 | 6.4 |
| | 2 | 362A1 | 131 | 17.4 | 46 | 72 | 5.1 | 7.2 | 234 | 26.1 | 67 | 111 | 7.5 | 9.0 |
| | 3 | 364C2 | 121 | 16.2 | 43 | 66 | 5.0 | 6.0 | 217 | 24.3 | 62 | 103 | 7.4 | 7.5 |
| 12 | 1 | 163C1 | 134 | 17.9 | 47 | 93 | 5.6 | 7.8 | 240 | 26.8 | 68 | 145 | 8.2 | 9.6 |
| | 2 | 163D2 | 119 | 16.3 | 42 | 83 | 4.9 | 6.8 | 213 | 24.4 | 60 | 128 | 7.2 | 8.5 |
| | 3 | 163E2 | 100 | 13.8 | 35 | 70 | 4.2 | 5.8 | 180 | 20.7 | 51 | 108 | 6.1 | 7.2 |
| | 4 | 478B1 | 0 | 0.0 | 0 | 0 | 0.0 | 2.4 | 0 | 0.0 | 0 | 0 | 0.0 | 3.0 |
| | 5 | 162C1 | 142 | 18.9 | 50 | 99 | 5.9 | 8.5 | 254 | 28.3 | 73 | 154 | 8.6 | 10.5 |
| 13 | 1 | 163C2 | 131 | 17.4 | 46 | 91 | 5.4 | 7.8 | 234 | 26.1 | 67 | 142 | 7.9 | 9.6 |
| | 2 | 163D2 | 119 | 16.3 | 42 | 83 | 4.9 | 6.8 | 212 | 24.4 | 60 | 128 | 7.2 | 8.5 |
| | 3 | 163E2 | 100 | 13.8 | 35 | 70 | 4.2 | 5.8 | 180 | 20.7 | 51 | .08 | 6.1 | 7.2 |
| | 4 | 478G1 | 0 | 0.0 | 0 | 0 | 0.0 | 2.4 | 0 | 0.0 | 0 | 0 | 0.0 | 3.0 |
| | 5 | 162C1 | 142 | 18.9 | 50 | 99 | 5.9 | 8.5 | 254 | 28.3 | 73 | 154 | 8.6 | 10.5 |

Table 32. (Cont.)

| Farm No. | Farm Soil No. | SMU No. | 1985 Crop Yields |  |  |  |  |  | 2020 Crop Yields |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Corn (bu./A) | Silage (tons/A) | Soybeans (bu./A) | Oats (bu./A) | Meadow (tons/A) | Pasture (AUM) | Corn (bu./A) | Silage (tons/A) | Soybeans (bu./A) | Oats (bu./A) | Meadow (tons/A) | Pasture (AUM) |
| 14 | 1 | 93D2 | 86 | 12.7 | 30 | 47 | 3.5 | 5.2 | 154 | 19.1 | 43 | 73 | 5.2 | 6.4 |
|  | 2 | 24E2 | 82 | 12.1 | 29 | 45 | 3.4 | 4.7 | 146 | 18.2 | 42 | 69 | 5.0 | 5.8 |
|  | 3 | 192C2 | 81 | 11.9 | 29 | 45 | 3.3 | 4.7 | 144 | 17.8 | 42 | 69 | 4.9 | 5.8 |
|  | 4 | 312B1 | 109 | 14.9 | 38 | 60 | 4.8 | 6.3 | 195 | 22.4 | 56 | 93 | 7.1 | 7.8 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  | 10.0 |
| 15 | 1 | 281C2 | 138 | 18.5 | 49 | 97 | 5.7 | 8.1 | 248 | 27.7 | 71 | 150 | 8.3 | 10.0 |
|  | 2 | 76C2 | 131 | 17.4 | 47 | 91 | 5.4 | 7.6 | 234 | 36.1 | 67 | 142 | 7.9 | 9.4 |
|  | 3 | 76D2 | 119 | 16.3 | 42 | 83 | 4.9 | 6.8 | 213 | 24.4 | 60 | 128 | 7.2 | 8.5 |
|  | 4 | 280B1 | 148 | 19.7 | 52 | 103 | 6.1 | 8.6 | 265 | 29.6 | 76 | 160 | 9.0 | 10.7 |
| 16 | 1 | 9B1 | 133 | 17.8 | 47 | 66 | 4.9 | 7.8 | 238 | 26.6 | 68 | 103 | 7.2 | 9.6 |
|  | 2 | 9C2 | 123 | 16.4 | 43 | 62 | 4.6 | 7.2 | 221 | 24.6 | 64 | 96 | 6.8 | 9.0 |
|  | 3 | 9D2 | 112 | 15.1 | 39 | 56 | 4.2 | 6.5 | 201 | 227 | 57 | 88 | 6.1 | 8.1 |
|  | 4 | 11B1 | 124 | 16.8 | 44 | 62 | 4.6 | 7.0 | 222 | 25.2 | 64 | 96 | 6.8 | 8.7 |
|  | 5 | 24D2 | 100 | 14.8 | 35 | 50 | 3.7 | 5.8 | 180 | 22.2 | 51 | 78 | 5.5 | 7.2 |
| 17 | 1 | 120C2 | 145 | 19.3 | 50 | 101 | 6.0 | 8.4 | 260 | 29.0 | 73 | 157 | 8.8 | 10.4 |
|  | 2 | 162D2 | 126 | 16.8 | 45 | 88 | 5.2 | 7.3 | 226 | 25.2 | 65 | 137 | 7.7 | 9.1 |
|  | 3 | 119A1 | 164 | 21.7 | 58 | 114 | 6.7 | 9.4 | 293 | 32.6 | 84 | 177 | 9.9 | 11.7 |
|  | 4 | 24E2 | 82 | 12.1 | 28 | 58 | 3.4 | 4.7 | 146 | 18.2 | 42 | 90 | 5.0 | 5.8 |
| 18 | 1 | 1D3 | 85 | 12.5 | 30 | 60 | 3.2 | 4.5 | 152 | 18.8 | 43 | 93 | 4.7 | 5.5 |
|  | 2 | 1E3 | 68 | 10.6 | 24 | 47 | 2.6 | 3.6 | 121 | 15.8 | 34 | 73 | 3.8 | 4.5 |
|  | 3 | 10C2 | 112 | 15.1 | 40 | 78 | 4.2 | 6.5 | 201 | 22.7 | 57 | 122 | 6.1 | 8.1 |
|  | 4 | 10D2 | 94 | 13.2 | 33 | 65 | 3.5 | 5.5 | 168 | 19.7 | 48 | 101 | 5.2 | 6.8 |
|  | 5 | 12C1 | 124 | 16.5 | 44 | 87 | 4.6 | 7.2 | 222 | 24.7 | 64 | 135 | 6.8 | 9.0 |

is not clear that there are any differences in yields. It is clear, however, that there is no consistent evidence that, given proper management, the different tillage systems have significantly different yields. It is therefore, assumed that there is no significant difference in yields between the tillage systems. Yields can be adjusted under different assumptions to see how different assumptions about the yield differences between tillage systems affect the solution of the models and how sensitive the models are to these assumptions.

### Yield adjustments for soil erosion

No adjustments for soil erosion are made on 1985 yields. However, 2020 yields are adjusted by an erosion adjustment factor. This factor is calculated by first calculating the number of inches of topsoil lost for each cropping activity as follows:

$$ITS = 35(A)/TPI$$

Where:

ITS = inches of A horizon lost;

A = soil movement as estimated by the Universal Soil Loss Equation; and

TPI = tons per acre inch of top soil.

Then for each crop and each soil type, yields are obtained for erosion phases 0, 1, 2, and 3 (Fenton, et al., 1971; and Iowa Soil Survey staff, 1971).

By assuming that total inches of topsoil in 1985 for a given erosion phase is equal to the average of the upper and lower limits of that erosion phase, the percentage reduction in yields because of soil loss can be extrapolated. For example, see Figure 4. It is assumed that in 1985 a given management system is being used on Weller silt loam C1, and that the same system is used until 2020 resulting in 5 1/2 inches of lost topsoil. In 1985, the inches of A horizon is 9 1/2 inches and the yield is 103. Because of soil erosion the thickness of the A horizon in 2020 is only 4 inches. By using linear interpolation the yield at 4 inches of A horizon would be 94. The ratio of these two yields, 94/103 = .913, results in an adjustment factor that is used to adjust the corn yield for this management system in 2020. This same method is used to adjust 2020 yields for each crop on each management system on each soil mapping unit.

Nitrogen

Based on information from several sources (Voss and Shrader, 1979; and Voss, 1972) and upon consultation with Regis Voss (extension agronomist, Iowa State University, Ames, Iowa) factors relating nitrogen requirements with corn yields and crop rotations are estimated. These factors are presented in Table 33.

These factors are multiplied by their respective corn yield for each soil mapping unit in order to arrive at nitrogen requirements for each year of corn in every rotation. These application rates are then adjusted upward by 10 percent for soils that are classified as naturally poorly drained. Corn silage is assumed to require the same level of nitrogen application as corn grain.

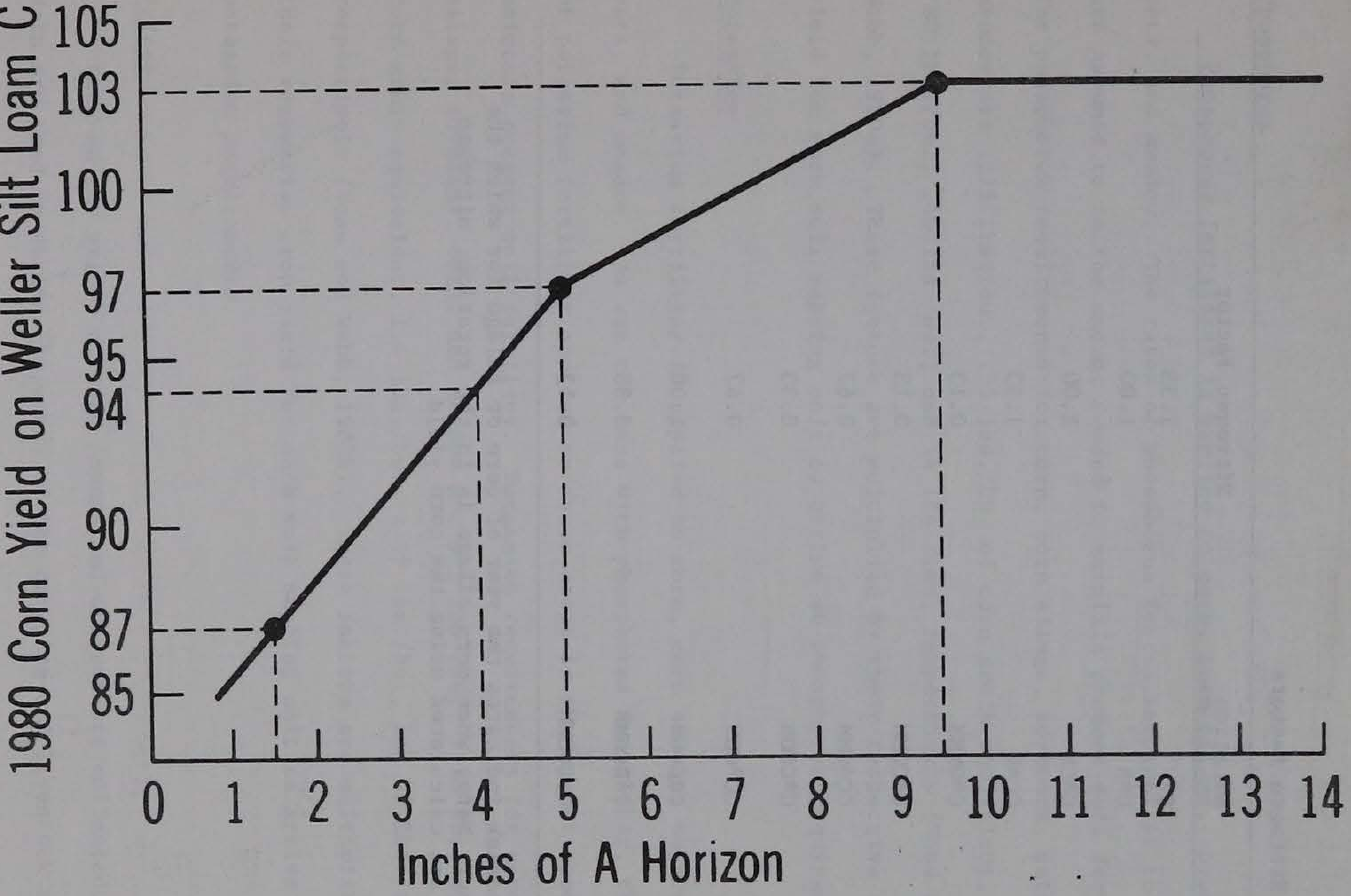

Figure 4. Yield adjustments for topsoil depth.

Table 33. Nitrogen factors

| Rotation | Nitrogen Factor |
|---|---|
| C* | 1.33 |
| C*B | 1.00 |
| C*CB | 1.00 |
| CC*B | 1.33 |
| C*OMMM | 0.13 |
| C*COMM | 0.13 |
| CC*OMM | 0.67 |
| C*CCOM | 0.33 |
| CC*COM | 0.67 |
| CCC*OM | 1.00 |
| C*BCOMM | 0.33 |
| CBC*OMM | 0.53 |

*The asterisk indicates the year of corn or silage for which the factor applies. Note, when corn silage is in the rotation, nitrogen requirements are calculated using the corn yield.

### Phosphorus

Phosphorus fertilizer is applied to corn, corn silage, soybeans, oats, and meadow. The rates of phosphorus fertilizer applied to these crops are assumed to be the amount needed to maintain present soil fertility. The phosphorus requirements for corn, corn silage, soybeans, oats, and meadow are .375 lbs./bu., .55 lbs./bu. of corn grain equivalent, .80 lbs./bu., .40 lbs./bu., and 14 lbs./ton, respectively (Voss and Webb, 1980a). These factors are multiplied by their respective crop yield for each soil mapping unit to arrive at phosphorus requirements.

### Potassium

Potassium fertilizer is applied to corn, corn silage, soybeans, oats, and meadow. As was the case with phosphorus fertilizer, the rates of potassium fertilizer applied to these crops is the amount needed to maintain present soil fertility. Potassium requirements for corn, corn silage, soybeans, oats, and meadow are .25 lbs./bu., 1.25 lbs./bu. of corn grain equivalent, 1.4 lbs./bu., 1.15 lbs./bu., and 45 lbs./ton, respectively (Voss and Webb, 1980b). These factors are multiplied by their respective crop yield for each soil mapping unit to arrive at potassium requirements.

### Prices

Data on the prices of both inputs and outputs are collected. These data are used to derive the costs of the cropping and livestock activities and are used directly in the objective function of the models for the prices paid for inputs and the prices received for outputs. The prices in this study are gathered to represent the general price level of 1980. The prices are presented in Table 34.

## Livestock Sector

The livestock sector consists of two major sub-sectors: (1) hog production, and (2) beef cattle production. Input and output prices required for the livestock sector are reported in Table 34 with the exception of the prices of additional machinery and equipment needed for livestock. These prices are obtained from the Firm Enterprise Data System (FEDS) budgets (Economic Research Service, 1980b).

Hog Sub-Sector. The FEDs budgets are relied upon heavily in the development of the hog production subsector. First, eleven activities, consisting of farrowing and farrow to finish operations under several different confinement systems, are generated from the FEDS budgets as follows:

1. The machinery and equipment initial list prices and purchase costs are adjusted to reflect 1980 prices.
2. Necessary changes are made on FEDs budget prices to make them correspond to prices reported in Table 34.
3. Pasture acres are converted to animal unit months.
4. Labor requirements are adjusted based on information in the Midwest Farm Planning Manual (James, 1979).
5. Fertilizer credits are calculated based on information from the Livestock Waste Facilities Handbook (Midwest

Table 34. Prices (In 1980 dollars)

| Item | Unit | Dollars/ Unit |
|---|---|---|
| Fertilizer and Lime | | |
| Nitrogen (Anhydrous Ammonia-$NH_3$: 82%N) | lb. | 0.14 |
| $P_2O_5$ (Super phosphate: 45% $P_2O_5$) | lb. | 0.27 |
| $K_2O$ (Muriate of Potash: 60% $K_2O$) | lb. | 0.12 |
| Limestone (spread on field) | ton | 9.53 |
| Seed | | |
| Corn (80,000 kernels/bag) | bag | 60.00 |
| Soybeans | bu. | 14.00 |
| Oats | bu. | 5.00 |
| Alfalfa | lb. | 2.00 |
| Brome grass | lb. | 0.90 |
| Energy | | |
| Gasoline (bulk delivery) | gal. | 1.29 |
| LP Gas | gal. | 0.686 |
| Diesel | gal. | 1.13 |
| Electricity | kwh. | 0.056 |
| Herbicide and Pesticide | | |
| Alachlor (Lasso 4E) | qt. | 4.30 |
| Cyanzine (Bladex 4L) | qt. | 3.86 |
| Parquat (Paraquat) | qt. | 11.00 |
| 2, 4-D (2, 4-D Amine) | qt. | 3.50 |
| Metribuzin (Sencor 50W) | lb. | 10.24 |
| (Furadan 10G) | lb. | 0.86 |
| (Counter 15G) | lb. | 1.17 |

Table 34. (Cont.)

| Item | Unit | Dollars/ Unit |
|---|---|---|
| Machinery (Used in Cropping Sector) | | |
| Tractor | 85 hp. | 23,400 |
| Tractor | 125 hp. | 31,700 |
| Combine | 110-125 hp. | 45,500 |
| Corn head | 6 row | 11,660 |
| Grain head (for soybeans) | 15 ft. | 5,220 |
| Windrower | 15 ft. | 3,620 |
| Forage harvester | 2-30 in. | 7,900 |
| Baler | Large round | 7,620 |
| Moldboard plow | 4-16 in. | 3,060 |
| Chisel plow | 11.3 ft. | 2,520 |
| Offset disk | 11.5 ft. | 6,660 |
| Tandem disk | 17 ft. | 6,480 |
| Stalk chopper (flail chopper) | 10 ft. | 3,600 |
| Field cultivator | 18 ft. | 3,510 |
| Sweep cultivator | 6 row | 2,340 |
| Rolling cultivator | 6 row | 2,715 |
| No-till cultivator | 6 row | 5,275 |
| Planter, double-disk opener | 6-30 in. | 7,700 |
| Planter, till | 6-30 in. | 8,550 |
| Planter, slot | 6-30 in. | 10,530 |
| Seed drill (grain drill) | 13 ft. | 3,600 |
| Rake | 7 ft. | 1,530 |
| Sprayer | 20 ft. T-mount | 1,080 |
| $NH_3$ applicator | 15 ft. (7 knife) | 2,250 |
| Bulk fertilizer applicator | 12 ft. | 2,160 |
| Wagons (2) | 300 bu. | 2,880 |
| Pick-up | 1/2 ton | 7,200 |
| Broadcast seeder | 20 ft. | 290 |
| Silage blower | -- | 2,255 |

Table 34. (Cont.)

| Item | Unit | Dollars/ Unit |
|---|---|---|
| Feed Supplement | | |
| 36-40% protein | cwt | 14.05 |
| Soybean oil meal | tn. | 50.00 |
| Miscellaneous Livestock Inputs | | |
| Grinding and Mixing, Farrow to Feeder | litter | 10.86 |
| Grinding and Mixing, Feeder to Finish | head | 4.46 |
| Grinding and Mixing, Farrow to Finish | litter | 32.14 |
| Vet and Medical, Farrow to Feeder | head | 2.50 |
| Vet and Medical, Feeder to Finish | head | 1.50 |
| Vet and Medical, Farrow to Finish | head | 3.87 |
| Vet and Medical, Feeder Calf | cwt | 7.00 |
| Vet and Medical, Beef Cow and Calf | head (yearlings) | 7.00 |
| Crops | | |
| Corn[a] | bu. | 2.56 |
| Soybeans[a] | bu. | 7.30 |
| Oats[a] | bu. | 1.56 |
| Straw | ton | 50.00 |
| Alfalfa[a] | ton | 57.73 |
| Pasture | AUM | 8.00 |
| Livestock[a] | | |
| Cull Cows | cwt. | 39.60 |
| Finished Steer and Heifers | cwt. | 58.66 |
| Calves | cwt. | 62.82 |
| Cull Sows | cwt. | 42.78 |
| Finished Hogs | cwt. | 50.51 |
| Feeder Pigs | cwt. | 94.08 |

Table 34. (Cont.)

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SOURCES: U.S. Department of Agriculture, Agricultural Prices (1980-1981, various issues).

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Personal communications with Emmet Stevermer, extension animal scientist, Iowa State University, Ames, Iowa; Gene Rouse, extension animal scientist, Iowa State University, Ames, Iowa; and William Edwards, extension economist, Iowa State University, Ames, Iowa.

[a]The prices of corn grain, soybeans, oats, and alfalfa are adjusted from actual 1980 prices to reflect historic (1976-1980) relationships between the different crops. The following formula is used to obtain the adjusted prices shown in the table:

$$AP_j = \left\{ \frac{\sum_{i=1976}^{1980} (CP_i / CMP_{ij})}{5} \right\} \left( CMP_{j1980} \right)$$

where: $CP_i$ = price of corn in year i,

$CMP_{ij}$ = price of commodity j in year i,

Table 34 . (Cont.)

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$AP_j$ = adjusted price of commodity j for 1980.

Livestock prices are similarly adjusted to reflect price relationship over the time period 1971-1980 with steers as the base commodity.

Personal communications with Emmet Stevenmer and Gene Rouse (extension animal scientists, Iowa State University, Ames, Iowa) and William Edwards (extension economist, Iowa State University, Ames, Iowa).

Plan Service, 1975) and on information obtained upon personal communication with Stewart Melvin (extension agricultural engineer, Iowa State University, Ames, Iowa).

6. The appropriate FEDs budget is run for each activity.

This provides an income and expense statement for each activity. Based on this information, it is determined that the most profitable of the eleven hog-producing activities is the farrow-finish partial confinement activity. This is the only hog-producing activity that was ultimately included in the livestock sector of the models.

Beef cattle sub-sector. The beef cattle production subsector consists of eight activities. Four of these activities are feeding steer calves under four different feed rations of corn grain, corn silage, alfalfa hay, and soybean oil meal. The other four of these activities are raising beef calves in a cow-calf operation using four different rations of corn grain, corn silage, alfalfa hay, soybean oil meal, and pasture. These rations are specified and balanced to meet the nutritional needs of the cattle fed, based on information obtained in the Midwest Farm Planning Manual (James, 1979) and upon consultation with Gene Rouse (extension animal scientist, Iowa State University, Ames, Iowa).

It is assumed that the steers in the feeding steer calves activities are purchased at 450 pounds, and are fed to 1050 pounds. In the cow-calf operations, heifer calves not held back for replacement are sold at 425 pounds, and steer calves are sold at 450 pounds.

As with the hog production subsector, the FEDs budgets are utilized to help generate the necessary data. Because the FEDs budgets provided for only two basic rations, these budgets are manipulated by adjusting feed requirement and corresponding machinery and equipment costs and energy requirements. Also, as with the hog production subsector appropriate adjustments in prices, labor requirements, and fertilizer credits are made, and the appropriate FEDs budget is utilized for each activity to generate necessary data requirements.

## Fieldwork Hours Available

One of the resource constraints facing farmers is labor hours. This constraint is dependent on the number of on-farm laborers, the number of hours in a day suitable for fieldwork, the number of days in the year suitable for fieldwork, and the availability of hired labor.

Because the busiest time of the year is generally in the spring and the fall, three cropping seasons are specified: spring, fall, and other. The spring season is defined as the period from March 29 to June 6. The fall season is defined as the period from September 6 to October 31. The "other" season includes all of the rest of the year.

Based on sunrise and sunset tables (Engel and Takle, 1975) the total daylight hours for the spring, fall and other seasons are estimated as 981, 653, and 2,834 respectively. Based on these data and data from Williams and Edwards (1978), the total number of daylight hours suitable for fieldwork is estimated and presented in Table 35.

Table 35 . Total daylight hours suitable for fieldwork

| Farms | Daylight Hours Suitable for Fieldwork<br>Spring | <br>Fall | <br>Other |
|---|---|---|---|
| 5 | 461.66 | 408.61 | 1236.21 |
| 1 | 425.52 | 404.83 | 1192.90 |
| 4,6,12 | 449.69 | 428.06 | 1166.77 |
| 2,18 | 482.48 | 419.16 | 1181.95 |
| 3,7,17 | 444.16 | 409.25 | 1173.42 |
| 13,15 | 413.32 | 413.71 | 1130.34 |
| 10,16 | 424.77 | 380.97 | 1112.83 |
| 11,14 | 375.11 | 348.34 | 1084.38 |
| 8,9 | 334.50 | 360.99 | 1035.45 |

## VI. SUMMARY

Linear Programming models that maximize before-tax net returns to land, labor, and management have been built for 18 representative farms on all major land resource areas throughout Iowa. The representative farms are defined in terms of soil resources such that the farms and soil situations represent typical and extreme conditions with respect to soils and erosion problems in Iowa, and such that they range over enough conditions so that major problems in attaining reduced soil erosion and application of soil conservation practices can be studied.

The LP models incorporate five tillage systems, three supporting practices and 15 crop rotations on three to five soil mapping units. The five tillage systems included are the conventional fall moldboard plow, spring-disk, chisel-plow, till-plant, and slot-plant systems. The supporting practices included are contouring, strip cropping, and terracing. The crop rotations include combinations of corn grain, corn silage, soybeans, oats, alfalfa, and pasture.

In order to build the LP Models much data was needed. Input and output prices, input requirements, yields, labor and land constraints, and other data needed to estimate the coefficients required to build the LP models was collected.

In summary soil erosion is a serious problem in Iowa. An extensive research effort to examine the economics of soil and water conservation practices in Iowa has been conducted. This report describes and documents some of the basic methodology, models, and data used in this research effort. Studies that utilize these models and data are reported in further reports.

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