HD
1401
.C37
no.49T
1974

DEC 9 1986

MODELS OF SOIL LOSS, LAND AND WATER USE, SPATIAL AGRICULTURAL STRUCTURE, AND THE ENVIRONMENT

CARD REPORT 49T

THE CENTER FOR AGRICULTURAL
AND RURAL DEVELOPMENT
578 EAST HALL
IOWA STATE UNIVERSITY
AMES, IOWA 50010

STATE LIBRARY OF IOWA
Historical Building
DES MOINES, IOWA 50319

MODELS OF SOIL LOSS, LAND AND WATER USE SPATIAL AGRICULTURAL STRUCTURE, AND THE ENVIRONMENT

By

Kenneth J. Nicol
Earl O. Heady
Howard C. Madsen

CARD REPORT 49T

This Research Study was completed under a
Grant from the RANN Program
(Research Applied to National Needs)
of the National Science Foundation
(GI-322990)

The Center for Agricultural and Rural Development

Iowa State University

Ames, Iowa 50010

July 1974

STATE LIBRARY OF IOWA
17 I64ARD 8:49T 1974 sdoc
Nicol, Kenneth J./Models of soil loss, l
3 1723 00033 8715

PREFACE

This report summarizes the nature and results of a model developed under an ISU-RANN project dealing with land and water use, agricultural technology, policy, and the environment. The model and its application represent only one of the several activities underway and being completed under this project. Subsequent models and reports will include other dimensions of problems surrounding resource use, agricultural productivity, and national environmental goals including livestock wastes, pesticides, and chemical fertilizers.

The model reported emphasizes alternatives and potential goals in soil loss control as one means of environmental improvement. At the same time, the model also evaluates alternatives in land use, irrigation water allocation, farming technologies, and export potentials as these affect food supplies, farm prices, consumer food costs, foreign market possibilities, and general goals in resource productivity and environmental improvement. The alternatives analyzed in this study represent a subset of the total for which it has capabilities. For example, the model allows evaluation of the impact of national goals or alternatives on the distribution

of benefits and costs among the various land and water owners, and their rural communities. However, because of the length of the report, analysis of differential regional impacts on prices, incomes and resource values are reserved for a later report.

The public environment goals implied in state and federal legislation being enacted or posed can have economic impact at both the regional or community level and the aggregate or macro level. The model applied to the U.S. agricultural sector is designed to measure impacts at both levels. Whether or not various environmental goals are politically acceptable will depend on the pattern and intensity of these impacts by region. Similarly, whether or not an environmental program enacted by a state and relating to soil loss or pesticide and chemical use brings gain at the national level at the expense of the state's farm income, or vice versa, will depend on the nature of regional interdependencies through commodity and resource markets. The models under construction in the ISU-RANN research project are specified in a manner to reflect interdependencies among regional, commodity, and resource groups.

This project has benefitted greatly through the direct help and the advice of many people and numerous organizations. The organizations which have provided services, data, and help include: the RANN Program of the National Science

Foundation, the Soil Conservation Service and the Economic Research Service of the U.S. Department of Agriculture, and the Bureau of Reclamation of the U.S. Department of Interior. Persons who have provided direct help and input for the study are James Wade, Dan Dvoskin, Vince Sposito, and others of the staff of the Center for Agricultural and Rural Development, Iowa State University. The project has benefitted from the guidance and advice of the project advisory committee including N.C. Brady, Cornell University; William M. Johnson, Soil Conservation Service; D.F. Peterson, Utah State University; Oscar R. Burt, University of California; Emil R. Mrak, University of California; and George E. Smith, University of Missouri. We are particularly indebted to William Johnson, Soil Conservation Service; Mac Gray, Soil Conservation Service; and Larry Tombaugh, the National Science Foundation, for their aid in obtaining data and research services. The Soil Conservation Service supplied detailed data on soil loss for the many land resource groups, crops, and field technologies included in the study and should be considered as a cooperating institution in this study.

Kenneth J. Nicol
Earl O. Heady
Howard C. Madsen

TABLE OF CONTENTS

	Page
PREFACE	ii
GENERAL SUMMARY	xviii
INTRODUCTION	1
ROLE OF LAND USE AND SOIL LOSS IN THE ENVIRONMENT	2
Soil Particle Movement	3
Distribution of Erosive Lands	6
THE STUDY	9
Objectives of the Study	10
Assumptions for the Analysis	11
THE MODEL	14
The Regions Used	17
The data regions	17
The producing areas	19
The water supply regions	19
The market regions	22
Activity and Resource Restraint Coefficients	22
The population and industry activities	24
International trade	27
The exogenous agricultural sector	29
The crop production sector	31

Page

The livestock production sector 38

Determination of resource levels..... 40

The commodity and resource transfer sections 46

Regional Restraints Imposed on the Model 48

Restraints imposed at the producing area level 48

Restraints defined at the water supply region level 54

Restraints at the market region level 56

Restraints defined at the national level 58

The Objective Function 59

SOIL LOSS RESTRICTIONS AND TRADEOFFS IN AGRICULTURAL PRODUCTION, RESOURCE USE, AND PRICES 62

Production Patterns Under No Soil Loss Restriction 64

Land use patterns 64

Acreage utilization by land class 69

Regional land use patterns 72

Production Patterns with Restriction on Soil Loss 77

Soil loss levels 77

Land use and agricultural production patterns 89

Shifts in irrigated and dryland acreages 97

Production shifts by land classes 107

Yield impacts 109

Page

Shifts in livestock production 119

Resource use and income distribution 121

Nitrogen balances 137

Price Effects 143

THE IMPACT OF EXPANDED EXPORTS 146

Production Patterns Under Expanded Exports 147

Land use and irrigated acreage 149

Average yields 153

Soil loss levels 158

Resource use patterns 168

Shifts in returns among resources 172

Use of water and nitrogen 176

Price and consumer impacts of export-increasing policies 180

SUMMARY AND IMPLICATIONS 184

Erosion and Erosion Control Methods 186

Land and Water Allocations 188

Agriculture and Environmental Improvement 192

Agricultural Technological Requirements 196

Agricultural Returns and Farm Price Levels 196

REFERENCES 199

APPENDICES 203

Appendix 1. Exogenous Crop Sector 203

Page

Acreages allocated for use by exogenous crops 204

Nitrogen for the exogenous crops 206

Appendix 2. Development of the Livestock Sector 207

The exogenous livestock sector 207

The endogenous livestock sector 208

Livestock production of nitrogenous wastes 210

Appendix 3. Determination of the Soil Loss Coefficient 212

Appendix 4. Development of the Crop Yield Coefficients 216

Yield determination 216

Fertilizer use coefficients for the crops 220

Appendix 5. Development of the Crop Management System Costs 222

Appendix 6. Determination of the Land Base 229

Land base for the endogenous crops 230

Acreage available for the noncultivated hays and pastures 231

LIST OF TABLES

Number		Page
1	Summary of erosion potential by land class on privately owned lands in the United States, 1967	8
2	Level of soil loss and exports for the alternative models	13
3	Projected per capita consumption levels for the commodities in the year 2000	26
4	Net foreign trade of the commodities used for the year 2000	28
5	Commodities produced by the endogenous livestock classes	40
6	Land class and subclasses aggregated to the nine land groups	42
7	Total dryland and irrigated acreages in the nine land groups	42
8	Dryland crop acreages in major zones by soil capability class in 1967	67
9	Dryland acreages in major zones with unlimited soil loss and 69-71 average exports in 2000 (Model A)	68
10	Irrigated crop acreages in major zones by soil class in 1967	70
11	Irrigated acreages in major zones with unlimited soil loss and 69-71 average exports in 2000 (Model A)	71
12	Total soil erosion on cultivated lands in major zones with unlimited soil loss and average level exports in 2000 (Model A)	78
13	Total soil erosion on cultivated lands in major zones with 10 maximum soil loss and average level exports in 2000 (Model B)	78

Number		Page
14	Total soil erosion on cultivated lands in major zones with 5 ton maximum soil loss and average level exports in 2000 (Model C)	79
15	Total soil erosion on cultivated lands in major zones with 3 ton maximum soil loss and average level exports in 2000 (Model D)	79
16	Average per acre soil loss by region for alternative soil loss restrictions in 2000	82
17	National average per acre soil loss by land class for alternative soil loss restrictions in 2000	82
18	Per acre soil erosion on cultivated lands in major zones with unlimited soil loss and average level exports in 2000 (Model A)	85
19	Per acre soil erosion on cultivated lands in major zones with 10 ton maximum soil loss and average level exports in 2000 (Model B)	85
20	Per acre soil erosion on cultivated lands in major zones with 5 ton maximum soil loss and average level exports in 2000 (Model C)	86
21	Per acre soil erosion on cultivated lands in major zones with 3 ton maximum soil loss and average level exports in 2000 (Model D)	86
22	Per acre soil loss by conservation-tillage practice for alternative soil loss restrictions in 2000	87
23	National production of row crops, close-grown crops, rotation roughage crops and permanent roughage crops under alternative soil restriction levels in 2000	87
24	Acreages of cultivated land by conservation-tillage practices for alternative soil loss restrictions in 2000	91
25	Acreages under conservation practices in major zones with unlimited soil loss and 69-71 average exports in 2000 (Model A)	92

Number		Page
26	Acreages under conservation practices in major zones with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)	93
27	Acreages under conservation practices in major zones with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)	94
28	Acreages under conservation practices in major zones with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)	95
29	Dryland acreages in major zones with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)	98
30	Dryland acreages in major zones with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)	99
31	Dryland acreages in major zones with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)	100
32	Irrigated acreages in major zones with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)	104
33	Irrigated acreages in major zones with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)	105
34	Irrigated acreages in major zones with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)	106
35	Percent of the acreage of specific crops falling in land classes I and II for alternate levels of allowable soil loss in 2000	108
36	Acreage and average yield of crops by land class in the United States with unlimited soil loss and 69-71 average exports in 2000 (Model A)	110
37	Acreage and average yield of crops by land class in the United States with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)	112

Number		Page
38	Acreage and average yield of crops by land class in the United States with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)	114
39	Acreage and average yield of crops by land class in the United States with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)	116
40	Commodity use in livestock production under alternative soil loss restrictions in 2000	120
41	Value of resource use in crop production by major zones in the United States for unlimited soil loss and 69-71 average exports in 2000 (Model A)	122
42	Value of resource use in crop production by major zones in the United States for 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)	123
43	Value of resource use in crop production by major zones in the United States for 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)	124
44	Value of resource use in crop production by major zones in the United States for 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)	125
45	Percent of the total return in national row crop and close-grown crops production for alternative levels of soil loss restriction in 2000	129
46	Returns to the national resource sectors of agriculture from the production of row crops and close-grown crops for alternative levels of soil loss restriction in 2000	131
47	Total returns to the regional agricultural related sectors from the production of row crops and close-grown crops for alternative levels of soil loss restriction in 2000	133
48	Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model A)	135
49	Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model B)	135

Number		Page
50	Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model C)	136
51	Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model D)	136
52	Withdrawals and consumptive use of water in the western river basins with unlimited soil loss and 69-71 average exports in 2000 (Model A)	138
53	Withdrawals and consumptive use of water in the western river basins with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)	139
54	Withdrawals and consumptive use of water in the western river basins with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)	140
55	Withdrawals and consumptive use of water in the western river basins with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)	141
56	Nitrogen sources and use for alternative levels of soil loss restriction in 2000	142
57	Indication of relative farm level prices for some agricultural commodities for alternative soil loss restrictions in 2000	142
58	The level of export of the feed grains, wheat and oilmeals in 2000, with a 5 ton soil loss restriction	146
59	National production of row crops, close-grown crops, rotation roughage crops, and permanent roughage crops with a 5 ton soil loss restriction and alternative export levels in 2000	148
60	Acreage of cultivated land by region with a 5 ton soil loss restriction and alternative export levels in 2000	148
61	Irrigated acreages in major zones with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)	151

Number		Page
62	Irrigated acreages in major zones with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)	152
63	Dryland acreages in major zones with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)	154
64	Dryland acreages in major zones with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)	155
65	Acreage and average yield of crops by land class in the United States with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)	156
66	Acreage and average yield of crops by land class in the United States with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)	159
67	Total soil erosion on cultivated lands in major zones with a 5 ton soil loss restriction and double 1969-71 average level exports in 2000	161
68	Total soil erosion on cultivated lands in major zones with a 5 ton soil loss restriction and triple 1969-71 average level exports in 2000	161
69	Per acre soil erosion on cultivated lands in major zones with 5 ton soil loss restriction and double 1969-71 average level exports in 2000	164
70	Per acre soil erosion on cultivated lands in major zones with 5 ton soil loss restriction and triple 1969-71 average level exports in 2000	164
71	Average acre soil loss under alternative soil conservation practices with a 5 ton soil loss restriction and alternative export levels in 2000	165
72	Acreages under conservation practices in major zones with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)	166
73	Acreages under conservation practices in major zones with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)	167

Number		Page
74	Value of resource use in crop production by major zones in the United States for 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)	169
75	Value of resource use in crop production by major zones in the United States for 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)	170
76	Returns to the national resource sectors of agriculture from the production of row crops and close-grown crops with a 5 ton soil loss restriction and alternative levels of exports in 2000	173
77	Total returns to the regional agricultural related sectors from the production of row crops and close-grown crops with a 5 ton soil loss restriction and alternative export levels in 2000	175
78	Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model E)	177
79	Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model F)	177
80	Withdrawals and consumptive use of water in the western river basins with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)	178
81	Withdrawals and consumptive use of water in the western river basins with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)	179
82	Nitrogen sources and use with a 5 ton soil loss restriction and alternative levels of export in 2000	181
83	Indication of relative farm level prices for some agricultural commodities with a 5 ton soil loss restriction and alternative levels of export in 2000	181

Number		Page
84	Commodity use in livestock production with a 5 ton soil loss restriction and alternative export levels in 2000	183
85	Summary of erosion and acres under alternative conservation practices with the alternative soil loss restrictions in 2000	187
86	Summary of land, water and nitrogen fertilizer allocation in agriculture under alternative soil loss restrictions in 2000	189
87	Summary of agricultural land use by the major zones under alternative soil loss restriction levels in 2000	191
88	Summary of erosion and percent of acres by conservation practice with the 5 ton per acre soil restriction and the alternative export levels in 2000	193
89	Summary of resource use in agriculture under a 5 ton soil loss restriction and alternative export levels in 2000	195
90	Nitrogen fertilizer equivalent wastes from livestock	211

LIST OF FIGURES

Number		Page
1	Interactions within the agriculturally related sectors	16
2	The SCS data collection areas	18
3	The 223 producing areas	20
4	The 51 water supply regions	21
5	The 30 market regions	23
6	Schematic of the development of the crop management system coefficients	33
7	Schematic of the development of the livestock production possibility coefficients	39
8	The seven major zones	65
9	Location of dryland and irrigated row crops in 2000 under no soil loss restriction and 69-71 average level exports	74
10	Location of dryland and irrigated close-grown crops in 2000 under no soil loss restriction and average level exports	75
11	Location of dryland and irrigated hay in 2000 under no soil loss restriction and 69-71 average level exports	76
12	Moisture deficient areas of the nation	225
13	Summer fallow areas of the nation	226

GENERAL SUMMARY

The study was undertaken to develop and test a model capable of simulating the changes in national and regional variables relating to agricultural production as the level of sheet and rill erosion from cultivated lands is controlled. The model incorporates the major agricultural commodities and determines their pattern of production in 223 areas of the continental United States. Within each area, nine land classes were defined based on the erosion characteristics of the soils. The production of the alternative crops is allocated to these areas and land classes based on their economic advantage and compatibility with restraints.

The results indicate that agriculture can meet present and expanded levels of demand while maintaining a gross field loss of soil set at a level below 5 tons per acre. The analysis consisted of reducing the allowed level of per acre soil loss from no limit to 10 tons per acre, to 5 tons per acre, and finally to 3 tons per acre. Then impacts of these restraints were traced to the implied shifts in such national and regional parameters as soil loss levels, crop production patterns, farming methods used, land and water resources and capital inputs required, and changes in the farm level prices of agricultural commodities. Changes in these parameters are also determined when export levels are increased. The soil loss analysis uses the 1969-71 average level of exports as a base and the export alternatives consider increases in exports to three times this level.

Total soil loss can be reduced substantially through shifts to the use of contouring, strip-cropping, terracing or reduced tillage methods on

the cultivated lands. Some shifts are indicated in crops grown as the more erosive row crops, especially the silages and other crops leaving little or no residue cover, are substituted for less erosive crops.

Regionally, the shifts in production level and pattern are more pronounced in the high moisture-high runoff areas such as the South Central, South Atlantic and North Central regions of the nation. These highly erosive regions do experience exports, but their proportionate increase in acreage is not as large as for the more arid regions. The more arid regions, where runoff is correspondingly lower, gain in production as the soil loss restriction level is reduced. Also, in all regions the more erosive lands are used progressively less as they lose competitive advantage to the less erosive lands. As exports increase, some of the more erosive lands are returned to production before lands of low erosion characteristics which are at a transportation disadvantage relative to the projected export ports.

The environmental impacts associated with the soil loss restriction are twofold. First, the level of sediment available to enter the waterways is reduced, as well as the level of other materials for which sediment serves as a transport mechanism. The second impact is not favorable from an environmental aspect. The reduction in sheet and rill erosion is accomplished through an increase in the use of reduced tillage methods and a corresponding increase in the use of pesticides to control weeds and insects. These had formerly been partially controlled through tillage practices. Reduced tillage requires a much greater chemical application per acre and presents a greater exposure possibility for the agricultural laborers handling and applying the chemicals.

The distribution of returns to the agricultural sector shifts with the imposition of a soil loss restraint which becomes progressively more limiting. The return to labor and water declines slightly while the return to land increases greatly. For land owners, shifts in returns result as the lands which can comply at low cost command a higher rent and those which require intensive operations command a reduced rent or no rent at all if the restriction forces the land into a non-use status.

The general trend is for little change in the farm level price of agricultural goods until the allowable soil loss level is reduced to 5 tons per acre or less. As the export levels were increased in conjunction with the 5 ton soil loss restraint, the farm price of the agricultural commodities increased significantly when the feed grain, wheat, and oilmeal exports reach a level exceeding two times the base level.

Besides determining the level of sheet and rill erosion control desired, policy makers should consider the environmental impacts resulting from the shifts in agricultural chemicals, the pressure for regional production pattern shifts, and the equity consideration in the changes in the participant shares of the return to the labor, land, and water sectors of agriculture. The imposition of a soil loss restraint could place a heavy burden on certain regions or farm operators.

This analysis is designed to supply information on the magnitude and implied directional effects in the agricultural parameters considered. Knowledge of the direction and differential magnitudes of the shifts by region and operator could be used to better formulate a piece of legislation which may expedite farmer compliance and alleviate some of the possible

considerable impacts resulting from indirect interactions with the compliance measures.

MODELS OF SOIL LOSS, LAND AND WATER USE, SPATIAL AGRICULTURAL STRUCTURE, AND THE ENVIRONMENT

INTRODUCTION

Society has come to be increasingly concerned with the environmental impacts accompanying economic development and population growth. Because it extends so widely over space, agriculture is complexly interrelated to problems of the environment. Economic development of agriculture has intensified these possibilities as the sector has come to depend on intensive use of chemicals and is organized into fewer and larger units which specialize in commodities that concentrate wastes and runoff.

Legislation to impose environmental controls on agriculture have been enacted or imposed at both state and national levels. However, it is not yet known how such controls might influence farm income, food costs, the interregional distribution of resource use and production, national requirements for water, rural community employment, and other complex aspects of this large industry. This study analyzes these effects through environmental controls emphasizing soil loss.

The impact of environmental controls can be complicated by levels of exports to be attained, institutional arrange-

ments affecting the allocation of water, agricultural supply-control programs, and other public goals or policies. Accordingly, this study on soil-loss control potentials incorporates considerations of alternative farm commodity export levels and complete flexibility in the allocation of irrigation water according to the value of its marginal product. The analysis rests on a regional model emphasizing soil-loss restraints and nitrogen balances for each of 223 regions. In addition to the 223 agricultural producing regions, the model incorporates 51 water supply regions, 30 market regions, a transportation network, international trade, and all major field crops, livestock products, agricultural lands, and irrigation water supplies of the nation.

ROLE OF LAND USE AND SOIL LOSS IN THE ENVIRONMENT

The major proportion of nonpoint pollution in the United States arises in agriculture in the form of water runoff and soil erosion. Contamination of streams results especially from intensive land use systems and technology that intensify runoff, erosion, and the transport of sediment into major water bodies. Sediment may also serve as the transport mechanism by which contaminating chemicals flow into streams and lakes. Environmental degradation through agricultural production generally arises through interaction of economic development and agricultural structure and technology. A high

state of economic development is accompanied by a shift in relative resource prices and the tendency for labor to become the costly factor. Consequently, with more favorable real prices for capital, farming becomes capital intensive and larger units are favored because of declining fixed costs per unit as the capital item is used more efficiently.

These phenomena have an environmental expression as the increased specialization of farm enterprises and the tendency toward concentrated grain farms result in intensive row-cropping patterns and heavy applications of fertilizers and pesticides. Spacewise, farming affects a greater proportion of land use and environment than any other economic sector. Also, the incidence of its environmental outputs are most complex with respect to both the extent and location of pollution and the relative magnitude of the costs and returns for either the ongoing environmental degradation or the potential methods to control it. Wastes of agriculture not only flow into the same streams as do those of industrial and urban sectors, but they also trespass on more land and property owners between origin and stream destination.

Soil Particle Movement

The soil has two roles in the environment, one reflecting the productive use of the resource, and the second, the negative environmental impacts in misuse of the resource. Productive lands providing food and fiber form the basis for

the desirable use pattern for soil, while soil particles moved into a waterway form the undesirable or pollution aspect of the soil. Erosion represents the movement of the soil particles by water or wind from their present position to a different location. Erosion also interferes with the utilization of other resources in what would be considered their normal pattern. Substances such as ammonium nitrogen, phosphorous, and potassium fertilizers and many of the pesticides are attracted by the soil particles and become fixed in a form such that they become less available to plants or the pests at which they are directed. These substances are transported in this bound position as the soil particles are eroded from the field and can be released later at a new location as chemical conditions change.

Probably the most noticeable effect of soil erosion and sedimentation is the gradual destruction of lakes as the sediment is deposited near the mouth of the river and on the bottom of the lake, gradually making the lake smaller and more shallow. The degree to which sedimentation occurs is related to many factors associated with the sediment carrying capacity of the stream. Each stream, depending on its energy balance, possesses the capacity to support a specific sediment load. Any factor altering this energy balance results in the supportable sediment load changing.

The majority of sediment in the waterways originates from sheet and rill erosion of farm lands, and alternative measures are available with present technologies to control the quantity of soil lost through this process. Techniques available to control sheet and rill erosion on farm land include combinations of crop tillage and land-treatment practices. The crop tillage practices include: altering the time of tillage to have the surface less exposed during normal high-runoff periods, altering the intensity of tillage by implementing alternative minimum-tillage practices, controlling the quantity of residue remaining on the field after harvest and fall tillage, and altering the rotation utilized such that the rotation includes a higher proportion of the close-grown and sod crops that are less susceptible to erosion. The land-treatment practices include: contouring, strip cropping, and terracing.

Once the soil particles have left the field, the conservation practices used attempt to control the energy level of the stream and thus its carrying capacity. The control measure used on agricultural lands depends on the use for the land, on the degree of control desired, and on the susceptibility of the land to erosion. The use of the land incorporates the above erosion-control practices and the types of crops. The level of control is the variable which the social welfare function must indicate as society trades the satis-

faction received from the reduced level of sedimentation and the change in cost, if any, of commodities produced on the land.

Legislation aimed at soil-loss control also must consider any interregional trade-offs in resource use and income generation as the production patterns shift to those lands on which erosion is most easily controlled. The interregional shifts can represent trade-offs in regional comparative advantage as farmers in affected regions adjust to the restricted production possibilities. The intraregional shifts represent trade-offs between lands which have different susceptibilities to erosion and the degree of influence of the erosion-related factors.

Distribution Of Erosive Lands

The distribution of lands susceptible to erosion is summarized in the National Inventory of Soil and Water Conservation Needs, 1967 (3). This study, conducted under leadership of the Soil Conservation Service with other government agencies cooperating, inventoried private land of the United States and classified with respect to its present use and the type and degree of use hazard most predominant based on a two percent sample of the 1967 privately-owned lands. The inventory covered 1,438 million acres in the 50 states, of which 30 percent was classed as cropland, 34 percent as permanent pasture and rangeland, and 32 percent as forest land. The

remaining 4 percent represents roadways, farmsteads, fence rows and marshes.

The lands are grouped into land use capability classes I through VIII, with classes I, II and III being suited for cultivation; IV, marginal land for cultivation; V, wetland lands; and classes VI through VIII not generally suited for cultivation. In the inventory 58 percent of the land suited for cultivation (classes I-III) was cropland, 18 percent was pasture, and 20 percent was in forest land. Of the marginally cultivatable lands (class IV), 28 percent was used for crops in 1967, and in the classes V-VIII, only 4 percent of the lands was cropland (3). Each of the major capability classes, except I, is divided into four subclasses indicating the dominant soil limitation. Alternatives include susceptibility to erosion, excess water, unfavorable soil features, and adverse climatic conditions. Class I land was assumed to be adequately treated and exhibited no need for further conservation practices.

Table 1 gives the acres of privately owned land by use category and grouping of land use capability class and indicates the percentage, as described in the National Inventory (3), which has erosion as the dominant hazard. Of the cropland in classes I and II, only 40 percent has an erosion problem, compared with 60 percent of the cropland in classes III and IV and 62 percent in classes V through VIII. Crop-

Table 1. Summary of erosion potential by land class on privately owned lands in the United States, 1967

Land class and erosion potential	Cropland	Pasture	Forest	Other land[a/]	Total
			(000 acres)		
Land I-II					
Erosion dominant problem	90330	22460	28736	5844	147370
Total land I-II	223534	47135	62849	12269	345787
% of total	40.4	44.5	45.7	47.6	42.6
Land III-IV					
Erosion dominant problem	116277	94370	83325	7465	301437
Total land III-IV	191450	130108	172881	16420	510859
% of total	60.7	72.5	48.2	45.5	59.0
Land V-VIII					
Erosion dominant problem	14108	155225	146418	5067	320818
Total land V-VIII	22600	304634	363378	27528	718140
% of total	62.4	51.0	40.3	18.4	44.7
Total all land					
Erosion dominant problem	220715	272055	258479	18376	769625
Total land I-VIII	437584	481877	599108	56217	1574786
% of total	50.4	56.5	43.1	32.7	48.9

Source: National Inventory (3).

[a/] Includes farmsteads, roads, and other land not in crops.

land acreages in the less-suited land classes are only a small proportion of the total lands in these classes, indicating that farmers tend not to farm their unsuited land. Table 1 also indicates that not all land suited for complete or limited cultivation is so used. Over 440 million acres of land in classes I through IV were not in the cropland uses, as compared to 415 million acres which were. Of the 1,575 million acres inventoried, 770 million acres or 49 percent had erosion and soil loss as their dominant management problem.

THE STUDY

This study is one in a sequence carried out by the Center for Agricultural and Rural Development relating to agricultural policy, income, and resource use. The research upon which it is based is designed particularly to evaluate possible trade-offs in land use and to determine impacts of legislated restrictions on permissible soil loss in terms of the changes in water and land use, production patterns and technology in agriculture, and direct costs to society of these changes in terms of prices of agricultural commodities. The model must include the proper variables and restraints and be designed so that the specified objectives can be met given the set of assumptions within which the model is to be operated.

Objectives of the Study

The study is made to evaluate impacts in the agricultural sector from possible imposed limits on soil loss allowed through sheet and rill erosion of cultivated lands. The main questions it attempts to answer are: Does agriculture have sufficient production capacity to meet domestic and export demands and also contribute to improvement of the environment through reducing the quantity of sediment discharged into the nation's waterways? If so, how far can environmental attainment through reduction of soil loss from agriculture be carried while food demands are met at reasonable real prices? What interregional changes in crop and livestock production, land use, and water allocation are posed as different levels of environmental improvement through soil-loss controls are attained?

Part of the research involved developing a model capable of implementing the analysis posed. Such a model must encompass the major commodities, resources, and interrelationships of both the agricultural sector and its individual land and water regions. The land, water, and other resources must be defined in such a manner that they exhibit the characteristics inherent in the interrelationships of the analysis. In this study, these interrelationships center around the concepts of soil loss and productivity differentials of

alternative combinations of the resource inputs. The alternative technologies must be defined representing the appropriate production, utilization, or transfer alternatives.

Given the developed model, the objectives then become ones of determining the impact of imposed environmental restrictions on the allowable soil loss from croplands. The analysis of the impact needs to apply at the national level in order for the overall production potential and price effects within the agricultural sector to be evaluated. Further, it needs to allow determination of any shifts in regional comparative advantage, indicating which regions will be affected differently by the national impacts. The resulting land-use patterns, cropping patterns, water reallocations, resource-use alternatives, and farming practices can indicate possible shifts in income and expenses of the farm and farm-related sectors.

Assumptions for the Analysis

When major impact alternatives are analyzed for agriculture by models capable of simulating interregional competition, a time horizon sufficiently far in the future must be selected to allow for the implied adjustments in technology and interregional shifts in production patterns. The year 2000 was selected as the base for the analysis, and the model was designed consistent with projected and expected production alternatives available at that time. The model

simulates a free market for commodity sales and resource purchase. Technology is projected on a trend basis in allowing for changes in livestock feeding rates and yields per unit of input for crops.

The international trade sector allows increases in imports proportionate to the population increase. Exports initially are held equal at annual 1969-71 levels. In a second stage of the study, exports are increased and the implications of increased demand are evaluated. A population level of 284 million persons in the continental United States is assumed for 2000. The level of per capita income projected by the Bureau of Economic Analysis (30) is used in evaluating the income effects on consumption.

A summary of the models evaluated is given in Table 2. Four models are associated with soil-loss analysis and a further two with the alternative export levels.

The solutions analyzed represent a finite number of the complete set of possible alternatives. It is hoped that those presented will allow identification of trends and trade-offs which need to be examined when controls on the per acre level of erosion are considered for legislation. The models allow evaluation of the effects of the soil-loss restraints separate from changes in the demand level. Then the solutions for higher export levels give an indication of the effects of increased demand levels with "already imposed"

soil-loss restraints.

Table 2. Level of soil loss and exports for the alternative models

Model	Per acre Soil loss Level	Export level[a/]
A	unlimited	69-71 average
B	10 Tons	"
C	5 Tons	"
D	3 Tons	"
E	5 Tons	double 69-71
F	5 Tons	triple 69-71

[a/] Exports are adjusted only for the feed grains, wheat and soybeans.

The models provide insight into potential changes in the cropping, land-use, and water-use patterns, and in farming techniques which are economically and technologically feasible given the implied restraints. Considered in the land-use patterns are shifts among land class alternatives and also the shifts between dryland and irrigated agriculture as their relative advantages change with soil-loss restraints and export levels. Price-related effects analyzed include changes in the farm-level cost of consumer food outlays and changes implied in the values of farm resources.

THE MODEL

This study is made by means of a linear programming model developed for the nation encompassing 223 producing areas, 1,891 land-resource groups, 51 water regions, and 30 commodity-market regions. A model capable of analyzing the major effects of proposed environmental restrictions on the agricultural sector must allow enterprise, resource, and regional adjustments. Interregional shifts in production occur as the regional comparative advantage changes, as is indicated by the broiler industry concentrating in the Southeast; the cattle feeding industry, moving south and west from the Cornbelt; and soybeans and sorghum grain being introduced in areas where technology in the form of agronomic practices, improved varieties, and/or economic forces have altered the production possibilities (34, 35).

The basis for an interregional model is the definition a number of sets of regions consistent with the characteristics used to describe the resources, production possibilities, or form of interregional interaction desired. Within the appropriate regions defined, restraints are imposed on interactions among (a) resource availabilities and uses and (b) commodity production and demands. Also, activities or variables

representing alternative production possibilities, resource transformations and resource transfers delineate the possible utilization of the resources and production of the commodities subject to the stated restraints.

The model developed uses five regional delineations, three of which are operational in the model. It incorporates restraints on the availability of cropland by quality class, permanent hay or pasture, water, nitrogen use for fertilizer, and regional demands for the crop and livestock commodities. A restraint imposed exogenously to the model initially screens all crop production activities, eliminating those activities which develop a soil loss above the allowable upper limit. Besides crop production, other activities define the possibilities for livestock production, fertilizer and water purchase, demand generation through population, industry and international trade activities, the transfer of resources or commodities among regions, and requirements for the resources for uses exogenous to the model. A sector and restraint group delineation of the above-implied interactions considered in the analysis is given in Figure 1.

The expanded model employed includes 4,386 restraints and commodity regulatory equations and 26,768 activities or variables. It is solved such that a minimum-cost agricultural bill is determined and the factor costs of farming are covered (thus simulating a competitive equilibrium) subject

Figure 1. Interactions within the agriculturally related sectors

	popln & ind. 1	popln & ind. 2	popln & ind. 3	intnl trade 1	intnl trade 2	exog. lvstk 1	exog. lvstk 2	exog. crops 1	exog. crops 2	crop prodn 1 i	crop prodn 2 i	crop prodn 3 i	livestock 1	livestock 2	livestock 3	buy fert. 1	buy fert. 2	buy fert. 3	buy water 1	buy water 2	water export 1	water transfer	comm. transp. 1-2	comm. transp. 2-1	non-rotn past 1	non-rotn past 2	non-rotn past 3	non-rotn hay 1	non-rotn hay 2	non-rotn hay 3				
Cropland 1 i										+																						a	a	a	*
Cropland 2 i											+																						a	a	a	
Cropland 3 i												+																						a	a	a	
Pasture 1						-							-												+								0	0	0	≧ 0
Pasture 2							-							-												+							0	0	0	≧ 0
Pasture 3								-							-												+						0	0	0	≧ 0
Water 1	-			-	-	-		-					+						-	-				-				-							≧ 0
Water 2		-	-		-		-		-					-	-					+		+			-	-			-	-					≧ 0
Fertilizer 1				+		-		-					+			+																			≧ 0
Fertilizer 2				+		-			-					+			+																			≧ 0
Fertilizer 3					+		-		-						+			+																		≧ 0
Commodities 1		-	-	±		-				+	+		±	±									-	+				+	+						≧ 0
Commodities 2			-		±		-					+			±								+	-						+					≧ 0
Cost										-	-	-	-	-	-	-	-	-	-	-		0	-	-	-	-	-	-	-	-					

*This represents the acreage of land in class i in the producing area.

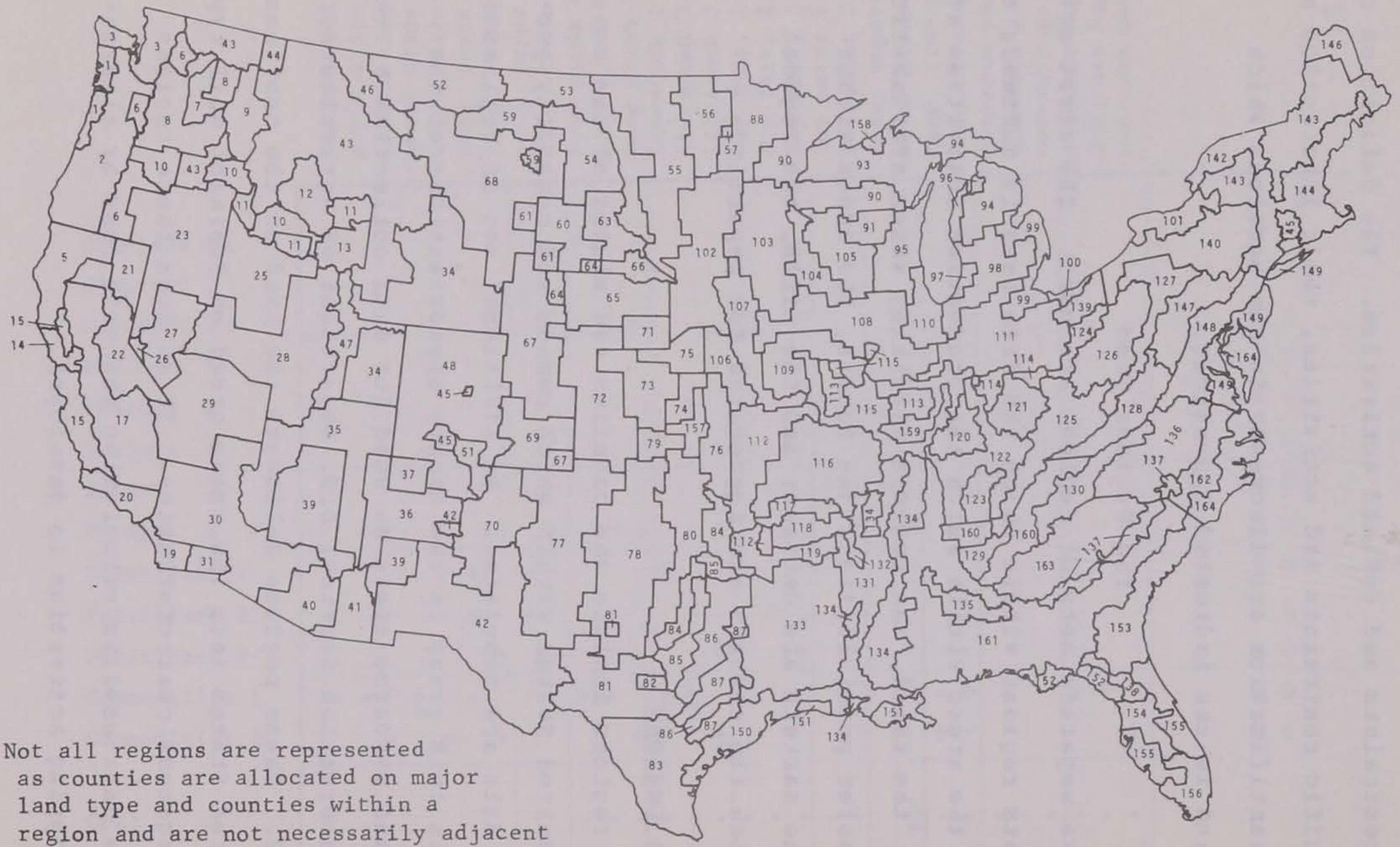
to the restraints and defined activities. The definition of the specific restraints and activities, their interaction and their quantification are discussed in the sections which follow and in the indicated Appendices.

The Regions Used

Five separate sets of regions are used. The first set represents regions within which the data base is defined; the second, the areas within which the production activities are defined; the third, the regions detailing water availability and transfer possibilities; the fourth, the areas within which the markets are defined; and the fifth, the regions into which the results are aggregated for reporting.

The data regions

The regions include the counties and states of the continental United States within which census and commodity production data are tabulated. An additional set of regions included in this group is the county approximations of the major land resource areas as used for data collection by the Soil Conservation Service, U.S. Department of Agriculture, Figure 2. These regions delineate the land of the continental United States into 156 areas based on dominant soil type and management characteristics. It is from these regions that the data used in calculating the soil loss by alternative cropping activities is developed.



Not all regions are represented as counties are allocated on major land type and counties within a region and are not necessarily adjacent as land types vary over counties.

Figure 2. The SCS data collection areas

Sets of weights based on relevant data relationships are used to transfer data from the regions in which they are obtained into the common resource or producing areas where the data are used in the model or in combination with other data to generate coefficients to be used in the model.

The producing areas

Figure 3 indicates the 223 producing areas used in the model. These areas are based on county approximations of the Water Resources Council's 206 subareas (36) modified to be consistent with the water supply regions and the market regions. Each producing area is an aggregation of contiguous counties contained in a watershed draining to a common waterway. The producing areas represent the regions in which crop and livestock production activities and the land, by quality class, pasture, and nitrogen balance restraints, are defined.

The water supply regions

Fifty-one water supply regions are defined in the 17 western states where water use and allocation are determined within the model, Figure 4. These regions are an aggregation of contiguous producing areas within which irrigated water supplies are available and can be used. The subdivisions of the 18 major river basins of the Water Resources Council form the basis of these regions (36). The model makes endogenous determination of the optimal amount of irrigated land and

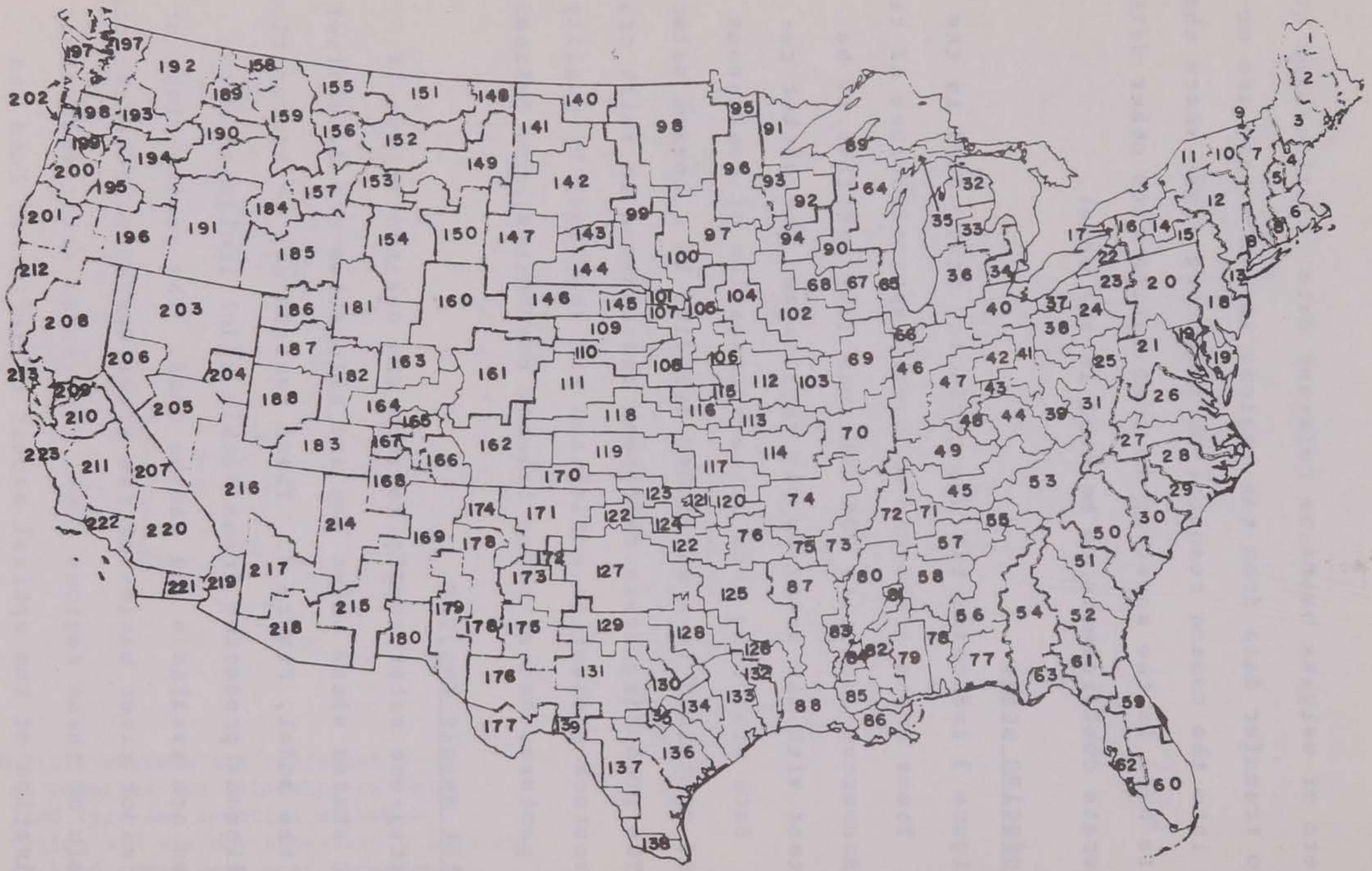


Figure 3. The 223 producing areas

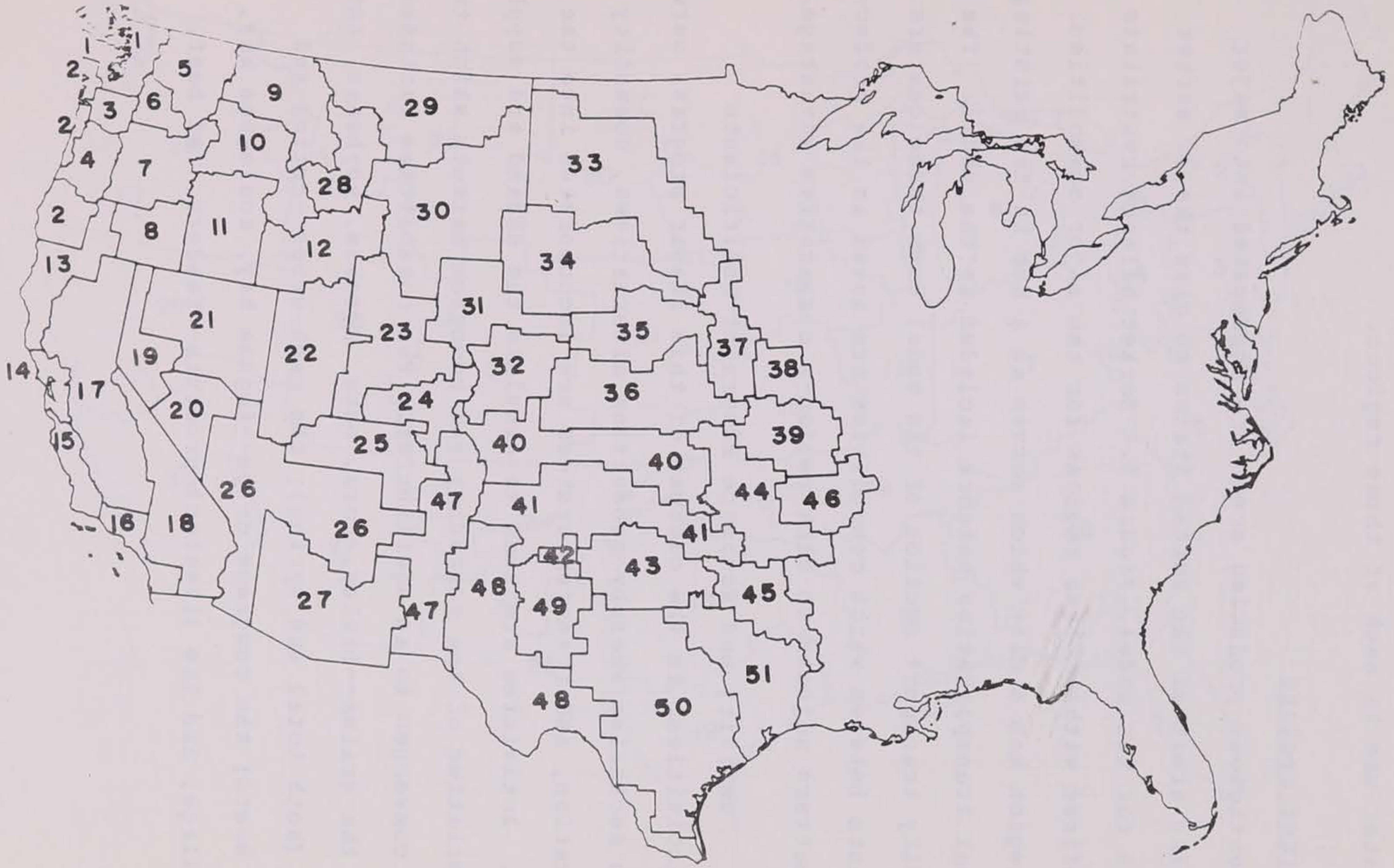


Figure 4. The 51 water supply regions

farm water use in each of these regions.

The market regions

Contiguous producing areas are aggregated into major marketing areas of the United States to give the 30 market regions for the model, Figure 5. Market balance restraints are defined within these regions for the major commodities. Each region has a city which serves as a hub in the existing national transportation network included in the model. The commodity transport section of the model uses these centers as points between which commodities are moved as the production pattern adjusts to each region's comparative advantage.

Activity and Resource Restraint Coefficients

Activities, in the context of this linear program, serve as the mechanism whereby production alternatives, commodity utilization, and transfer systems are incorporated into the model. Activities are used to simulate the demand and supply possibilities of the commodity and resource markets which the model converges to an equilibrium. The commodities included are: the grains--barley, corn, oats, sorghum, soybeans, and wheat (both total and spring); the cash crops--cotton and sugar beets; the roughage crops--legume hay, nonlegume hay, and silage; and the livestock products--feeders, fed beef,

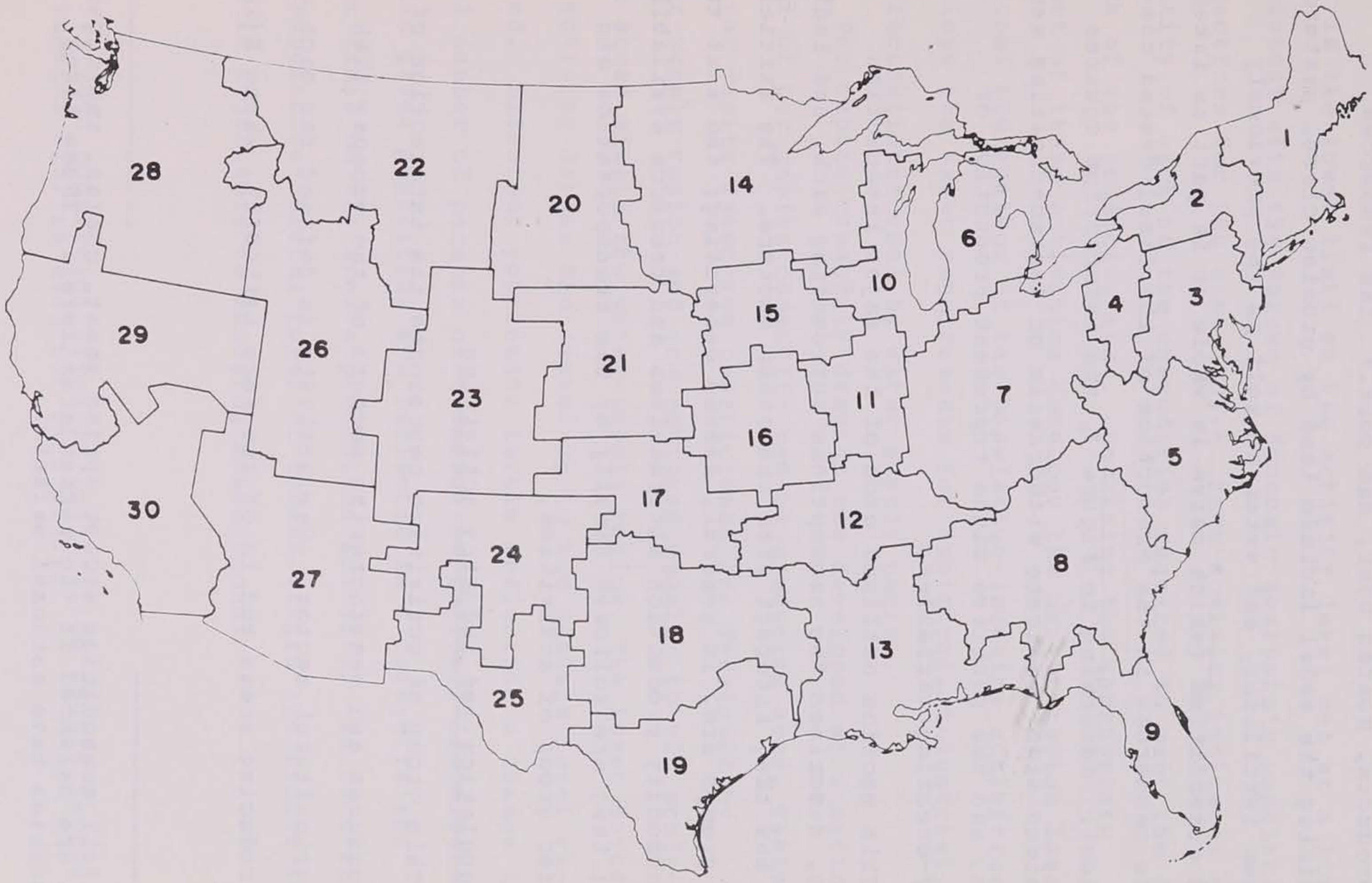


Figure 5. The 30 market regions

milk products, nonfed beef, and pork.[1] The resources restraining the model include land by erosion class, pasture, nitrogen fertilizer, and water as well as the previously listed commodities (which serve in whole or in part as intermediate resources in the production of the final demand commodities). Returning to Figure 1, the interaction squares with minus signs indicate withdrawals or demand-creating variables, and the positive signs represent production or supply-creating variables.

This section outlines each of the major interaction groups, describes the assumptions surrounding each, and indicates how they interact with the other sectors. The initial three groups are, in general, demand generating; the next two are commodity production alternatives and resource availabilities; they are followed finally by the transportation and transfer group of activities.

The population and industry activities

This group of activities represents the interaction of the consumer and manufacturing sectors of the economy with the agricultural sector. One activity is defined for each of the producing areas and is of the form $L(i) < N(i)$, where $N(i)$

---

[1]All commodities except spring wheat, cotton, and sugar beets are balanced at the market area level. These three commodities have national markets.

is the level of population activity in producing area i and L(i) is the lower limit on the activity level set at a limit consistent with the Bureau of Economic Analysis's population projections for the area (30).[1] Each activity indicates the quantity of each of the commodities required to meet the demands of the producing area. Combining the appropriate subset of these activities develops the market region demand. A second aggregation of the population-industry activities develops the water requirements for municipal, industrial, and recreational uses by water supply region.

Per capita commodity demands are developed at a national level of per capita commodity use by producing area, Table 3. The per capita water-use coefficients are developed by water-supply region and are assigned equally to all producing areas within the water-supply region. The lower bound on the activity drives the demand up to the minimum level required. Different population levels reflecting a change in total number of persons or a change in regional distribution of the given population are reflected in a change in the lower limit on the area's production activity. In this way the population-related level of demand within the market region is adjustable to changing assumptions.

---

[1] A 2000 population level of 284 million people in the continental U.S. is used for this study.

Table 3. Projected per capita consumption levels for the commodities in the year 2000

Commodity	Consumption	Commodity	Consumption
Corn	1.20 bushels	Fed beef	108 lbs carc wt.
Sorghum	0.05 bushels	Nonfed beef	51 lbs carc wt.
Wheat-total	2.58 bushels	Dairy products	4.04 cwt.milk eq.
Wheat-spring	0.52 bushels	Pork	68 lbs carc wt.
Oats	0.22 bushels	Broilers[b/]	40 lbs ready to cook
Barley	0.58 bushels	Turkey[b/]	9 lbs ready to cook
Oilmeals[a/]	0.09 cwt.	Lamb & mutton[b/]	3 lbs carc wt.
Lint cotton	12.0 pounds	Eggs[b/]	207.5 eggs
Sugar beets	0.11 tons		

[a/]Oilmeal requirement reflects an adjustment for the high protein grain by-products provided from the milling of the per capita equivalent of the other grains.

[b/]Not used directly in the population-industry activities but used in conjunction with the population to determine the level of commodity demand and the resource use by class of livestock in the exogenous livestock sector.

An additional set of activities, closely related to the population-industry activities, generates a demand for water in each of the 51 water-supply regions to reflect the increased demand for water for navigation, wetlands, and other onsite water-consuming activities. The onsite demand for water reflects a use over and above the level in 1969 (i.e., the 1969 level of use is not part of the calculated available supply).

International trade

This sector of the model adjusts the commodity demands to reflect foreign trade. For the base model, trade of all commodities is held at the 1969-71 annual average net trade level, Table 4. Trade levels for commodities with production and demand exogenous to the model (i.e., broilers, turkeys, and eggs) are specified by adjusting projected per capita requirements by an amount equal to the 1969-71 per capita net foreign trade.

Export demands for corn, sorghum, barley, oats, wheat, and oilmeals are allocated to the market regions proportionately to the average exports of the respective commodity from the ports in the region over the 1967-1969 period (28, 29, 3, 4). For commodities which have a net import balance, the total import is allocated to each market region proportionate to the projected population.

The two solutions for the expanded export analysis have exports of corn, sorghum, barley, oats, wheat, and soybeans at twice 1969-71 levels and at three times 1969-71 levels. In the expanded trade models, no adjustments are made in the net foreign trade position of other commodities.

Table 4. Net foreign trade of the commodities used for the year 2000

Commodity	Import	Export
Corn		626,333 thou. bu.
Sorghum		126,666 thou. bu.
Barley		48,666 thou. bu.
Oats		16,179 thou. bu.
Wheat		658,719 thou. bu.
Oilmeals[a/]		276,407 thou. cwt.
Cotton B		3,306 thou. bales
Beef	22,453 thou. cwt.	
Pork	3,349 thou. cwt.	
Dairy products	4,661 thou. cwt.	
Broilers		295,416 thou. cwt.
Turkeys		44,162 thou. cwt.
Eggs		68,699 thou. doz.
Sheep and lamb	1,647 thou. cwt.	

[a/] Oilmeals are expressed as soybean oilmeal equivalent exports of both meal and soybeans.

Three activities are used to simulate expected changes in water availability due to international water agreements. They represent the increased transfer of 1.5 million acre feet of water to Mexico from the Colorado River according to the Mexican treaty of 1944 (21), an increase of 45 thousand acre feet in the depletion of the Milk River by Canada (15) and the transfer of 1.1 million acre feet from the Missouri

River Basin in the Dakotas through the Garrison Diversion Project to the Souris-Red-Rainy River Basin (a basin outside the included water regions) by the year 2000 (15).

The exogenous agricultural sector

Resource allocation in part of the agricultural sector is predetermined exogenously to the active model. The two major exogenous groups are (a) fruits, vegetables, and minor crops and (b) the small, extremely intensive animal enterprises. Included in the exogenous crop sector are broomcorn, buckwheat, cowpeas, dry beans, dry peas, flax, hops, orchards and vineyards, peanuts, potatoes, proso-millet, rice, rye, safflower, sugar cane, sunflowers, sweet potatoes, tobacco, and vegetables.

Resource availabilities are adjusted to account for requirements of the above crops in 2000. Appendix 1 covers the computational procedures required to estimate the level of land, water, and fertilizer nitrogen use by these crops. The projected acreage requirement for these crops by land class in each producing area is subtracted from the available land in that class in the producing area. Where projections indicated a greater increase in acreage than available land allowed, the projected acreage is handled by adjusting either (a) the acreage in another land class of equal productivity in the producing area, or (b) the acreage in the same land class in an adjacent producing area. The alternatives used

depended on the historic (1964 and 1969 Census of Agriculture, (34, 35) data) similarity of the production pattern of adjacent producing areas and the characteristics of the crop which may allow it to be grown on land of different productivity and management requirements.

Projected water requirements for the exogenous crops grown in the appropriate producing areas were subtracted from total water available for use in the respective water supply region. Thus, exogenous crops have prior access to water. Most of the exogenous crops represent high value crops or those grown under contract and which generally can bid water away from endogenous grain and roughage crops.

Nitrogen fertilizer requirements for exogenous crops are projected to 2000 with a determination of the total requirement made for the producing area. This quantity is then introduced as a pre-solution deficit represented by the right-hand side of the nitrogen restraints in the nitrogen markets.

Livestock in the exogenous agricultural production sector includes broilers, eggs, turkeys, sheep and lambs, and other small animals (horses, mules, ducks, geese, fur-bearing animals, and zoo animals). The rations for each of the livestock categories are determined as outlined in Agricultural Water Demands (9) and give the quantity of each of the commodities required per unit of the livestock class. Except for the oilmeal coefficient, these quantities represent a

direct demand on the relevant commodity markets. Oilmeal is adjusted to represent a net demand for high protein feed by accounting for the amount of high protein animal feed produced as a byproduct of the slaughter of the livestock class. The method of calculating the animal protein production is outlined in Appendix 2. Per unit water requirements, for those areas where water restraints are defined, are obtained by livestock class from Agricultural Water Demands (9).

The quantity of nitrogen-equivalent wastes produced by each of the classes of livestock is determined and forms an interaction with the fertilizer nitrogen sector. The quantity of fertilizer-equivalent wastes from broilers is determined as outlined in Appendix 2, and a comparable production of nitrogen waste is calculated for the other poultry classes based on feed consumption and commodity production relative to broilers. Sheep and lamb wastes are calculated from the coefficients of the other ruminants, based on waste production per unit of output (Appendix 2). No nitrogen waste is associated with the other livestock category, as neither the exact mix of these animals nor waste production data for them are quantified.

The crop production sector

The crop production sector simulates production of grain sorghum, barley, corn, corn silage, cotton, legume and nonlegume hay or pasture in rotation, oats, sorghum silage,

soybeans, sugar beets, and wheat in rotational combinations consistent with the production possibilities of the region. These activities are defined by both producing area and land class, representing alternative crop sequences, tillage and conservation practices, and irrigated or dryland agriculture. A unique combination of the above factors represented in one activitiy is referred to as a cropping management system. Each of these systems produces commodities for intermediate or final demands while simultaneously creating a demand for nitrogen, land and, in the west--water.

In completely defining one of the cropping management systems, many interactions and influencing factors must be considered. Figure 6 outlines the interaction of the soil characteristics, technology, and the natural factors in determining the possible cropping management systems and their resulting coefficients. The soil characteristics require determination of the slope length and gradient of the soil, the physical makeup of the soil (determining its descriptive classification), and the natural fertility levels of the soil. The natural possibilities include the quantity and annual distribution of precipitation and the length of the growing season as determined by the frost free period. These factors combine with the technological possibilities, such as production method and the response function resulting from commercial or animal fertilizer applications. In general,

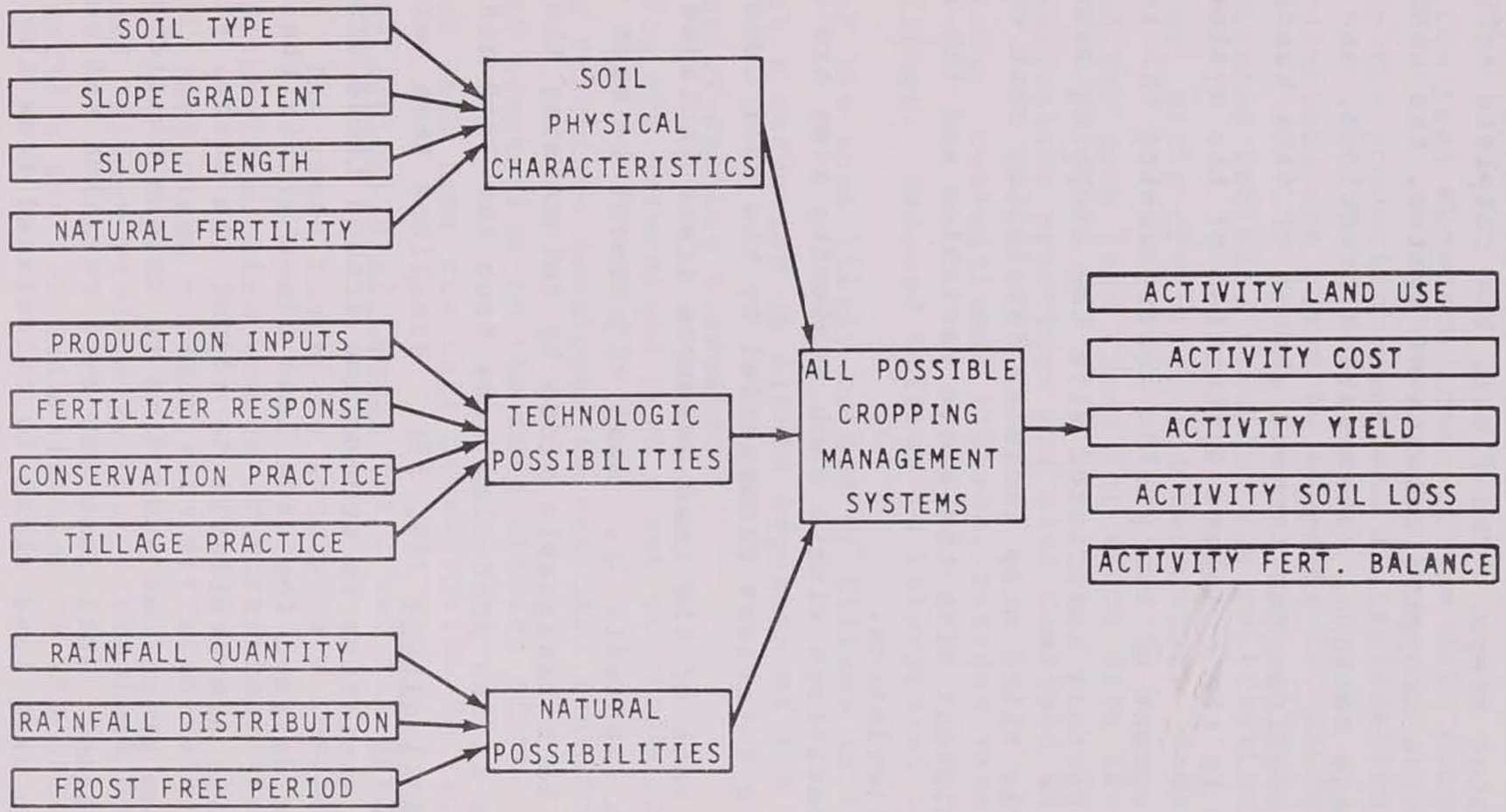


Figure 6. Schematic of the development of the crop management system coefficients

the data development for the model was divided into three closely related steps. The first, the complete definition of the alternative cropping management system, the associated crops, tillage methods, conservation practices, and resulting soil loss, requires the largest amount of data handling. The second step in the complete definition of the system represents development of the yields incorporating the influences of all the factors associated with the cropping management systems. The third step includes developing cost coefficients consistent with the above variables and the regional farm characteristics.

Crop rotations within each producing area are determined by combining rotations recommended by the Soil Conservation Service in each of the Land Resource Areas included in a producing area (Appendix 3). Some adjustment is made to reduce the number to a manageable group by determining the relevant crops grown in the producing area from the 1964 and 1969 Census of Agriculture (34, 35). Rotations then were selected to allow a variation in production around these crops. Each rotation is defined for each land class within the region if relevant data are available to adjust the costs, yields, and conservation practices according to unique characteristics of the land class. Soil loss for each rotation and mechanical practice on each land class is calculated from the Universal Soil Loss Equation as developed by Wischmeier and Smith (38)

and the data from the regional specialists of the Soil Conservation Service (Appendix 3). The methods used to adjust the data from the Land Resource Areas of the Soil Conservation Service to the producing areas and an explanation of the soil loss calculations are given in Appendix 3. Conservation practices considered included straight row cultivation as the base, contouring, strip cropping, and terracing. Each practice is defined for each land class for which data are available. The conservation practices are also combined with the tillage practices: conventional tillage, residue management, and reduced tillage. Reduced tillage is interpreted to be the adoption of the most likely method of tillage in the area consistent with a reduction in direct exposure of the soil surface to erosion-causing elements.

Crop yields are determined from a set of producing area yield-response functions developed in the CARD research program (27), with adaptation to the land classes of the study on the basis of data from the Soil Conservation Service survey, the 1964 Agricultural Census (34), and the National Inventory (3). The yield functions incorporate response to fertilizer applications, time trends of technology (for this model to 2000), land class productivity differentials, and conservation and tillage yield effects. A complete description of the function and the determination of the relevant data is given in Appendix 4. An additional part of the yield

determination is the development of the fertilizer nitrogen requirements of the rotation. The response function has fertilizer input as a variable and projections of the optimum level of fertilization leading to the fertilizer coefficient for the interaction between the crop management system and the fertilizer nitrogen restraint. In calculating this coefficient, adjustments are made if the rotation includes either a legume hay or soybeans. Nitrogen fixed in their root nodules is projected to be available to the crop following in the next year of the rotation. In determining the quantity of nitrogen fertilizer required, the quantities of the non-nitrogen fertilizer elements required are also determined and their purchase becomes a part of the production costs associated with the cropping management system.

The crop costs are calculated individually from the data developed by Eyvindson (8). The individual crop costs include a breakdown into labor cost, machinery cost, pesticides, fertilizer (non-nitrogen), and miscellaneous costs including lime, grain drying, and seed. In calculating the projected total costs, adjustments in the fertilizer cost comes from the yield calculations, labor is adjusted for each of the crops to reflect a continued decline in labor per unit of output as determined from historic trends; while per acre machinery, pesticide, and miscellaneous costs are assumed to increase proportionately to the increase in yield calcula-

tions. Labor is adjusted over time for each crop and reflects a continued decline in labor input per unit of output. Per acre machinery, pesticide, and miscellaneous costs are assumed to increase proportionately to the increase in yield. All costs are determined in terms of 1970 dollars, and the methods and adjustments are outlined in Appendix 5.

Water coefficients are determined as outlined in Agricultural Water Demands (9). The requirements for the irrigated crop activity are weighted by the percentage of the crop in the crop management system. Water coefficients represent net diversion requirements and are not directly a determinant in the crop yields. However, the trend yields of irrigated crops reflect the past trends of water use on a per irrigated acre basis, and the functions are consistent with the calculated water demands.

An initial evaluation of the cropping management systems allow for the selection of one conservation tillage practice combination for each of the unique rotations. The difference between conservation-tillage practice alternatives is represented in yield and cost differentials but not in resource-use differentials. Thus, when evaluated in the linear program, that alternative with lowest cost per unit output will be selected. On this basis, all crop management systems within a unique rotation are evaluated and the most profitable alternative is chosen, (i.e., the one with the largest

income, given the resource costs).

The livestock production sector

The livestock production sector provides a secondary or intermediate demand on feed resource and transforms grains and roughage into the "desired" meat portions of the American diet. Figure 7 indicates the interactions relating to the development of the livestock production activities. The rations depend on the livestock class, relative feed costs, climatic influences, and management decisions. These factors combine with the technologic characteristics such as production inputs, feed and waste handling systems, enterprise size, and climate to define the alternative livestock possibilities.

Livestock production alternatives in the model are defined for each of the 223 producing areas. They represent the beef cow, beef feeding, hog, and dairy operations and are adapted from data by Eyvindson (8). Other livestock are allocated exogenously as described previously. Each livestock type in a producing area forms a set of activities with nutritionally balanced but commodity differentiated rations. The rations for each livestock group is balanced in separate mathematical formulations based on the nutrient requirements specified by the National Academy of Science (17, 18, 19). Rations are adjusted to reflect the expected difference between experimentally recommended levels of nutrient consump-

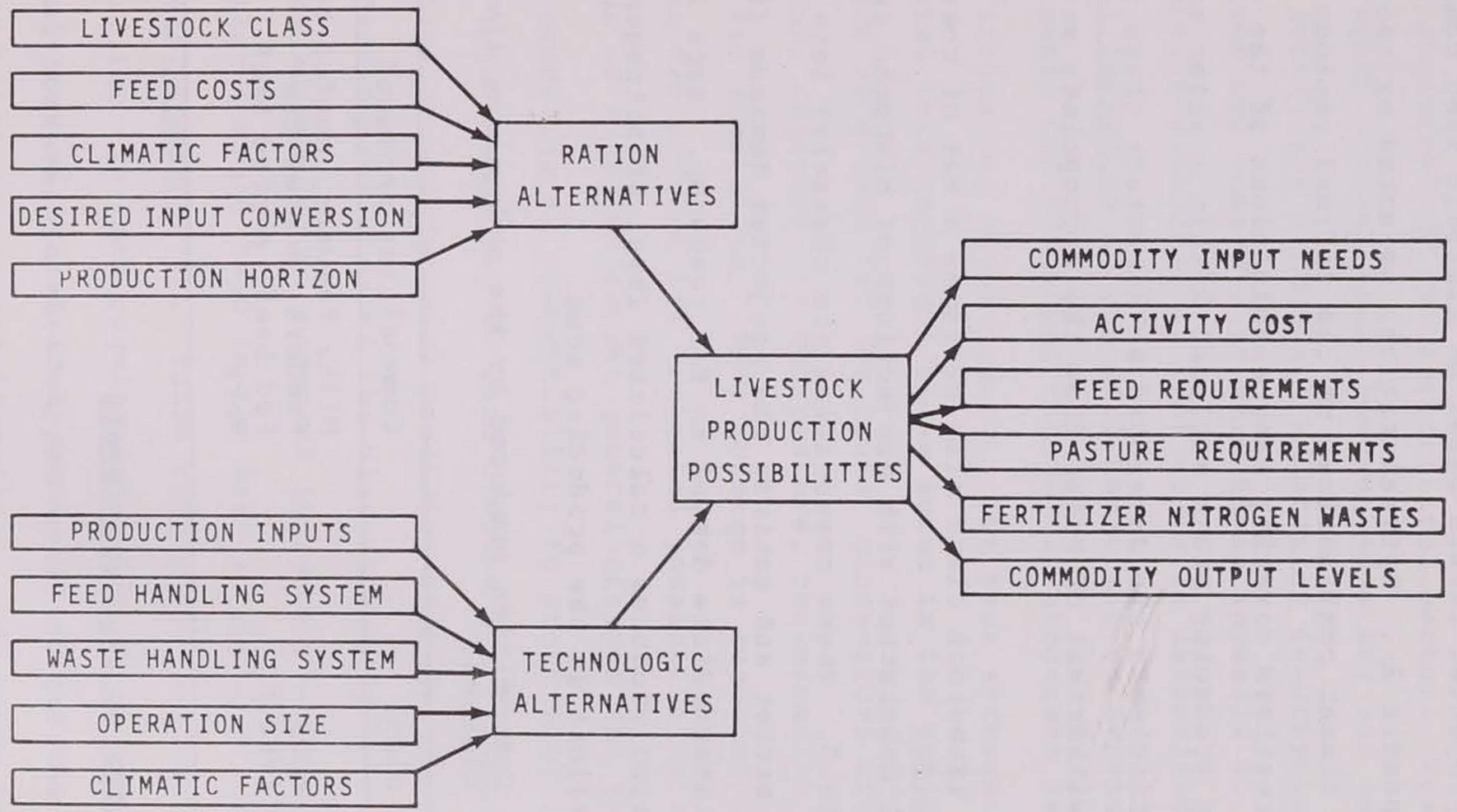


Figure 7. Schematic of the development of the livestock production possibility coefficients

tion and projected levels based on historic feed consumption rates (Appendix 2). Optimal rations selected by the model represent linear combinations of the defined rations and provide alternatives covering many combinations of the available feeds. In producing areas enclosed within a water supply region, coefficients are developed by livestock class to indicate the withdrawal of water from the appropriate water balance.

Each livestock class also produces a set of commodities at a level consistent with projections of historic regional data, Table 5. These commodities are channeled into the appropriate market and satisfy the projected demands (in some cases an intermediate demand as for feeders). Each livestock activity also produces a calculated level of nitrogen fertilizer equivalent in the producing area.

Table 5. Commodities produced by the endogenous livestock classes.

Livestock class	Commodities produced
Dairy	Milk, feeders, nonfed beef
Beef cows	Feeders, nonfed beef
Beef feeding	Fed beef, nonfed beef
Hogs	Pork

Determination of resource levels

This section outlines the methods of inventorying and delineating resources. A description is included of the model sector which determines the quantities of resources

available, their cost, and how and where they are to be used in the "optimization" of the agricultural sector. Resources in this category include land, non-rotation hay and pasture, water, and fertilizer nitrogen. A detailed description of the procedures and assumptions used is in Appendix 6.

The acreage available by land class is determined from the National Inventory of the Soil Conservation Service (3) with adjustments for projected changes in exogenous land uses and future irrigation developments. The base acreages used for cultivated land represent those acres in the National Inventory which were used for row crops, close-grown crops, summer fallow, rotation hay and pasture, conservation uses, and fruits and vegetables. This acreage is reported by 29 land classes for dryland and irrigated possibilities and represent lands of eight different general classes and four subclasses according to susceptibility to erosion by water or wind. For this study, the 29 land classes are aggregated into nine land groups for each producing area as indicated in Table 6. This aggregation to the nine land groups by producing area is adjusted for projected increases in land used for irrigation through 1980 in the West as outlined in Agricultural Water Demands (9). These available acreages also are adjusted for the land requirements of the exogenous crops as described previously and in Appendix 1. After these adjustments any land group with less than 1,000 acres is

Table 6. Land class and subclasses aggregated to the nine land groups[a/]

Land Groups	Inventory class-subclass	Land Groups	Inventory class-subclass
1	I	6	IVe
2	IIe	7	IVs, IVc, IVw
3	IIs, IIc, IIw	8	all of V
4	IIIe	9	all of VI, VII & VIII
5	IIIs, IIIc, IIIw		

[a/]Inventory class and subclasses are as defined by the Soil Conservation Service for the National Inventory (3).

Table 7. Total dryland and irrigated acreages in the nine land groups[a/]

Land Group	Dryland acres (000)	Irrigated acres (000)
1	23458	5632
2	76672	7257
3	73748	4796
4	65598	3648
5	45838	4120
6	29034	1410
7	10738	1168
8	305	14
9	12829	287
Total	338220	28332

[a/]Represents the total acres available for use by the endogenous crops.

aggregated to the next closest land group in erosion characteristic. Each land group remaining by producing area forms a land restraint in the model, and the acreage so calculated forms the right-hand side or upper limit on the availability of land of that quality in the producing area. The acreage by land group at the national level, after the above adjustments are made, totals 338,220 million acres of dryland and 28,332 million acres of irrigated lands (Table 7).

Dryland and irrigated nonrotation hay activities are developed from the acreages of hayland in the National Inventory with an estimate made of the lower yielding wild hay from the 1964 Census of Agriculture (34). These two groups, the wild hay and remaining nonrotation hay, are defined by producing area and are used as weights to adjust the cost and yield coefficients for tame hay and wild hay as reported in Agricultural Water Demands (9) to give a single tame, nonrotation hay activity by producing area. This activity contributes to the nonlegume hay balance in the relevant market area. No nitrogen fertilizer use coefficient is developed for this activity. Water requirements for irrigated nonrotation hay activities are weighted from the activities described in Agricultural Water Demands (9).

The range and pasture category from the National Inventory (3) gives dryland and irrigated nonrotation pasture activities. The costs and yields are developed by transferring

the pasture activities reported in Agricultural Water Demands (9). The yields from these pasture activities contribute to the hay-equivalent measurement of pasture land by producing area. The measurement of fertilizer use on the nonrotation pastures reflects the wastes of the livestock which are dropped while the animal is grazing. In order to quantify the requirements per acre and to reflect wastes produced while grazing, waste production of the animal is related to the consumption of roughage. This amount of waste per unit of roughage consumed is used to calculate the waste applied per acre grazed as a function of the yield of hay equivalent roughage from the acre of pasture.

The water coefficient for irrigated pasture is determined by adjusting the coefficient from irrigated pasture on farms as reported in Agricultural Water Demands (9). A similar activity on dryland only is developed from the forest grazed category with the coefficients being determined from the "pasture not on farms" activities described in Agricultural Water Demands. The fertilizer nitrogen coefficient is determined as for the pasture activities. The forest grazed activity represents mostly low-yielding lands which are grazed on an extensive basis and occur in large blocks in the regions of the West.

Pasture and hay production thus developed for each producing area is included in the model as an activity with an

upper bound equal to the estimated acreage in the producing area. These activities are then available to be considered as a source of roughage production depending on the per unit costs of the roughage produced.

The water sector is developed directly from Agricultural Water Demands (9) except for an alteration on the transfers of water into the Southwest seacoast areas. An activity is defined in each of the 51 water supply regions to add to the supply of available water. These activities are of the form $W(w) < U(w)$, where $W(w)$ is the level of water-buying activity in water-supply region w and $U(w)$ is the upper limit on the activity equal to the dependable water-supply estimated for water-supply region w. An additional water-supply activity is defined in all water-supply regions adjacent to a salt water source which allows for desalting of ocean water. This activity has no upper limit but is given a cost of $100 per acre foot thus making it feasible only for extremely high return uses.[1]

The remaining group of activities controlling the availability of resources represents the nitrogen fertilizer buy activities. These activities, defined by producing area, allow for the purchase of nitrogen fertilizer to meet the re-

---

[1]The $100 per acre foot cost is an estimate of the per unit cost of presently feasible large scale desalting attempts (9).

quirements of the cropping management system. The costs associated with these activities are determined from state fertilizer prices over the 1969-1971 period (27). These activities have no upper bound preventing fertilizer scarcity from placing any production limitation on the crop sector.

The commodity and resource transfer sections

Transfer activities are used in the model to transport commodities from areas of surplus production to areas of excess demand, to transfer water on a downstream flow or through interbasin channels, and to change the quality parameter in the beef market.

The commodity transportation activities are defined for the crops--barley, corn, oats, sorghum, soybeans, and wheat, and for the livestock products--fed beef, nonfed beef, pork, feeders, and dairy products on a milk equivalent basis. Transportation activities move the commodities between adjacent market regions and over some long haul routes if the long haul rail mileage is less than 90 percent of the miles associated with a movement through all intermediate markets. No discrepancy occurs as market handling costs are not charged at each point and the transportation cost functions utilized are linear in distance (9). The activities for transporting commodities are of the form $0<T(i,j,k)<\infty$, where $T(i,j,k)$ is the quantity of commodity i transported from market region j to market region k, with j and k having defined

values in the range from 1 to 30 except j= k.

The transfer of water has two components, the downstream flow and the interbasin flows. The downstream flow simulates natural water movement and is defined such that WNij < .75Wi, where WN(i,j) is the level of water transfer by natural flow from water supply region i to water supply region j, and W(i) is the total quantity of water available for use in water supply region i. This restrained activity allows for only 75 percent of the available water to be moved as outlined in Agricultural Water Demands (9). The second water transfer is the interbasin transfer system where existing interbasin transfer systems are simulated. The activities are of the same mathematical form as the natural flow transfers except the bound represents the capacity of the system rather than the water availability.

The final transfer sector is more realistically a transformation activity as the model allows fed beef to be used as part of the supply requirements to meet the nonfed beef demand. This activity approximates slaughtering cattle in a less finished state to be used as lower-quality meat. If this type of substitution were not possible, excess livestock (dairy and/or beef cows) could be introduced into the model to satisfy the nonfed beef demand, thereby producing an excess of the primary products, milk and feeders.

The description of all the coefficients used in the model have now been completed. The following section indicates how these are related to the model's restraints.

Regional Restraints Imposed on the Model

Restraints on the level of an activity or group of activities are included in the linear programming model at the producing area, water supply region, market region, and national levels. Restraints have already been explained for certain of the activities, such as the population industry, water buy, water transfer, export, and the nonrotation pasture and hay activity groups. It remains to define one individual activity restraint regulating soil loss and the group restraints on commodity balances, water use and transfer, land quantity, pasture availability, the nitrogen fertilizer balance, and commodity demands.

Restraints imposed at the producing area level

A restraint at the producing area level, not covered by the individual activity restraints already defined, is used to control the per acre soil loss by the crop management system. Also, restraints at the producing area level control the acres of land available for use by quality group, the fertilizer nitrogen balance, and the roughage equivalent production from pasture. The soil loss restrictions are of the form $SL(i,j) < MSL$ where $SL(i,j)$ is the calculated per acre

soil loss associated with crop management system i in producing area j, and MSL is the maximum allowed soil loss. A maximum soil loss restraint is imposed equally on all lands in all producing areas. (It would be possible to conduct the same analysis imposing different upper limits on soil loss on each land group and in each producing area). This restraint is not directly executed in the programming model but is a pre-solution condition. Each activity is evaluated as the model is constructed, and only those crop management systems which have a determined soil loss less than the per acre limit are included for that analysis.

The restraints regulating the availability of land by quality class make up the base for the entire model. The use of the land available provides an easy means of either expanding or contracting agricultural output. In the coefficients section, the land class groups are outlined along with the method of calculating the acreages available for use given the requirements for the exogenous crops. A possible 18 land restraints for each producing area are defined, 9 for each of the dryland and irrigated possibilities. The level of use of the available dryland or irrigated cropland is determined by restraints of the general form.

$$\sum_{k} X(i,j,k)A(i,j,k) \leq L(i,j)$$

$i = 1, \ldots, 223$ for the producing areas,
$j = 1, \ldots, 18$ for the land classes defined,

k = 1, 2, ..., for the number of crop management systems defined on land class j in producing area i,

where:

A(i,j,k) is the acres of cropland defined in rotation k on land class j in producing area i;

X(i,j,k) is the level of use of rotation k in land class j in producing area i;

L(i,j) is the acres of cropland on land class j available for use in producing area i.

The land groups run 1 through 18 with 1 through 9 indicating dryland (the only alternative in areas where water supplies are not defined) and 10 through 18 indicating the potentially irrigated lands. When irrigated cropland is included, the activities defined for possible use on the land include irrigated as well as dryland possibilities. Thus, if the water supply is fully utilized prior to using all possibly irrigated lands, the land unused for irrigation may be switched to rainfed agricultural uses. The model does not include the possibility of irrigated activities on dryland acres even when excess water is available.

The second general restraint defined at the producing area level regulates the production, purchase, and use of fertilizer nitrogen. Fertilizer nitrogen is balanced at the producing area level rather than the market region level to prevent the production of livestock wastes in one producing

area and the consumption of the nitrogen from these wastes in another producing area within the market region. The fertilizer nitrogen restraint has the form:

$$\sum_m Y(i,m)\,L(i,m) + Z(i) - \sum_j \sum_k X(i,j,k)\,A(i,k) - \sum_n P(i,n)\,N(i,n)$$

$$+ EL(i) - EC(i) = 0$$

i = 1, ..., 223 for the producing areas,
j = 1, ..., 18 for the land classes,
k = 1, 2, ..., for the number of rotations defined on land class j in producing area i,
m = 1, 2, ..., for the number of livestock activities defined in producing area i,
n = 1, ..., 5 for the permanent pasture and hay activities,

where:

L(i,m) is the pounds of fertilizer nitrogen equivalent produced in the wastes of livestock activity m in producing area i;

Y(i,m) is the level of operation for livestock activity m in producing area i;

Z(i) is the number of units of fertilizer nitrogen purchased in producing area i;

A(i,k) is the per acre nitrogen equivalent requirement of rotation k on land class j in producing area i;

X(i,j,k) is the level of use of rotation k on land class j in producing area i;

EL(i) is the level of fertilizer nitrogen equivalents

produced by the exogenous livestock in producing area i;

EC(i) is the level of fertilizer nitrogen equivalents required by the exogenous crops in producing area i;

P(i,n) is the level of permanent pasture or hay activity n in producing area i;

N(i,n) is the per acre requirements of fertilizer nitrogen equivalents for permanent pasture or hay type n in producing area i.

These nitrogen restraints are in the form of equalities. This formulation requires sufficient nitrogen fertilizer to be produced or bought for use (as would be done with a "greater than" restraint) and also prevents surplus fertilizer nitrogen from accumulating in the producing area (as might be the case if a concentration of livestock develops with insufficient crop or permanent pasture or hayland on which to dispose of the wastes). For computational purposes, these restraints are allowed a limited deviation from the equality constraint when solving the model.

The final producing area restraint balances pasture production and utilization on a producing area basis. All units are defined in terms of tons of hay equivalent per acre rather than acres of pasture. With this restraint defined by producing area, use of pasture can be controlled by producing area rather than by market region so that livestock in one

producing area cannot consume pasture located in any other producing area within the same market region. The restraints are of the form:

$$\sum_{j} X(i,j)\,AP(i,j) + \sum_{n} P(i,n)\,PY(i,n) - \sum_{k} Y(i,k)\,PC(i,k) \geq 0$$

i = 1, ..., 223 for the producing areas,
j = 1, ..., for the rotations defined in producing area i,
n = 1, ..., 3 for the permanent pasture activities,
k = 1, ..., for the livestock activities defined in producing area i,

where:

X(i,j) is the level of crop rotation j in producing area i;

AP(i,j) is the per acre yield of aftermath pasture by rotation j;

P(i,n) is the acres of pasture activity n in producing area i;

PY(i,n) is the yield of pasture activity n in producing area i (in hay equivalents);

Y(i) is the level of livestock activity k in producing area i;

PC(i,k) is the per unit level of pasture consumption by livestock activity k in producing area i.

Aftermath pasture is the grazing equivalent received from cropland after harvest or in the early spring before the crop develops. These balance equations complete the set of

restraints defined by producing area. The final resource restraint is defined by water supply region.

Restraints_defined_at_the_water_supply_region_level

The only restraint defined by water supply region regulates the use of water for all purposes such that it remains less than the quantity available, including any inflows defined. The restraints in this set are of the form:

$$WB(w) + WT(w) + WI(w) - WO(w) - WX(w) - WE(w)$$

$$\sum_{n} WR(n,i)\,R(n,i) - \sum_{i \in w} \sum_{j} X(i,j)\,WU(i,j)$$

$$\sum_{i \in w} \sum_{k} Y(i,k)\,WL(i,k) - WP(i)\,PN(i) \geq 0$$

i = 1, ..., 223 for the producing area,
j = 1, ..., for the cropping activities defined in producing area i,
k = 1, ..., for the livestock activities defined in producing area i,
n = 2, 4 for the irrigated permanent pasture and hay,
w = 1, ..., 51 for the water supply regions,

where:

WB(w) is the level of the water buying activity in water supply region w;

WT(w) is the level of the net natural water transfer associated with water supply region w;

WI(w) is the level of the net interbasin transfer of water associated with water supply region w;

WO(w) is the level of water use for onsite needs in

water supply region w;

WX(w) is the level of water exports from water supply region w;

WE(w) is the level of water use for exogenous crops and livestock in water supply region w;

WU(i,j) is the per acre water use by cropping activity j in producing area i;

X(i,j) is the level of use of cropping activity j in producing area i;

WL(i,k) is the per unit requirement for water by livestock activity k in producing area i;

Y(i,k) is the level of use of livestock activity k in producing area i;

WR(n,i) is the per acre requirement for water by permanent roughage activity n in producing area i;

R(n,i) is the level of use of permanent roughage activity n in producing area i;

WP(i) is the level of water use per person in producing area i;

PN(i) is the number of persons in producing area i.

All measurements are in acre feet of water per unit of activity. Of activities interacting in this restraint, the water buy, water transfer, interbasin flow, water for onsite uses, water exports, water for exogenous crops and livestock, and water for the permanent pasture and hay uses all are con-

trolled by individual activity bounds regulating their level of incorporation in the model as explained with the definition of the relevant activities.

Restraints at the market region level

The restraints at the market region level act as the market balancing mechanism for each of the commodities.[1] Each producing area in the market region interacts directly with these market restraints to satisfy its requirements for commodities as resources or to market the commodities produced in the area. Transportation activities link the commodity markets of adjacent market regions and allow the transfer of commodities to facilitate the interregional comparative advantage characteristics and satisfy the demands of the model. These restraints are of the general form:

$$\sum_{i \in m} \sum_{j} CC(i,j,p)\,X(i,j) + \sum_{i \in m} \sum_{k} CL(i,k,p)\,Y(i,k)$$

$$+ \sum_{q} T(p,q,m) + PC(i,p)\,N(i) + E(p,m) - X(m,p) \geq 0$$

i = 1, ..., 223 for the producing areas,
j = 1, ..., for the cropping activities defined in producing area i,

---

[1]The commodities include the crop products--barley, corn grain, legume and nonlegume hay, oats, oilmeals, silage, sorghum grain, and wheat, and the livestock products--fed and nonfed beef, dairy products (in milk equivalent), feeders and pork.

k = 1, ..., for the livestock activities defined in producing area i,
m = 1, ..., 30 for the market regions,
p = 1, ..., 15 for the commodities,
q = 1, ..., for the transportation activities defined in market region m,

where:

CC(i,j,p) is the per unit production of commodity p by crop activity j in producing area i;

X(i,j) is the level of use of cropping activity j in producing area i;

CL(i,k,p) is the per unit use or production of commodity p by livestock activity k in producing area i;

Y(i,k) is the level of use of livestock activity k in producing area i;

T(p,q,m) is the net movement of commodity p on transportation route q in market region m;[1]

E(p,m) is the net export of commodity p from market region m;

PC(i,p) is the per capita consumption of commodity p in producing area i;

N(i) is the population level in producing area i;

X(m,p) is the net use of commodity p by the exogenous

---

[1]Transportation activities are defined for the crop commodities--barley, corn, oats, oilmeals, sorghum, and wheat, and the livestock products--dairy products, fed beef, feeders, nonfed beef, and pork.

livestock in market region m.

The restraints balance the distribution and production of each of the commodities allowing for the interactions of the commodities as intermediate goods, where applicable, and also for the level of international trade.

Restraints_defined_at_the_national_level

Individual restraints at the national level simulate the markets for cotton, sugar beets, and spring wheat. Each of the producing areas which has the ability to produce these commodities feeds directly into the national market. The restraints have the general form:

$$\sum_i \sum_j X(i,j,p)\,CC(i,j,p) - Q(p) - E(p) \geq 0$$

i = 1, ..., 223 for the producing areas,
j = 1, ..., for the rotations defined in producing area i containing production possibilities for commodity p,
p = 1, 2, 3 for the commodities balanced at a national level,

where:

CC(i,j,p) is the per unit production of commodity p by crop activity j in producing area i;

X(i,j) is the level of use of cropping activity j in producing area i;

Q(p) is the demand quantity for commodity p;

E(p) is the net export level of commodity p.

National activities are defined for cotton and sugar beets, as no definite regional market is defined. In the case of spring wheat the regional allocation is controlled by the total wheat equilibrium by market area and the national restraint is defined only to ensure that sufficient of the wheat be of the spring varieties.

The Objective Function

The objective function in the model is developed to minimize the cost of producing the national agricultural bill, including both domestic and export demands, given the available land, water and fertilizer nitrogen resources, environmental goals, and the technology implied in the defined activities. It also requires that costs of resources used in production are covered, thus simulating a long-run competitive equilibrium of agriculture. The restraints on the objective function include balancing all markets as outlined in the market region and national market restraint sets. The objective function includes the costs of production, resource purchase, transfer, and transport as it minimizes the cost of the national agricultural bill and, considering only the nonzero elements, is of the form:

$$\text{minimize} \sum_{i}\sum_{j}(X(i,j)\,CC(i,j)) + \sum_{k} Y(i,k)\,LC(i,j)$$

$$+ \sum_{n} P(i,n)\,PC(i,n) + F(i)\,FC(i)) + WB(w)\,WC(w)$$

$$+ WD(w)DC(w) + WT(w)TC(w) + \sum_{m}\sum_{p}\sum_{q} T(m,p,q)TC(m,p,q)$$

i = 1, ..., 223 for the producing areas,
j = 1, ..., for the crop management systems in producing area i,
k = 1, ..., for the livestock activities in producing area i,
m = 1, ..., 30 for the market regions,
n = 1, ..., 5 for the nonrotation hay and pasture activities,
p = 1, ..., 15 for the commodities considered in market area m,
q = 1, ..., for the transportation activities defined in market area m for commodity p,
w = 1, ..., 51 for the water-supply regions,

where:

X(i,j) is the level of crop activity j in producing area i;

CC(i,j) is the cost per unit of crop activity j in producing area i;

Y(i,k) is the level of livestock production activity k in producing area i;

LC(i,j) is the cost per unit of livestock activity k in producing area i;

P(i,n) is the level of nonrotation pasture or hay activity n in producing area i;

PC(i,n) is the cost per unit of nonrotation pasture or hay activity n in producing area i;

F(i) is the level of fertilizer nitrogen purchase in

producing area i;

FC(i) is the cost per unit of fertilizer nitrogen purchase in producing area i;

WB(w) is the level of water buying in water-supply region w;

WC(w) is the cost per acre foot of water buying in water-supply region w;

WD(w) is the level of water desalting in water-supply region w;

DC(w) is the cost per acre foot of desalting water in water-supply region w;

WT(w) is the level of water transfer through natural flow, exports or interbasin transfers from water-supply region w;

TC(w) is the cost per acre foot of water transferred from water-supply region w;

T(m,p,q) is the level of transportation for commodity p through transport activity q from market region m;

TC(m,p,q) is the cost per unit of transporting commodity p through transport activity q from market region m.

The per unit costs defined in the objective function include only the purchase and utilization of resources exterior to the model. That is, no charge is included for internal inputs such as land, fertilizer, or livestock feeds.

SOIL LOSS RESTRICTIONS AND TRADEOFFS IN AGRICULTURAL PRODUCTION, RESOURCE USE, AND PRICES

The soil loss analysis is based on four solutions of the programming model. The solutions simulate production possibilities with (a) no restriction on per acre soil loss, (b) a 10 ton per acre upper limit on soil loss, (c) a 5 ton per acre upper limit on soil loss, and (d) a 3 ton per acre upper limit on soil loss. The four solutions provide approximations of the agricultural production pattern at specific points on a continuum with (a) the unrestricted alternative on one end and (b) some minimum soil loss level, consistent with production to satisty the defined demands, at the other end. The 10, 5 and 3 ton restriction alternatives provide estimates at intermediate points along the continuum. Given the tradeoffs in resource use and production patterns at both the inter- and intraregional level, the policy maker can determine the point along the continuum which approaches "equilibrium," given the policy maker's concept of the public's social welfare function.

Each alternative solution estimates the agricultural production and resource use pattern in 2000, subject to the conditions upon which the model is built. The unrestricted

soil loss model estimates production patterns given in a free market for the outputs and inputs and a nonrestrictive transportation network. The only restraint preventing a completely free market allocation of the factors is a semi-environmental requirement, the fertilizer nitrogen balance. It prevents livestock production in areas where land is insufficient to allow livestock waste disposition at a level which provides more nitrogen than the cropping pattern is capable of utilizing efficiently. The three restricted models of this section operate under the additional restraint simulating upper limits on per acre gross soil loss.

Model solutions reflect changes in land use patterns, resource use levels, farming practices employed, water allocation, agricultural income, and at the national levels, farm level food prices. The four solutions represent movement along the continuum of soil loss per acre and reflect the trade-offs in the above factors. The results provide estimates of the level and distribution of land and water use, crop production, total and per acre soil loss, the erosion control measures utilized to achieve the proposed level of erosion control, farm level prices and farm level expenditures for alternative crop inputs. Most of these data are generated for each of the 223 producing areas. However, because of space limitations, the data are presented at the national level and at a regional level for those variables

where regional variation is important to the implied productivity changes. The seven zones used for reporting the data are approximated in Figure 8. Initially, a comparison is made of the production patterns under the unrestricted soil loss model and the production patterns depicted by the most recent comparable data available.[1] Then, in following sections, the comparison is made of trade-offs and impacts of successively lower levels of allowable soil loss.

Production Patterns Under No Soil Loss Restriction

The unlimited soil loss model serves as the benchmark model in the analysis against which the other models are compared to determine the implications of the alternative levels of restriction on soil loss. The optimizing techniques used in mathematical programming estimate the optimum production patterns subject to the defined constraints at the national level.

Land use patterns

Land use comparisons indicate the acreages and the relative concentration of crops by land class and by region for both dryland and irrigated alternatives. A continuation of the land use analysis indicates the additional production ca-

---

[1] Most of the data for the comparisons are obtained from the 1967 National Inventory (3).

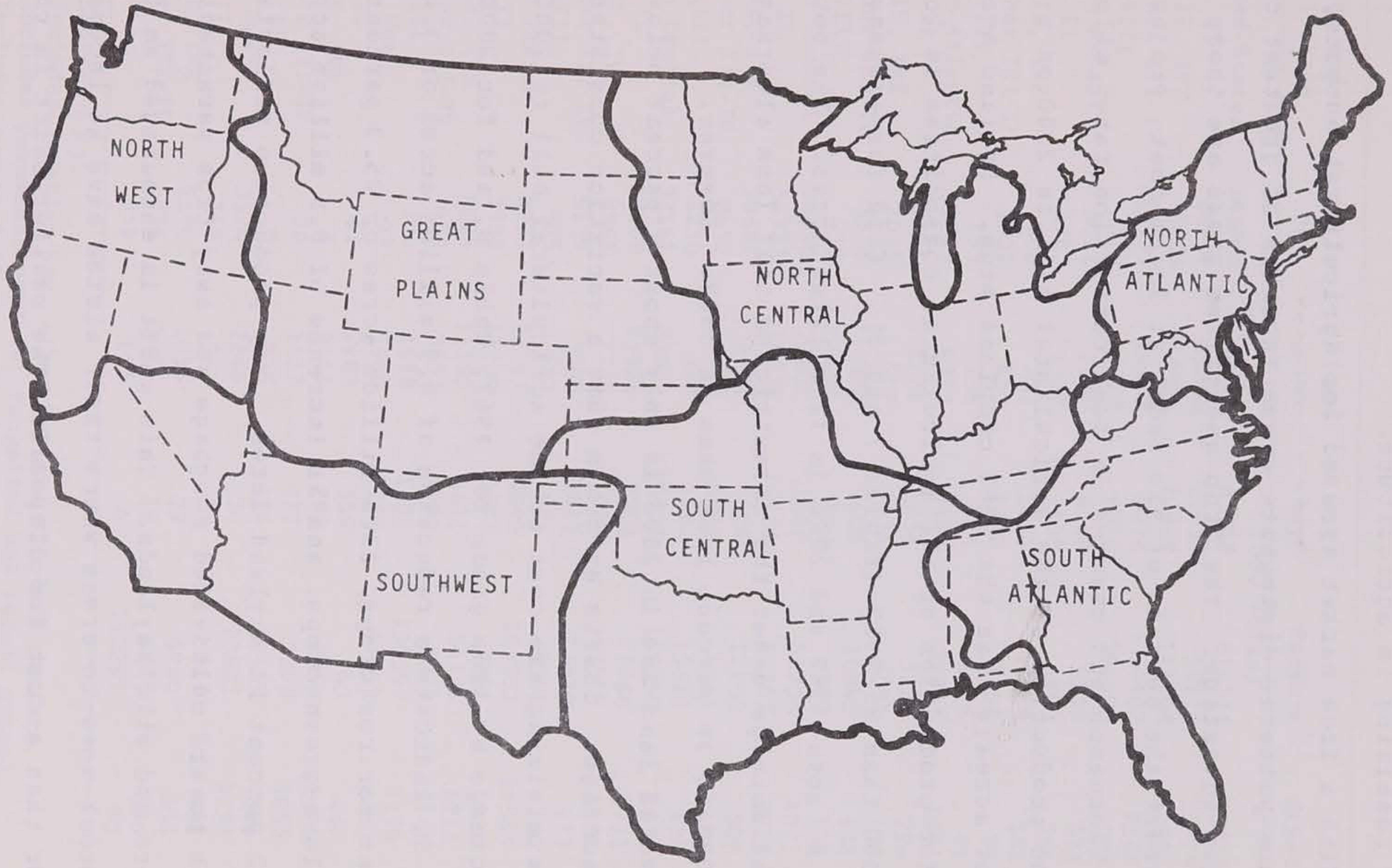


Figure 8. The seven major zones

pacity remaining in agriculture.

With a free market assumed for agricultural outputs, land use patterns distribute crops in areas of greatest comparative advantage. The crop quantities grown are those which meet the demands of the model at least cost. Projected yield increases and changes in feed conversion rates allow for the production of the agricultural bill in 2000 on a smaller acreage than the 1967 cropland base. Dryland acreage used for production of all agricultural commodities is lower for 2000 than in 1967 (Tables 7 and 8). Land for exogenous crops in both 1967 and 2000 is 12 million acres. The total dryland acreage under the unrestricted soil loss alternative for 2000 is 38 percent less than in 1967. However, cultivated land use in 2000 is only about 6 percent below the 1967 acreage. Shifts by crops show a variation consistent with minimizing the cost of the agricultural bill in 2000. The acreage by crop group for 1967, Table 8, and for 2000, Table 9, indicate a reduction of 4.9 million acres or 3.4 percent for row crops, 23.6 million acres or 25.3 percent for the close-grown crops, and an increase of 0.8 million acres or 1.2 percent in hayland acres. Hay production reflects a switch toward cultivated roughage and away from permanent pasture and wild haylands. This shift is encouraged as the livestock move to areas where their wastes have an income, rather than a cost for disposal. The smaller shift in row

Table 8. Dryland crop acreages in major zones by soil capability class in 1967

Zone and soil class	Row	Close grown	All hay[a]	Pasture[b]	Other[c]	Total
			(000 acres)			
United States	143905	93832	65548	614311	35036	952632
I, II	88747	47000	28657	58111	12779	235294
IIIE, IVE	28064	28908	20889	111908	12896	202665
Other III-IV	23499	14447	9976	49902	7266	105090
V VIII	3595	3477	6026	394390	2095	409583
North Atlantic	5071	2660	8749	9539	571	26590
I, II	2967	1337	3600	1893	266	10063
IIIE, IVE	908	732	2654	2813	141	7248
Other III-IV	1001	453	1770	1558	73	4855
V-VIII	195	138	725	3275	91	4424
South Atlantic	15243	2313	3389	32029	1491	54445
I, II	9191	1271	1234	5226	294	17216
IIIE, IVE	2035	617	1231	6051	109	10043
Other III-IV	3578	321	405	10843	938	16085
V-VIII	439	104	519	9909	130	11101
North Central	74690	28801	31446	46708	4021	185666
I, II	54327	19826	16761	13767	2913	107594
IIIE, IVE	10681	4452	8468	12260	509	36370
Other III-IV	8452	3933	4003	4865	475	21728
V-VIII	1230	590	2214	15816	124	19974
South Central	37161	23667	10637	169350	4272	245087
I, II	18069	11928	3802	27786	1735	63320
IIIE, IVE	8968	7734	4088	45325	1384	67499
Other III-IV	9139	3346	1811	17878	973	33147
V-VIII	985	659	936	78361	180	81127
Great Plains	8073	27567	9093	185352	19565	249650
I, II	3983	11204	2676	7551	6912	32326
IIIE, IVE	3275	11193	3621	34130	8211	60430
Other III-IV	433	3552	1292	8274	3146	16697
V-VIII	382	1618	1504	135397	1296	140197
North West	93	5980	2158	47651	3883	59765
I, II	61	1183	559	945	468	3216
IIIE, IVE	7	3145	798	5069	2176	11195
Other III-IV	20	1427	677	2298	1055	5477
V-VIII	5	225	124	39339	184	39877
South West	3574	2844	76	123682	1253	131429
I, II	149	251	25	943	191	1559
IIIE, IVE	2190	1035	29	6260	366	9880
Other III-IV	876	1415	18	4186	606	7101
V-VIII	359	143	4	112293	90	112889

Source: (3).
[a] Includes rotation hay, other hay and cropland pasture.
[b] Includes permanent pasture, rangeland and forest grazed.
[c] Includes summer fallow, orchards and vineyards.

Table 9. Dryland acreages in major zones with unlimited soil loss and 69-71 average exports in 2000 (Model A)

Zone and soil class	Row	Close grown	All hay[a/]	Pasture	Other[b/]	Total
			(000 acres)			
United States	138980	70205	66333	303059	7584	586261
I,II	101349	38536	29197	0	2543	171625
IIIE,IVE	22163	21934	13908	0	2198	60203
Other III,IV	15248	9500	5998	0	2702	33448
V-VIII	220	235	347	0	241	1043
North Atlantic	3713	1698	1614	6806	295	14126
I,II	3320	1193	493	0	137	5143
IIIE,IVE	216	491	5	0	81	793
Other III,IV	162	11	0	0	45	218
V-VIII	15	3	0	0	32	50
South Atlantic	10691	3201	2007	23592	1505	41096
I,II	7979	2387	1218	0	229	11813
IIIE,IVE	1152	383	48	0	70	1653
Other III,IV	1476	428	0	0	1166	3070
V-VIII	84	3	0	0	140	227
North Central	90902	19440	16755	29775	215	157087
I,II	71954	16121	7918	0	70	96063
IIIE,IVE	11266	2659	2767	0	54	16746
Other III,IV	7656	642	162	0	70	8530
V-VIII	26	18	0	0	21	65
South Central	27510	19863	27185	110694	1124	186376
I,II	14064	8753	11970	0	251	35038
IIIE,IVE	7933	6447	7285	0	518	22183
Other III,IV	5487	4563	4817	0	331	15198
V-VIII	26	100	183	0	24	333
Great Plains	4210	15015	14199	41388	4071	78883
I,II	3246	6574	6443	0	1764	18027
IIIE,IVE	776	6025	2279	0	1355	10435
Other III,IV	161	2359	84	0	952	3556
V-VIII	27	57	0	0	0	84
North West	335	6235	3048	24515	319	34452
I,II	77	1334	904	0	77	2392
IIIE,IVE	37	3424	499	0	97	4057
Other III,IV	207	1460	830	0	131	2628
V-VIII	14	17	21	0	14	66
South West	1619	4753	1525	66289	55	74241
I,II	709	2174	251	0	15	3149
IIIE,IVE	783	2505	1025	0	23	4336
Other III,IV	99	37	105	0	7	248
V-VIII	28	37	143	0	10	218

[a/] Including other hay and cropland pasture.
[b/] Summer fallow lands and orchards and vineyards.

crops, as compared to the close-grown crops, is indicative of the greater production of nutrients per acre by the row crops at a lower per unit cost as the two groups of commodities substitute in the livestock rations.

A reduction of 20 percent in irrigated acreage (Table 10), when compared to the 1967 acreages, occurs under the unrestricted soil loss model, Table 11. Irrigated row crops decline by 8 million acres and account for over 80 percent of the reduction in total irrigated acreage. (Total irrigated acreage includes nearly 8 million acres of exogenously determined irrigated crops.)

Acreage utilization by land class

One reason for the reduced acreage in 2000 is the shift in production to the less erosive and more productive class I and II lands relative to the 1967 cropping patterns. Nearly 73 percent of the row crops under the unrestricted soil loss alternative are grown on the class I and II lands, compared to about 62 percent in 1967. For the close-grown crops, 55 percent of the acreage is on class I and II lands under the unrestricted soil loss model compared with approximately 50 percent in 1967. Part of the shift results from the lower total acreage in production and most of the acres not in use in 2000 are in the more erosive land classes. During the period 1960-1972, approximately 50 million acres of land were withdrawn from production under government farm programs.

Table 10. Irrigated crop acreages in major zones by soil class in 1967

Zone and soil class	Row	Close grown	All hay[a/]	Pasture[b/]	Other[c/]	Total
			(000 acres)			
United States	16085	6801	12079	3010	1998	39973
I, II	11763	3771	4622	759	1151	22066
IIIE, IVE	2108	978	2275	633	299	6293
Other III-IV	2108	1968	4032	992	513	9613
V-VIII	106	84	1150	626	35	2001
North Atlantic			Not available			
I, II						
IIIE, IVE						
Other III-IV						
V-VIII						
South Atlantic			Not available			
I, II						
IIIE, IVE						
Other III-IV						
V-VIII						
North Central	68	1	7	0	0	76
I, II	42	1	6	0	0	49
IIIE, IVE	2	0	0	0	0	2
Other III-IV	24	0	1	0	0	25
V-VIII	0	0	0	0	0	0
South Central	2506	1168	715	180	118	4687
I, II	2112	701	332	109	103	3357
IIIE, IVE	285	90	18	52	15	460
Other III-IV	99	371	363	5	0	838
V-VIII	10	6	2	14	0	32
Great Plains	4889	1805	6545	1628	53	14920
I, II	3698	882	2107	236	19	6942
IIIE, IVE	677	428	1526	422	20	3073
Other III-IV	476	449	2074	535	12	3546
V-VIII	38	46	839	435	2	1359
North West	1801	1545	3513	872	949	8680
I, II	957	585	1378	275	582	3777
IIIE, IVE	188	253	613	71	154	1279
Other III-IV	639	683	1229	396	193	3140
V-VIII	17	24	293	130	20	484
South West	6821	2282	1299	330	878	11610
I, II	4954	1602	799	139	447	7941
IIIE, IVE	956	207	118	88	110	1479
Other III-IV	870	465	365	56	308	2064
V-VIII	41	8	17	47	13	126

Source: (3).

a/Includes rotation hay, other hay and cropland pasture.

b/Includes permanent pasture, rangeland and forest grazed.

c/Includes summer fallow, orchards and vineyards.

Table 11. Irrigated acreages in major zones with unlimited soil loss and 69-71 average exports in 2000 (Model A)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	9246	5330	12402	2921	1519	31518
I,II	6961	2184	5108	0	948	15201
IIIE,IVE	1282	851	598	0	205	2936
Other III,IV	980	2291	600	0	444	4315
V-VIII	23	4	2	0	22	51
North Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	24	0	435	0	0	459
I,II	22	0	326	0	0	348
IIIE,IVE	2	0	0	0	0	2
Other III,IV	0	0	109	0	0	109
V-VIII	0	0	0	0	0	0
South Central	1156	880	262	0	92	2390
I,II	888	524	161	0	91	1664
IIIE,IVE	160	64	77	0	1	302
Other III,IV	108	289	4	0	0	401
V-VIII	0	3	2	0	0	5
Great Plains	3302	1177	6852	472	8	11811
I,II	2506	633	2410	0	3	5552
IIIE,IVE	472	376	157	0	3	1008
Other III,IV	318	168	380	0	2	868
V-VIII	6	0	0	0	0	6
North West	1405	1528	2631	2381	701	8646
I,II	914	617	1141	0	450	3122
IIIE,IVE	149	318	349	0	100	916
Other III,IV	329	592	94	0	140	1155
V-VIII	13	1	0	0	11	25
South West	3359	1745	2222	68	318	8212
I,II	2631	410	1070	0	404	4515
IIIE,IVE	499	93	15	0	101	708
Other III,IV	225	1242	13	0	302	1782
V-VIII	4	0	0	0	11	15

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

The land not farmed was not selectively allocated to the more-erosive, less-productive soils. In this study, land previously retired is allowed to return to use. Hence, the more productive of it replaces less-productive lands formerly cropped on a greater than 1:1 basis.

Little change is shown in the land capability class concentration of the irrigated row crops with 73 percent of the 2000 and 73 percent of the 1967 production being on class I and II lands, Tables 10 and 11, respectively. A lower percent of the irrigated close-grown crops is on class I and II lands in 2000 (41 percent) than in 1967 (55 percent). A reason for the reduction in close-grown crops on class I and II lands is the greater quantity of these lands used for exogenous crops in 2000, with the remaining acreage used for row crops in class I and II lands. As the data in Table 11 indicates, there is essentially no class I and II land capable of being irrigated that is not used in 2000.

Regional land use patterns

A second factor contributing to the reduced total acreage required in 2000 is the ability for the production of crops and livestock to shift to areas of greatest comparative advantage. The South Central Region has 31.8 percent of the dryland acreage in 2000, compared with 25.7 percent in 1967. Other zones which increase in the proportion of the dryland acreage in 2000 when compared to 1967 include (with 1967 per-

centage in parentheses) the North Central with 26.8 percent (19.5 percent) and the South Atlantic with 7.0 percent (5.7 percent). The Great Plains zone has a total 2000 dryland acreage of 13.5 percent, compared to 26.2 percent in 1967.

Considering only the dryland acreage of row crops, the North Central with 65.4 percent, the South Central with 19.8, and the South Atlantic with 7.7 percent account for 92 percent of all dryland row crop acreage in 2000, Figure 9. In 1967, these same zones accounted for 88 percent. These shifts are consistent with the dryland yields of the regions. The North Central has yield advantages for corn and soybeans. The South Central and South Atlantic regions have yield advantages for dryland cotton, soybeans and sorghum (35).

Concentration of close-grown crops is in the South Central with 28.3 percent, the North Central with 27.7 percent, and the Great Plains with 21.4 percent of the national acreage. These zones account for over 85 percent of the 2000 dryland close-grown crop acreage compared to 77 percent in 1967, Figure 10. These same three zones account for over 87 percent of the dryland hay acreage in 2000 in the unrestricted soil loss alternative, compared to 78 percent in 1967, Figure 11.

The regional production patterns of the irrigated crops do not show changes similar to those which occurred for the dryland crops.

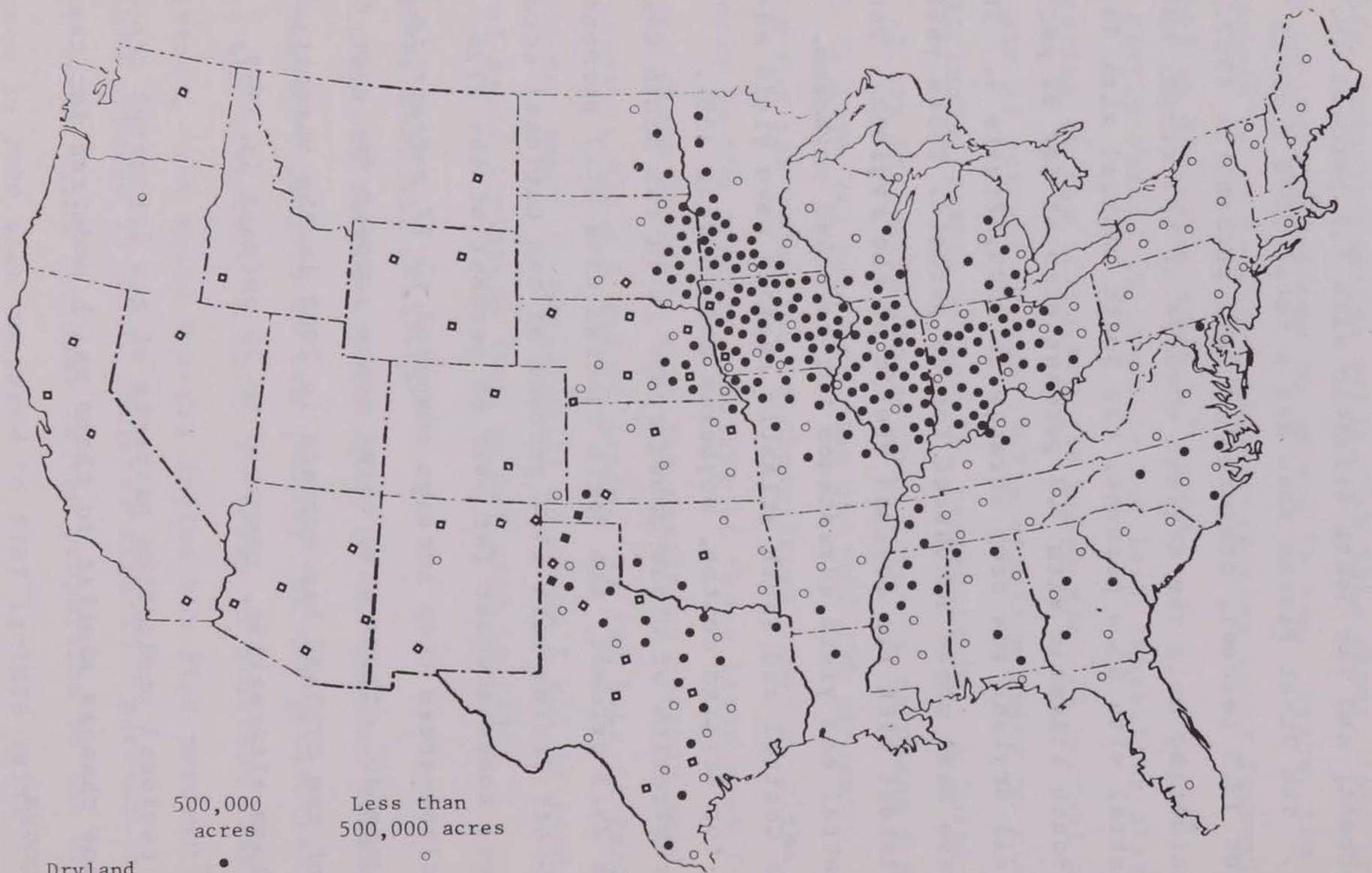


Figure 9. Location of dryland and irrigated row crops in 2000 under no soil loss restriction and 69-71 average level exports

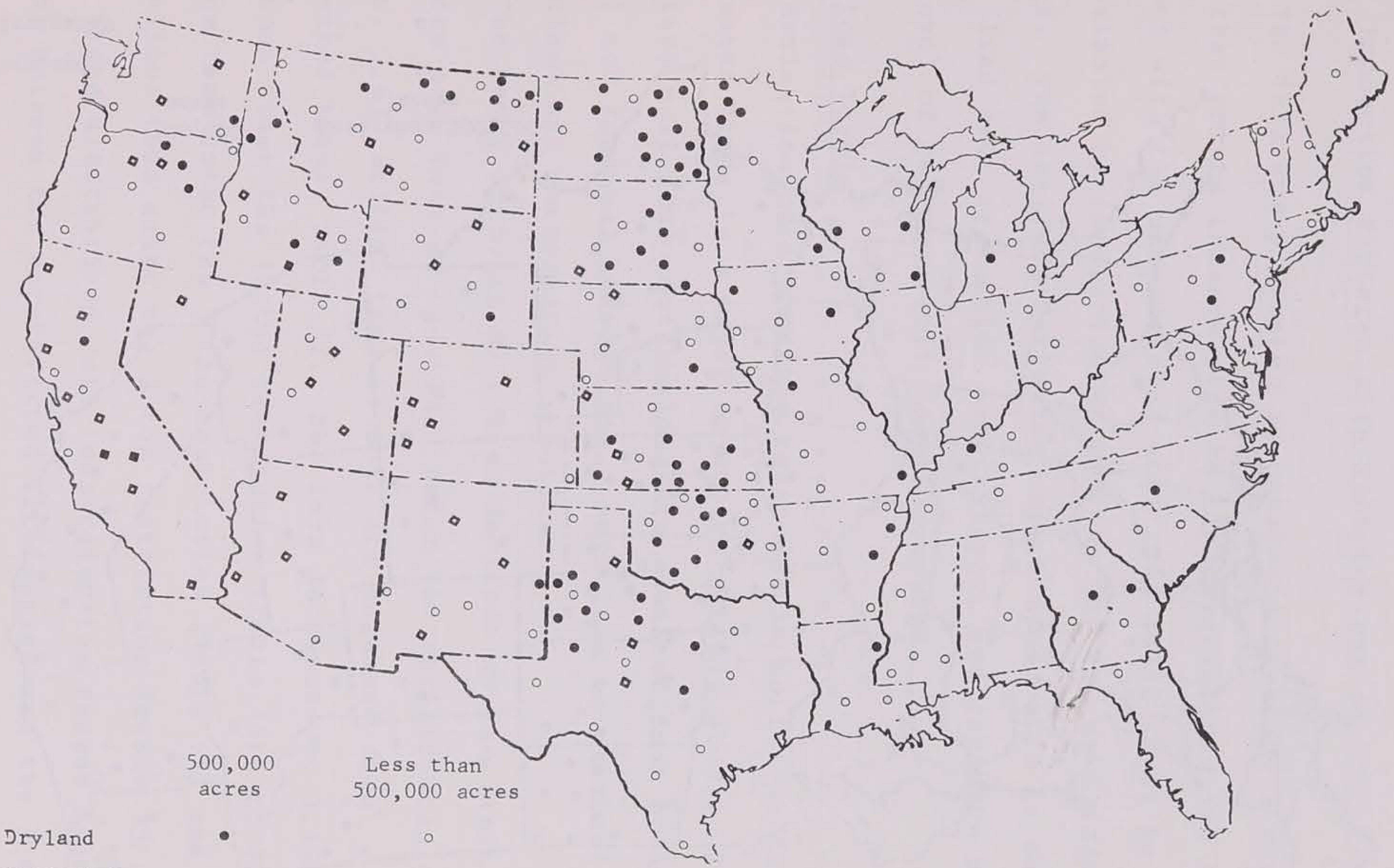


Figure 10. Location of dryland and irrigated close-grown crops in 2000 under no soil loss restriction and average level exports

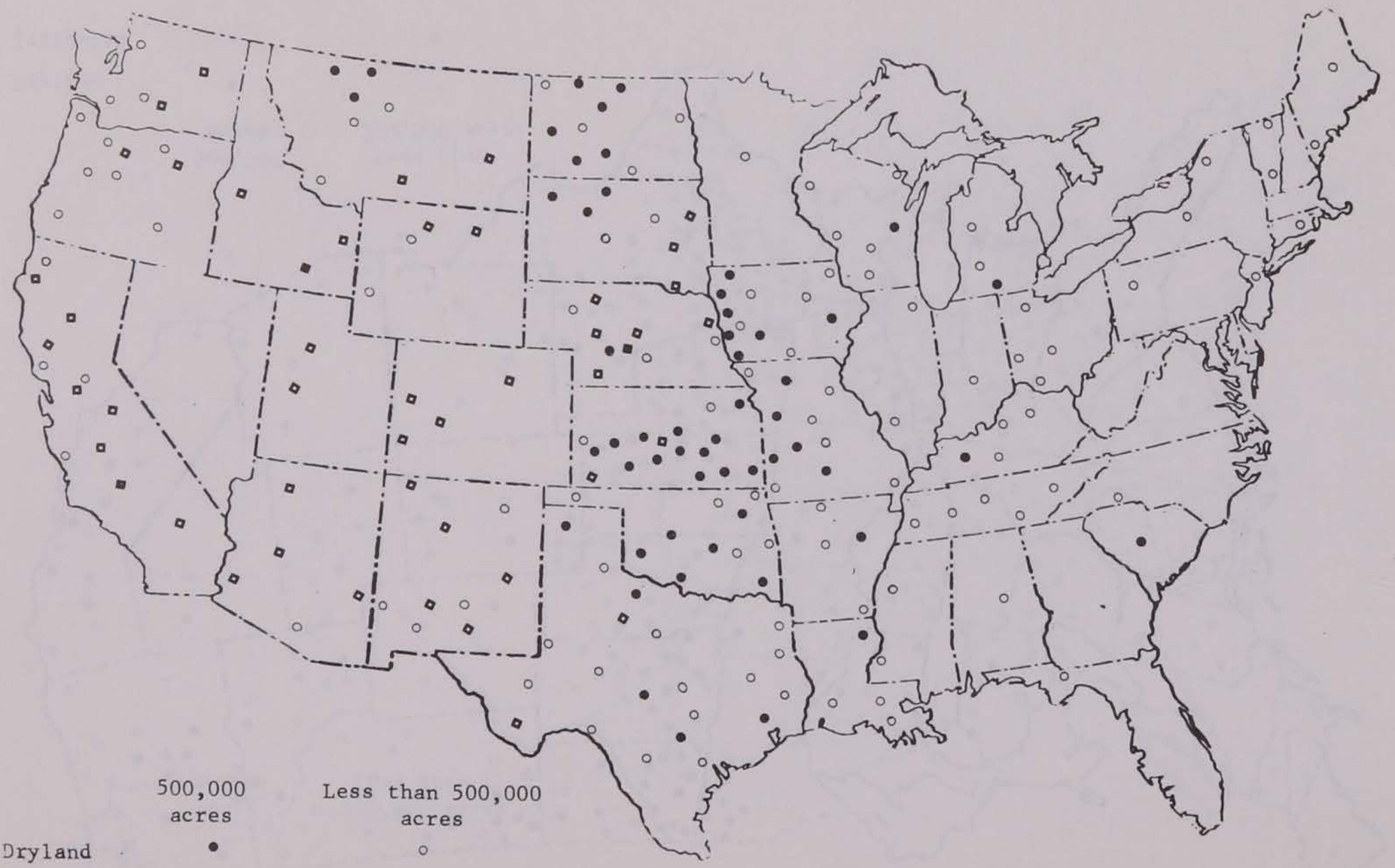


Figure 11. Location of dryland and irrigated hay in 2000 under no soil loss restriction and 69-71 average level exports

Production Patterns with Restrictions on Soil Loss

The data are presented as observations along a continuum such that points intermediate to the observations and in comparison with the unrestricted soil loss model might be approximated by interpolation between the two most adjacent points. The analysis following covers trade-offs in soil loss, land use, production alternatives, and resource use as the level of per acre soil loss is reduced.

Soil loss levels

Evaluation of a possible reduction in soil loss from cultivated lands is a major objective of this study. The alternative soil loss restrictions are examined from both national and regional standpoints. Soil loss is examined by soil class and conservation practice.

The level of total soil loss declines as the limit on per acre soil loss is reduced. Under the unrestricted alternative, 2,677 million tons of soil are released from cultivated lands, Table 12. The loss decreases to 1,132 million tons under the 10 ton restriction (Table 13), to 726 million tons under the 5 ton restriction (Table 14) and to 438 million tons under the 3 ton restriction (Table 15). Among these alternatives, soil loss reduction ranges from 92 percent between the unrestricted alternative and the 3 ton

Table 12. Total soil erosion on cultivated lands in major zones with unlimited soil loss and average level exports in 2000 (Model A)[a/]

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(million tons)				
United States	1100	1073	491	13	2677
North Atlantic	35	11	---	--	46
South Atlantic	168	81	21	--	270
North Central	521	479	86	--	1086
South Central	285	413	376	13	1087
Great Plains	64	52	5	--	121
North West	6	18	2	--	26
South West	21	19	1	--	41

[a/] For all cultivated crops including rotation hay.

Table 13. Total soil erosion on cultivated lands in major zones with 10 maximum soil loss and average level exports in 2000 (Model B)[a/]

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(million tons)				
United States	720	277	135	---	1132
North Atlantic	22	---	---	---	22
South Atlantic	60	5	5	---	70
North Central	389	80	31	---	500
South Central	169	126	91	---	386
Great Plains	52	36	5	---	93
North West	6	11	2	---	19
South West	22	19	1	---	42

[a/] For all cultivated crops including rotation hay.

Table 14. Total soil erosion on cultivated lands in major zones with 5 ton maximum soil loss and average level exports in 2000 (Model C)[a/]

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(million tons)				
United States	474	161	91	0	726
North Atlantic	20	2	1	0	23
South Atlantic	28	3	3	0	34
North Central	257	44	19	0	320
South Central	114	65	59	0	238
Great Plains	33	18	2	0	53
North West	7	11	2	0	20
South West	15	18	5	0	38

[a/]For all cultivated crops including rotation hay.

Table 15. Total soil erosion on cultivated lands in major zones with 3 ton maximum soil loss and average level exports in 2000 (Model D)[a/]

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(million tons)				
United States	336	111	36	0	483
North Atlantic	11	10	0	0	21
South Atlantic	17	1	1	0	19
North Central	189	36	16	0	241
South Central	71	43	13	0	127
Great Plains	33	16	3	0	52
North West	6	6	2	0	14
South West	9	9	1	0	19

[a/]For all cultivated crops including rotation hay.

restriction to 36 percent between the 10 ton restriction and the 5 ton restriction.

The data in Tables 12, 13, 14 and 15 indicate the total soil loss by the 7 regions in the nation for the alternative restriction levels. Under the unrestricted alternative, Table 12, the North Central and South Central regions have the largest erosion levels and account for 81 percent of total national erosion. Compared to the unrestricted soil loss alternative, erosion reduces to 78 percent under the 10 ton restriction, Table 13, to 77 percent under the 5 ton restriction, Table 14, and to 76 percent under the 3 ton restriction, Table 15. The South Atlantic region accounts for 10 percent of the national soil loss under the unrestricted alternative and is reduced to only 4 percent under the 3 ton restriction. The Great Plains area is "offsetting" in soil loss and accounts for less than 5 percent of the national total under the unrestricted alternative and 11 percent under the 3 ton restriction. Even though the class I and II lands have low susceptibility to erosion, they make the largest contribution to total erosion in all models and all regions, except for the South Central zone under the unrestricted alternative.

On a per acre basis at the national level, soil loss decreases from 9.9 tons under the unrestricted alternative to 4.3 tons under the 10 ton restriction, 2.8 tons under the 5

ton restriction and 1.9 tons under the 3 ton restriction, Table 16. These national levels do not fall exactly at the upper limit if allowed soil loss for several reasons. As the soil loss limit is set at 5 ton for example, and enforced for some regions, the national average is less because level areas such as the Great Plains already have lower levels. Also, when a soil loss limit is imposed the most economical method of obtaining the required reduction may reduce soil loss to a level below the restriction. The per acre soil loss varies from 21.5 tons in the South Atlantic under the unrestricted alternative to 1.2 tons in the Great Plains and Northwest zones under the 3 ton restriction, Table 16. Under the unrestricted alternative, the per acre soil loss is above the national average in both the South Atlantic and South Central zones. The limitations on soil loss affect the per acre soil loss in each region to a different degree. However, the initial restriction to 10 tons results in large declines in the majority of zones as the excessively erosive alternatives are eliminated. The reduction in the South Atlantic region, from the unrestricted alternative to the 10 ton restriction, is 15.1 tons per acre or by 70 percent. Other zones with large declines include the South Central with a 9.5 ton or 63 percent decline, the North Central with a 5.1 ton or 57 percent decline and the North Atlantic with a 4.9 ton or 53 percent decline. The other zones had average

Table 16. Average per acre soil loss by region for alternative soil loss restrictions in 2000

Region	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(tons per acre)			
National	9.9	4.3	2.8	1.9
North Atlantic	9.0	4.9	3.5	2.9
South Atlantic	21.5	6.4	3.3	2.2
North Central	9.2	4.3	2.8	2.0
South Central	15.1	5.6	3.6	2.2
Great Plains	3.2	1.7	1.5	1.2
North West	2.3	1.7	1.7	1.2
South West	3.3	3.3	2.6	1.6

Table 17. National average per acre soil loss by land class for alternative soil loss restrictions in 2000

Region	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(tons per acre)			
Average	9.9	4.3	2.8	1.9
Class I & II	6.2	4.1	2.7	1.9
Class IIIE & IVE	17.8	5.1	3.1	2.0
Other III & IV	15.6	4.4	2.8	1.5
Class V-VIII	28.5	1.8	1.5	1.5

soil loss levels well below even the 10 ton limit and the declines were of less than 50 percent. This low level of soil loss for the more arid Western zones is consistent with their low annual runoff rates. The per acre declines from the 10 ton restriction to the 5 ton restriction are consistently less than the 50 percent reduction for the Western zones. Their actual levels are closer to the 5 ton restriction level than to the 10 ton restriction.

The data in Table 17 indicate the per acre soil loss by land class under the alternative soil loss restrictions. These data suggest the relative erosiveness of the alternative land classes and their response to the soil loss limitations. The class I and II lands have the lowest per acre rate of soil loss under the unrestricted alternative even though, due to their large acreage, they have the greatest loss in total tonnage. The U.S. per acre soil loss from land class group V-VIII declines immediately, upon the implementation of a restriction on soil loss, from 28.5 tons per acre under the unrestricted alternative to less than 2 tons per acre. This drastic reduction in per acre soil loss, when compared to the other land classes, indicates that if a restriction is imposed at the 10 ton or less level, the conservation practices required to maintain use of the lands are also consistent with a soil loss level approaching the natural rate. After land group V-VIII, the IIIE and IVE soil

class group is the most erosive, Table 17. This is consistent with the "E" subcode of their classification which indicates erosion as the most serious limitation to production under the production possibilities consistent with class III and IV lands.

Regionally, the most erosive lands under the unrestricted model are the IIIE and IVE lands in the South Atlantic zone with an annual average soil loss of 10.6 tons per acre, Table 18. The more erosive class V-VIII lands in this region are not brought into agricultural production. The next most erosive lands are the V-VIII lands in the South Central zone with 47.6 tons of soil loss per acre. As the restriction on soil loss is imposed, the more erosive V-VIII lands either drop to low levels of erosion or go out of production while the lands in the IIIE and IVE group have soil losses nearer the limit than any of the other lands, Tables 18, 19, 20 and 21. Reducing the soil loss restriction to 3 tons causes most regions and soil groups to drop erosion rates to between 1 and 3 tons or to drop out of the cultivated land base.

Conservation-tillage practices are important in controlling the per acre soil loss. The soil loss by these practices varies as the production shifts to the most economical practices capable of giving the restrained level of control. The data in Table 22 indicates that under the unrestricted soil loss alternative, straight row tillage practices have

Table 18. Per acre soil erosion on vultivated lands in major zones with unlimited soil loss and average level exports in 2000 (Model A)

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Average
	(tons per acre)				
United States	6.2	17.8	15.6	28.5	9.9
North Atlantic	7.8	18.0	0	0	9.0
South Atlantic	16.5	60.6	20.4	0	21.5
North Central	5.6	29.2	11.0	0	9.2
South Central	8.1	18.8	26.2	47.6	15.1
Great Plains	2.8	2.4	1.2	0	3.2
North West	1.5	4.0	0.8	6.9	2.3
South West	3.4	3.9	0.6	1.7	3.3

Table 19. Per acre soil erosion on cultivated lands in major zones with 10 ton maximum soil loss and average level exports in 2000 (Model B)

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Average
	(tons per acre)				
United States	4.1	5.1	4.4	1.8	4.3
North Atlantic	4.9	9.1	2.8	0	4.9
South Atlantic	6.2	8.7	6.1	0	6.4
North Central	4.2	5.6	4.2	0	4.3
South Central	4.8	6.4	6.4	2.1	5.6
Great Plains	2.3	3.3	1.2	0	1.7
North West	1.5	2.6	0.8	2.5	1.7
South West	3.4	3.9	0.6	1.7	3.3

Table 20. Per acre soil erosion on cultivated lands in major zones with 5 ton maximum soil loss and average level exports in 2000 (Model C)

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(tons per acre)				
United States	2.7	3.1	2.8	1.5	2.8
North Atlantic	3.5	4.4	2.5	0	3.5
South Atlantic	3.3	3.7	3.4	0	3.3
North Central	2.7	3.4	2.6	0	2.8
South Central	3.2	4.0	4.2	1.2	3.6
Great Plains	1.5	1.8	0.5	0	1.5
North West	1.6	2.1	0.9	2.1	1.7
South West	2.3	2.0	0.7	1.7	2.6

Table 21. Per acre soil erosion on cultivated lands in major zones with 3 ton maximum soil loss and average level exports in 2000 (Model D)

Zone	Land Class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(tons per acre)				
United States	1.9	2.0	1.5	1.5	1.9
North Atlantic	2.0	1.7	2.2	0	2.0
South Atlantic	2.2	2.5	2.1	0	2.2
North Central	2.0	2.3	1.7	0	2.0
South Central	2.1	2.4	2.2	1.3	2.2
Great Plains	1.3	1.3	0.7	0	1.2
North West	1.4	1.3	0.8	0.7	1.2
South West	1.4	2.2	0.6	1.6	1.6

Table 22. Per acre soil loss by conservation-tillage practice for alternative soil loss restrictions in 2000

Conservation tillage	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(tons per acre)			
Conventional tillage				
straight row	10.9	3.4	2.5	1.4
contoured	0.8	4.8	3.1	2.1
strip cropped or terraced	0.3	5.7	3.3	2.0
Reduced tillage				
straight row	5.3	4.7	2.7	1.9
contoured	0.0	5.6	3.7	2.4
strip cropped or terraced	0.0	7.4	2.9	2.5

Table 23. National production of row crops, close-grown crops, rotation roughage crops and permanent roughage crops under alternative soil restriction levels in 2000

Land use	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(000 acres)			
Acres cultivated	269113	261564	258882	258058
row crops	148226	141415	136035	134440
close-grown crops	75535	74309	73478	72813
rotation roughage crops	45352	45840	49369	50805
Permanent roughage crops	339360	341764	346640	351207
Summer fallow and exogenous crops	9306	8471	7788	8801
Total agricultural lands	617779	611799	613310	618066

the highest soil losses while the conservation practices have insignificant soil losses, Tables 18, 19, 20 and 21. Only the less-erosive lands, continue to be farmed under straight row practices. The erosive lands incorporate the conservation practices and reduce average soil loss including level lands under straight row methods. The soil loss control methods result in per acre soil losses on erosive soils which are nearer the associated restriction level than for nonerosive lands still farmed under straight row techniques, Table 22.

An upper limit imposed on per acre soil loss can be used as a mechanism to reduce total soil loss by region and by land groups. The changes vary by region with the South Central, South Atlantic and North Central zones showing the largest reduction in soil loss especially on the more erosive land groups. Thus, given a societal welfare function desiring a lower soil loss, a position can be chosen along the continuum of soil loss possibilities which is capable of reducing the levels of sheet and rill erosion from cultivated lands. The location and method of production are affected by the soil loss restriction level imposed and are considered in the following section.

Land use and agricultural production patterns

As upper limits on allowable soil loss are reduced, some shifts in land use and cropping patterns must occur as land is shifted to less erosive rotations and highly erosive lands are shifted from the cropland base. For the purposes of comparing the cropping patterns and land use, the endogenously allocated crops are categorized into three groups. The row crops category represents corn, sorghum, cotton, soybeans and sugar beets; the close-grown crops category represents barley, oats and wheat; and the roughage or sod crops category includes the hay crops grown on cultivated lands. As the cropping patterns change an adjustment in livestock rations also occurs and provides for additional flexibility in the agricultural sector.

The national levels of production for each of the crop categories and permanent pasture are given in Table 23. The total acres cultivated declines as the level of allowable soil loss is reduced. The agricultural sector utilized 269 million acres of cultivated cropland and 339 million acres of permanent hay or pasture land to meet the predetermined demands with no soil loss restriction. As the soil loss restriction becomes more severe, the cultivated acreage declines and the acres of permanent hay and pasture increase. The initial restriction to 10 tons per acre reduces the total

cultivated land base by 6 million acres. As the soil loss restriction level is reduced more, the permanent roughage crops are utilized, offsetting the declining cultivated land base such that at the 3 ton restriction level the agricultural sector is utilizing approximately the same total acreage as under the unrestricted soil loss alternative.

Row crops are located on 55 percent of all cultivated land under the unrestricted alternative and decline to 52 percent of all cultivated lands under the 3 ton restriction. The relative decline by row crops in proportion of all cultivated crops is offset by a proportionate increase in rotation roughage crops. But, not all of the production lost from the reduced acreage is replaced by the roughage crops.

The data in Table 24 indicate the acres of cultivated land by conservation-tillage practice. The unrestricted alternative allocates 87 percent of the cultivated lands to conventional tillage-straight row farming methods. This percentage declines to 63 under the 10 ton restriction, to 50 under the 5 ton restriction, and to 36 under the 3 ton restriction. The lands which are no longer under the conventional tillage-straight row method switch to the contouring, strip cropping and terracing alternatives of the conventional tillage method and also to the alternatives within the reduced tillage method. All production alternatives within reduced tillage increase by only 54 million acres compared to

the non-straight row options of conventional tillage which increase by 74 million acres, Table 25.

Table 24. Acreages of cultivated land by conservation-tillage practices for alternative soil loss restrictions in 2000

Conservation tillage	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(000 acres)			
Conventional tillage	247894	217319	201238	182585
straight row	233475	165305	129120	93838
contoured	11254	32553	37116	44986
strip cropped	3165	19461	35002	43761
Reduced tillage	21219	44245	57644	75573
straight row	21219	27092	24822	32281
contoured	0	13830	18902	19955
strip cropped	0	3323	13920	23337

Regionally, the change in acreage under conventional tillage and reduced tillage does not follow a set pattern but varies with the level of runoff in the particular area. The North Atlantic, Great Plains, North West and South West zones have almost an equal distribution of lands cultivated under both tillage alternatives for all levels of soil loss restriction, Tables 25, 26, 27 and 28. Also the distribution among the conservation practices and land classes is not identical for all zones under all soil loss restriction levels. In each region conventional-tillage switches to the contouring and strip cropping-terracing alternatives, but to

Table 25. Acreages under conservation practices in major zones with unlimited soil loss and 69-71 average exports in 2000 (Model A)[a/]

Zone and soil class	Conventional tillage			Reduced tillage		
	Str. row	Contour only	S. crop terrace	Str. row	Contour only	S. crop terrace
	(000 acres)					
United States	233475	11254	3165	21219	0	0
I,II	145433	11039	2989	17318	0	0
IIIE,IVE	57404	0	175	2774	0	0
Other III,IV	30155	216	0	1128	0	0
V-VIII	484	0	0	0	0	0
North Atlantic	4074	0	0	1010	0	0
I,II	3510	0	0	977	0	0
IIIE,IVE	565	0	0	33	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	12549	0	0	0	0	0
I,II	10172	0	0	0	0	0
IIIE,IVE	1330	0	0	0	0	0
Other III,IV	1047	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	88210	10431	0	19260	0	0
I,II	67700	10431	0	15515	0	0
IIIE,IVE	13703	0	0	2707	0	0
Other III,IV	6807	0	0	1039	0	0
V-VIII	0	0	0	0	0	0
South Central	71261	0	0	550	0	0
I,II	34757	0	0	427	0	0
IIIE,IVE	21961	0	0	34	0	0
Other III,IV	14264	0	0	89	0	0
V-VIII	280	0	0	0	0	0
Great Plains	33633	527	3165	399	0	0
I,II	18856	527	2989	399	0	0
IIIE,IVE	10647	0	175	0	0	0
Other III,IV	4130	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North West	11166	296	0	0	0	0
I,II	4172	80	0	0	0	0
IIIE,IVE	4426	0	0	0	0	0
Other III,IV	2543	216	0	0	0	0
V-VIII	26	0	0	0	0	0
South West	12581	0	0	0	0	0
I,II	6267	0	0	0	0	0
IIIE,IVE	4772	0	0	0	0	0
Other III,IV	1364	0	0	0	0	0
V-VIII	178	0	0	0	0	0

[a/] For all cultivated crops including rotation hay.

Table 26. Acreages under conservation practices in major zones with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)[a/]

Zone and soil class	Conventional tillage			Reduced tillage		
	Str. row	Contour only	S. crop terrace	Str. row	Contour only	S. crop terrace
	(000 acres)					
United States	165305	32553	19461	27092	13830	3323
I,II	111950	22182	8339	22091	11344	22
IIIE,IVE	36591	3862	8324	3677	926	1289
Other III,IV	16527	6509	2799	1325	1560	2012
V-VIII	237	0	0	0	0	0
North Atlantic	2564	133	644	1208	0	16
I,II	2485	133	644	1195	0	0
IIIE,IVE	14	0	0	0	0	16
Other III,IV	65	0	0	14	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	4696	1802	4343	191	0	0
I,II	4567	1148	3655	191	0	0
IIIE,IVE	78	475	0	0	0	0
Other III,IV	51	178	688	0	0	0
V-VIII	0	0	0	0	0	0
North Central	61984	13222	3519	22209	13277	1147
I,II	51773	12751	0	18255	10977	0
IIIE,IVE	5970	0	3519	2916	740	1049
Other III,IV	4241	471	0	1039	1560	98
V-VIII	0	0	0	0	0	0
South Central	41139	14247	8227	2875	553	2159
I,II	24886	5901	2057	1868	366	22
IIIE,IVE	11876	2702	4059	761	186	223
Other III,IV	4334	5644	2110	246	0	1914
V-VIII	43	0	0	0	0	0
Great Plains	31194	2853	2728	609	0	0
I,II	17801	2168	1983	582	0	0
IIIE,IVE	9470	684	745	0	0	0
Other III,IV	3923	0	0	26	0	0
V-VIII	0	0	0	0	0	0
North West	11163	296	0	0	0	0
I,II	4173	80	0	0	0	0
IIIE,IVE	4426	0	0	0	0	0
Other III,IV	2549	216	0	0	0	0
V-VIII	16	0	0	0	0	0
South West	12565	0	0	0	0	0
I,II	6265	0	0	0	0	0
IIIE,IVE	4758	0	0	0	0	0
Other III,IV	1364	0	0	0	0	0
V-VIII	178	0	0	0	0	0

[a/] For all cultivated crops including rotation hay.

Table 27. Acreages under conservation practices in major zones with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)[a/]

Zone and soil class	Conventional tillage			Reduced tillage		
	Str. row	Contour only	S. crop terrace	Str. row	Contour only	S. crop terrace
	(000 acres)					
United States	129120	37116	35002	24822	18902	13920
I,II	84478	27873	17769	19998	15962	9279
IIIE,IVE	27577	8450	5681	3648	2851	3073
Other III,IV	16836	793	11552	1176	89	1568
V-VIII	228	0	0	0	0	0
North Atlantic	2489	1370	2516	38	267	8
I,II	2066	1365	2043	24	267	0
IIIE,IVE	66	5	473	0	0	0
Other III,IV	358	0	0	14	0	8
V-VIII	0	0	0	0	0	0
South Atlantic	3261	2845	2583	448	200	918
I,II	2964	2552	1615	367	200	918
IIIE,IVE	246	0	475	0	0	0
Other III,IV	51	294	493	80	0	0
V-VIII	0	0	0	0	0	0
North Central	45299	16415	4744	21373	14650	11859
I,II	36713	16266	3860	17136	12373	7680
IIIE,IVE	4883	149	0	3155	2277	2618
Other III,IV	3703	0	884	1082	0	1560
V-VIII	0	0	0	0	0	0
South Central	27447	11998	20068	1709	3785	1135
I,II	17510	5492	7042	1220	3122	680
IIIE,IVE	5894	6007	2932	489	574	455
Other III,IV	3926	499	10094	0	89	0
V-VIII	117	0	0	0	0	0
Great Plains	27330	2757	4025	1255	0	0
I,II	14787	2184	3209	1251	0	0
IIIE,IVE	8673	573	735	4	0	0
Other III,IV	3869	0	82	0	0	0
V-VIII	0	0	0	0	0	0
North West	9028	1509	1066	0	0	0
I,II	4189	0	0	0	0	0
IIIE,IVE	2642	1509	1066	0	0	0
Other III,IV	2178	0	0	0	0	0
V-VIII	19	0	0	0	0	0
South West	14266	221	0	0	0	0
I,II	6249	13	0	0	0	0
IIIE,IVE	5173	207	0	0	0	0
Other III,IV	2752	0	0	0	0	0
V-VIII	93	0	0	0	0	0

[a/]For all cultivated crops including rotation hay.

Table 28. Acreages under conservation practices in major zones with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)[a/]

Zone and soil class	Conventional tillage			Reduced tillage		
	Str. row	Contour only	S. crop terrace	Str. row	Contour only	S. crop terrace
	(000 acres)					
United States	93838	44986	43761	32281	19955	23337
I,II	62184	30709	28647	23994	12977	19265
IIIE,IVE	19735	10407	12865	6763	4480	940
Other III,IV	11720	3866	2249	1523	2498	3132
V-VIII	199	3	0	0	0	0
North Atlantic	2021	441	1673	14	92	1196
I,II	1904	401	1673	14	79	1196
IIIE,IVE	40	0	0	0	0	0
Other III,IV	78	40	0	0	14	0
V-VIII	0	0	0	0	0	0
South Atlantic	1746	1533	2939	1271	693	344
I,II	1610	1482	2482	1271	691	244
IIIE,IVE	72	0	198	0	2	0
Other III,IV	64	51	259	0	0	100
V-VIII	0	0	0	0	0	0
North Central	32559	17103	9227	26880	14973	19184
I,II	27092	14195	7201	20554	9658	16388
IIIE,IVE	3380	2575	1065	4805	2843	837
Other III,IV	2087	332	961	1521	2473	1959
V-VIII	0	0	0	0	0	0
South Central	12277	18183	17729	2791	3998	2613
I,II	9482	9961	9216	1164	2351	1437
IIIE,IVE	1787	4992	7804	1627	1635	103
Other III,IV	972	3227	709	0	12	1074
V-VIII	36	3	0	0	0	0
Great Plains	28413	1498	11569	706	199	0
I,II	15003	1368	8074	703	199	0
IIIE,IVE	9010	130	3175	0	0	0
Other III,IV	4400	0	320	3	0	0
V-VIII	0	0	0	0	0	0
North West	10952	712	624	0	0	0
I,II	4178	80	0	0	0	0
IIIE,IVE	3997	416	624	0	0	0
Other III,IV	2765	216	0	0	0	0
V-VIII	12	0	0	0	0	0
South West	5869	5517	0	618	0	0
I,II	2915	3222	0	287	0	0
IIIE,IVE	1449	2294	0	331	0	0
Other III,IV	1355	0	0	0	0	0
V-VIII	151	0	0	0	0	0

[a/] For all cultivated crops including rotation hay.

varying degrees depending on the erosive characteristics of the land in the region. The South Central and South Atlantic zones have a shift to reduced tillage and also experience a decline in the total acreage used under any type of cultivation. The South Atlantic has over 12 million acres of cropped land under the unrestricted soil loss alternative but only 8.5 million acres under the 3 ton restriction. Acreage cultivated in the South Central region also declines to 57.5 million acres under the 3 ton restriction. The North Central zone has a major shift in production pattern and acreage under reduced tillage increases from 19 million acres to over 61 million acres, a change almost directly offsetting the decline in the conventional tillage practices.

The data in Tables 25, 26, 27 and 28 also indicate the impact of soil restrictions on alternative land groups. Shifts in farming practices on the more erosive lands are relatively large. In most regions, especially high rainfall areas, little land is farmed under conventional tillage-straight row relative to the concentrations indicated with the unrestricted alternatives. Nationally, 42 percent of the cultivated acres which were originally in conventional tillage-straight row usage continue to be farmed under this method under the 3 ton soil loss alternative. This compares to 34 percent for the IIIE and IVE land group, 39 percent for the other III and IV group and 41 percent for the V-VIII

lands. The V-VIII lands under conventional tillage-straight row are concentrated in the South West and shifts in tillage practices on these lands occurs in the other zones but the acreages are small and the South West zone dominates the total acreage in this land group.

Shifts in irrigated and dryland acreages

Associated with shifts in conservation-tillage method are (a) shifts among regions of the production base, (b) shifts between the land classes, and (c) possible shifts among irrigated and rainfed agriculture. As the soil loss restriction is reduced, a reduction occurs in acreages of both row crop and close-grown crops. An increase occurs in both cultivated and permanent roughage crops, Table 23. As indicated in the section comparing the unrestricted model to 1967 production patterns, there is a shift in production to the North Central and South Central zones. The data in Tables 9, 29, 30 and 31 indicate the regional dryland production patterns and the relative use of the alternative land groups by regions.

Row crop production concentrates in the North Central zone under all alternatives with only a 2 million acre reduction between the unrestricted alternative and the 3 ton restriction. The zone experiencing the largest shift in row crop production is the South Central. Its row crop acreage declines from 27.5 million acres under no soil loss restric-

Table 29. Dryland acreages in major zones with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	132636	68911	67289	304614	6852	580302
I,II	101795	38804	27989	0	2021	170609
IIIE,IVE	15890	20701	16217	0	1388	54696
Other III,IV	14734	9227	6016	0	2702	32679
V-VIII	217	179	159	0	241	796
North Atlantic	3661	1225	1608	6888	295	13677
I,II	3286	1191	499	0	137	5113
IIIE,IVE	119	20	5	0	81	225
Other III,IV	241	11	0	0	45	297
V-VIII	15	3	0	0	32	50
South Atlantic	9647	2729	2006	23632	1605	39619
I,II	7516	2240	1218	0	229	11203
IIIE,IVE	636	123	47	0	70	876
Other III,IV	1411	363	0	0	1166	2940
V-VIII	84	3	0	0	140	227
North Central	87831	19117	17608	30304	215	155075
I,II	73086	16271	6746	0	70	96173
IIIE,IVE	7391	2244	4842	0	54	14531
Other III,IV	7328	584	112	0	70	8094
V-VIII	26	18	0	0	21	65
South Central	25503	19601	27248	111368	827	184547
I,II	14050	8806	11848	0	251	34955
IIIE,IVE	6143	6153	7498	0	221	20015
Other III,IV	5287	4593	4884	0	331	15095
V-VIII	23	49	0	0	24	96
Great Plains	3937	15370	14310	41477	3536	78630
I,II	2968	6898	6523	0	1242	17631
IIIE,IVE	781	6236	2310	0	1342	10669
Other III,IV	161	2179	84	0	952	3376
V-VIII	27	57	0	0	0	84
North West	335	6230	2994	24652	319	34530
I,II	77	1334	905	0	77	2393
IIIE,IVE	37	3424	499	0	97	4057
Other III,IV	207	1460	831	0	131	2629
V-VIII	14	12	16	0	14	56
South West	1722	4639	1515	66293	55	74224
I,II	812	2064	250	0	15	3141
IIIE,IVE	783	2501	1016	0	23	4323
Other III,IV	99	37	105	0	7	248
V-VIII	28	37	143	0	10	218

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

Table 30. Dryland acreages in major zones with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	128505	66732	72508	310699	6169	584613
I,II	100214	37178	31453	0	1601	170446
IIIE,IVE	14076	20292	15322	0	1733	51423
Other III,IV	13998	9070	8367	0	2594	34029
V-VIII	217	192	142	0	241	792
North Atlantic	4318	2491	2043	7098	295	16245
I,II	3745	1975	564	0	137	6421
IIIE,IVE	125	502	30	0	81	738
Other III,IV	433	11	109	0	45	598
V-VIII	15	3	0	0	32	50
South Atlantic	10065	870	2686	25222	1605	40448
I,II	7712	552	1764	0	229	10257
IIIE,IVE	687	123	165	0	70	1045
Other III,IV	1582	192	0	0	1166	2940
V-VIII	84	3	0	0	140	227
North Central	84706	18756	19965	33820	215	157462
I,II	70689	15854	9833	0	70	96446
IIIE,IVE	7250	1979	4139	0	54	13422
Other III,IV	6741	905	190	0	70	7906
V-VIII	26	18	0	0	21	65
South Central	23116	18773	27360	108031	637	177917
I,II	15119	8582	10690	0	206	34597
IIIE,IVE	4497	5487	6581	0	76	16641
Other III,IV	3477	4629	7019	0	331	15456
V-VIII	23	75	52	0	24	174
Great Plains	2708	14077	15495	41488	3043	76811
I,II	2431	6485	6988	0	807	16711
IIIE,IVE	178	5239	2864	0	1284	9565
Other III,IV	72	2296	132	0	952	3452
V-VIII	27	57	0	0	0	84
North West	418	6285	3207	27687	319	37916
I,II	160	1035	1058	0	137	2390
IIIE,IVE	37	4234	527	0	145	4943
Other III,IV	207	1000	812	0	23	2042
V-VIII	14	16	16	0	14	60
South West	3174	5480	1752	67353	55	77814
I,II	358	2695	556	0	15	3624
IIIE,IVE	1302	2728	1016	0	23	5069
Other III,IV	1486	37	105	0	7	1635
V-VIII	28	20	74	0	10	132

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

Table 31. Dryland acreages in major zones with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	127925	66828	72858	313854	7182	588647
I,II	102086	36623	33732	0	1795	174236
IIIE,IVE	11792	22163	18800	0	2444	55199
Other III,IV	13830	7864	2523	0	2702	26919
V-VIII	217	178	130	0	241	766
North Atlantic	3359	2089	2247	8315	295	16305
I,II	2937	2050	799	0	137	5923
IIIE,IVE	113	25	16	0	81	235
Other III,IV	294	11	0	0	45	350
V-VIII	15	3	0	0	32	50
South Atlantic	8549	736	2913	25615	1605	39418
I,II	6944	469	1780	0	229	9422
IIIE,IVE	353	123	50	0	70	596
Other III,IV	1168	141	21	0	1166	2496
V-VIII	84	3	0	0	140	227
North Central	88372	17652	23232	35810	215	165281
I,II	74427	12870	10311	0	70	97678
IIIE,IVE	5637	3355	6798	0	54	15844
Other III,IV	8282	1409	249	0	70	10010
V-VIII	26	18	0	0	21	65
South Central	19196	19241	23017	105322	861	167637
I,II	11762	9780	12066	0	285	33893
IIIE,IVE	3771	7113	7160	0	221	18265
Other III,IV	3640	2299	674	0	331	6944
V-VIII	23	49	0	0	24	96
Great Plains	4866	16720	16901	45113	3520	87120
I,II	4442	7741	7277	0	982	20442
IIIE,IVE	230	6425	3637	0	1586	11878
Other III,IV	167	2497	594	0	952	4210
V-VIII	27	57	0	0	0	84
North West	341	6419	3200	26826	531	37417
I,II	83	1321	911	0	77	2392
IIIE,IVE	37	3612	606	0	409	4664
Other III,IV	207	1470	880	0	131	2688
V-VIII	14	16	9	0	14	53
South West	3242	3971	1348	66853	55	75469
I,II	1491	2392	588	0	15	4486
IIIE,IVE	1651	1510	533	0	23	3717
Other III,IV	72	37	105	0	7	221
V-VIII	28	32	121	0	10	191

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

tion, to 25.5 million acres under the 10 ton restriction, to 23.1 million acres under the 5 ton restriction and to 19.2 million acres under the 3 ton restriction. The South Atlantic zone also experiences a decline in row crop acreage but the reduction is only 2 million acres over the range of the soil loss restrictions. To partially compensate for the reduced acreages in the South Central and South Atlantic zones, the Great Plains and South West zones have increased row crop production. The increase in row crops in the Great Plains is associated with an increase in total acreage cultivated since hay also increases in acreage. This is not the case in the South West where the increase of 1.6 million acres of row crops between the unrestricted and 3 ton restriction alternatives is accompanied by a reduction of 0.8 million acres in close-grown crops and 0.3 million acres of hayland.

In most zones the proportion of dryland row crops grown on classes I and II increases even though total crop acreage declines. The acreage of row crops on class V-VIII lands is almost negligible in all zones and changes do not occur. The acreage on the IIIE and IVE lands declines 47 percent nationally and the change in the production on this land group by zone is: -48 percent in the North Atlantic, -70 percent in the South Atlantic, -50 percent in the North Central, -53 percent in the South Central, -70 percent in the Great

Plains, no change in the North West and +110 percent in the South West where just over 1 million acres of this land group are shifted from close-grown crops to row crop production. Shifts in the use of the other III and IV land group are in the form of increased row crops except the South Central zone which has a reduction of 34 percent (1.8 million acres) in dryland row crops on this land group as the soil loss restriction is reduced to the 3 ton level, Tables 9 and 31.

The national production of close-grown crops on dryland declines as the soil loss restriction level is reduced but the total production change is not as great as for row crops. (Close-grown crop acreage under the 3 ton restriction is 96 percent of the unrestricted acreage, compared to 90 percent for row crops.) There is little change in the percentage of the close-grown crops in classes I and II lands as the soil loss restriction is reduced. Under all alternatives the national distribution has between 55 and 56 percent of the close-grown crops on the class I and II land group. Regionally, the concentration of close-grown crops on the less erosive class I and II lands under the 3 ton restriction, Table 31, varies as follows; the North Atlantic with 58 percent, the South Atlantic with 64 percent, the North Central with 73 percent, the South Central with 51 percent, the Great Plains with 46 percent, the North West with 71 percent and the South West with 60 percent. The zones with the lower

susceptibility to erosion (the Great Plains and North West) have the lowest proportion of the close-grown crops on the less erosive lands since their production patterns are more influenced by yield related factors in the row crop close-grown crop trade-off than by erosion control factors.

Irrigated acreage of row crops declines as the soil loss restriction level is reduced. The unrestricted alternative has 9.2 million acres of irrigated row crops, Table 10, and this declines to 8.8 million acres under the 10 ton restriction, Table 32, to 7.5 million acres under the 5 ton restriction, Table 33, and to 6.5 million acres under the 3 ton restriction, Table 34. Irrigated close-grown crops increase about 1.4 million acres under the 5 ton restriction from 5.3 million acres utilized under the less restrictive models. The irrigated acreage of close-grown crops declines to 6.0 million acres under a 3 ton restriction. Irrigated hay remains near the 12 million acre level for all alternative soil loss restrictions. Total acres irrigated vary only slightly from the 31 million acres under the unrestricted alternative, reaching a low of 28.7 million acres under the 5 ton restriction.

The South Central and South West regions experience declines in total irrigated acreage as the soil restriction is reduced, Tables 11, 32, 33 and 34; with most of the shifts being in the class I and II land group where the national de-

Table 32. Irrigated acreages in major zones with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)

Zone and soil class	Row	Close grown	All hay[a/]	Pasture	Other[b/]	Total
			(000 acres)			
United States	8779	5398	12780	2921	1619	31497
I,II	6787	2219	5400	0	948	15354
IIIE,IVE	1003	878	674	0	205	2760
Other III,IV	966	2297	610	0	444	4317
V-VIII	23	4	2	0	22	51
North Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	12	0	446	0	0	458
I,II	12	0	336	0	0	348
IIIE,IVE	0	0	1	0	0	1
Other III,IV	0	0	109	0	0	109
V-VIII	0	0	0	0	0	0
South Central	898	968	400	0	92	2358
I,II	724	584	256	0	91	1655
IIIE,IVE	70	92	119	0	1	282
Other III,IV	104	289	5	0	0	398
V-VIII	0	3	2	0	0	5
Great Plains	3080	1179	7075	472	8	11814
I,II	2471	636	2600	0	3	5710
IIIE,IVE	285	375	190	0	3	853
Other III,IV	318	168	380	0	2	868
V-VIII	6	0	0	0	0	6
North West	1399	1532	2637	2381	701	8650
I,II	918	615	1138	0	450	3121
IIIE,IVE	149	318	349	0	100	916
Other III,IV	319	598	103	0	140	1160
V-VIII	13	1	0	0	11	25
South West	3390	1719	2222	68	318	8217
I,II	2662	384	1070	0	404	4520
IIIE,IVE	499	93	15	0	101	708
Other III,IV	225	1242	13	0	302	1782
V-VIII	4	0	0	0	11	15

[a/] Including other hay and cropland pasture.
[b/] Summer fallow lands and orchards and vineyards.

Table 33. Irrigated acreages in major zones with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	7530	6746	12094	708	1619	28697
I,II	5971	3294	4735	0	948	14948
IIIE,IVE	606	1223	608	0	205	2642
Other III,IV	930	2227	647	0	444	4248
V-VIII	23	2	0	0	22	47
North Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	8	0	456	0	0	464
I,II	8	0	340	0	0	348
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	116	0	0	116
V-VIII	0	0	0	0	0	0
South Central	1189	947	362	0	92	2590
I,II	1038	588	260	0	91	1977
IIIE,IVE	47	69	79	0	1	196
Other III,IV	104	289	5	0	0	398
V-VIII	0	1	0	0	0	1
Great Plains	2885	1433	6948	511	8	11785
I,II	2301	822	2400	0	3	5526
IIIE,IVE	336	448	254	0	3	1041
Other III,IV	242	163	385	0	2	792
V-VIII	6	0	0	0	0	6
North West	1563	1466	2391	146	701	6267
I,II	1038	628	945	0	450	3061
IIIE,IVE	153	308	260	0	100	821
Other III,IV	359	529	132	0	140	1160
V-VIII	13	1	0	0	11	25
South West	1885	2900	1937	51	818	7591
I,II	1586	1256	790	0	404	4036
IIIE,IVE	70	398	15	0	101	584
Other III,IV	225	1246	9	0	302	1782
V-VIII	4	0	0	0	11	15

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

Table 34. Irrigated acreages in major zones with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	6515	5985	12716	2584	1619	29419
I,II	5056	2460	5108	0	948	13572
IIIE,IVE	582	1241	751	0	205	2779
Other III,IV	854	2282	757	0	444	4337
V-VIII	23	2	0	0	22	47
North Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	0	0	291	0	0	291
I,II	0	0	175	0	0	175
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	116	0	0	116
V-VIII	0	0	0	0	0	0
South Central	687	644	287	0	92	1710
I,II	622	309	200	0	91	1222
IIIE,IVE	57	47	67	0	1	172
Other III,IV	8	287	2	0	0	297
V-VIII	0	1	0	0	0	1
Great Plains	2038	1572	7874	466	8	11958
I,II	1487	959	3263	0	3	5712
IIIE,IVE	303	419	331	0	3	1056
Other III,IV	242	194	370	0	2	808
V-VIII	6	0	0	0	0	6
North West	1470	1487	2786	2046	701	8490
I,II	902	636	1139	0	450	3127
IIIE,IVE	176	312	333	0	100	921
Other III,IV	379	538	260	0	140	1317
V-VIII	13	1	0	0	11	25
South West	2320	2282	1478	72	818	6970
I,II	2045	556	331	0	404	3336
IIIE,IVE	46	463	20	0	101	630
Other III,IV	225	1263	9	0	302	1799
V-VIII	4	0	0	0	11	15

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

cline is 1.3 million acres. In the South Central region most of the decline in irrigated acres occurs in row crops on the more erosive lands. There is also a reduction of 0.2 million acres in close-grown crops. The South West has reductions of 1.0 million acres in irrigated row crops and 0.8 million acres of irrigated hay which is partially offset by an increase of 0.5 million acres of close-grown crops. The irrigated land in the IIIE and IVE land group switches from the production of row crops to the production of the less erosive close-grown crops.

Production shifts by land classes

Shifts in production patterns vary by crop type. The percent of the more erosive crops on the less erosive class I and II lands increases from 66.1 under the unrestricted soil loss alternative to 67.7 percent under the 10 ton restriction, to 68.2 percent under the 5 ton restriction and to 69.5 percent under the 3 ton restriction, Table 35. The shift to the less erosive lands for the individual crops is consistent with the relative susceptibility of the crops to erosion. The data in Table 35 indicates the percent of the acres of each crop which falls on the the class I and II lands for the alternative restriction levels. The more erosive crops such as cotton, soybeans and the silages undergo a large shift to the class I and II lands while the less erosive crops such as barley, wheat and nonlegume hay have a reduction in the per-

centage of their acres which are on the class I and II lands. The increase in the percentage of legume hay and oats on class I and II lands resulted as the rotations selected to adjust the soil loss limits for the more erosive crops favored the use of legume hay over the nonlegume hay due to the inclusion of the nitrogen carryover effect of the legume hay. The decline in the percentage of corn on the class I and II lands results from the larger acreage and the increase in acreage dividing equally on both land groups. Also, corn is less erosive than soybeans and cotton, and in those areas where they are competitive crops, corn shifts to allow production of soybeans and cotton on less erosive soils.

Table 35. Percent of the acreage of specific crops falling in land classes I and II for alternate levels of allowable soil loss in 2000

Crop	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
Barley	52.1	53.8	43.3	50.4
Corn	84.9	85.7	83.1	83.6
Corn silage	83.2	95.5	95.6	95.6
Cotton	57.6	61.1	77.0	80.4
Legume hay	64.1	59.8	59.3	68.2
Nonlegume hay	56.5	55.9	58.6	52.9
Oats	68.3	65.7	66.4	67.7
Sorghum	52.1	55.8	47.2	57.2
Sorghum silage	55.8	79.4	81.6	89.0
Soybeans	70.1	73.9	80.7	82.2
Wheat	53.6	55.3	57.0	52.7
All crops	66.1	67.7	68.2	69.5

Yield impacts

The shift in land class utilization by crops is reflected in the national average yields, Tables 36, 37, 38, and 39. The change in average yields also reflects changes in the proportion of the crop grown under irrigated and rainfed agriculture and the changes in regional allocation of the crops. As an example, the average yield of barley is 62.4 bushels under the no soil loss restriction alternative but declines to 58.5 bushels under the 3 ton soil loss restriction since a greater proportion is grown on dryland. A change in the proportion grown under irrigation is reflected in the acreages given in the same tables. These acreages combine with the changed yields, lower on dryland and higher on irrigated, to give a lower average yield. Shifts in yield by land class reflect changes in regional production patterns as the crop shifts from areas where the yields by land class change.

Silage data exhibit how alternative use of lands and regional shifts affect yields under various soil loss restrictions. The yield of corn silage increases from 12.9 tons under no soil loss restriction to 14.0 tons under a 10 ton soil loss restriction, drops to 13.1 under the 5 ton restriction and then increases again to 16.7 tons under the 3 ton restriction. The initial change from the unrestricted to the 10 ton soil loss level reflects mild yield increases on the dryland and irrigated acres, but the change in acreage under

Table 36. Acreage and average yield of crops by land class in the United States with unlimited soil loss and 69-71 average exports in 2000 (Model A)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Barley	(000 acres)			(bu./acre)		
I,II	5657	781	6438	70.0	81.0	71.3
IIIE,IVE	2599	206	2805	50.8	56.3	51.2
Other III,IV	1717	1390	3107	48.0	61.7	54.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	9973	2377	12350	61.2	67.6	62.4
Corn grain	(000 acres)			(bu./acre)		
I,II	44764	1540	46303	123.1	145.2	123.8
IIIE,IVE	4694	254	4948	101.1	94.9	100.8
Other III,IV	3192	87	3280	86.8	95.9	87.0
V-VIII	0	0	0	0.0	0.0	0.0
Total	52650	1881	54531	118.9	136.1	119.5
Corn silage	(000 acres)			(tons/acre)		
I,II	4704	658	5362	13.0	18.7	13.7
IIIE,IVE	662	69	731	8.5	16.0	9.2
Other III,IV	308	40	348	6.6	13.0	7.3
V-VIII	0	0	0	0.0	0.0	0.0
Total	5674	768	6441	12.1	18.2	12.9
Cotton	(000 acres)			(bales/acre)		
I,II	3312	370	3682	1.7	1.5	1.7
IIIE,IVE	1035	76	1111	1.4	0.9	1.3
Other III,IV	1590	3	1594	1.5	0.9	1.5
V-VIII	3	0	3	0.3	0.0	0.3
Total	5940	449	6389	1.6	1.4	1.6
Legume hay	(000 acres)			(tons/acre)		
I,II	18744	4796	23539	3.8	7.4	4.6
IIIE,IVE	7342	514	7857	3.2	4.0	3.2
Other III,IV	4750	509	5259	3.5	4.9	3.6
V-VIII	62	0	62	2.2	0.0	2.2
Total	30898	5819	36717	3.6	6.9	4.1
Nonlegume hay	(000 acres)			(tons/acre)		
I,II	10454	313	10766	2.3	2.8	2.3
IIIE,IVE	6565	83	6648	2.2	2.1	2.2
Other III,IV	1248	90	1338	2.1	1.3	2.1
V-VIII	284	2	286	1.3	2.0	1.3
Total	18551	488	19039	2.2	2.4	2.2

Table 36. (Continued)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Oats	(000 acres)			(bu./acre)		
I,II	3621	225	3846	71.6	91.8	72.8
IIIE,IVE	1433	15	1448	49.1	51.6	49.1
Other III,IV	252	22	274	63.9	70.8	64.5
V-VIII	66	0	66	17.3	0.0	17.3
Total	5373	261	5634	64.6	87.8	65.7
Sorghum grain	(000 acres)			(bu./acre)		
I,II	4030	1260	5290	63.2	72.7	65.5
IIIE,IVE	2509	388	2896	45.5	67.9	48.5
Other III,IV	1904	69	1973	40.7	60.9	41.4
V-VIII	0	0	0	0.0	0.0	0.0
Total	8443	1717	10160	52.9	71.2	56.0
Sorghum silage	(000 acres)			(tons/acre)		
I,II	3597	580	4178	12.3	18.2	13.1
IIIE,IVE	2941	56	2998	10.8	9.4	10.8
Other III,IV	263	50	313	10.3	10.1	10.3
V-VIII	0	0	0	0.0	0.0	0.0
Total	6802	687	7489	11.5	16.9	12.0
Soybeans	(000 acres)			(bu./acre)		
I,II	34963	641	35604	42.0	50.6	42.1
IIIE,IVE	9239	140	9379	36.7	41.5	36.8
Other III,IV	5759	25	5783	34.2	45.8	34.2
V-VIII	0	0	0	0.0	0.0	0.0
Total	49961	806	50766	40.1	48.9	40.2
Sugar beets	(000 acres)			(tons/acre)		
I,II	1365	158	1522	17.4	24.9	18.2
IIIE,IVE	0	17	17	0.0	18.4	18.4
Other III,IV	101	41	142	21.4	19.3	20.8
V-VIII	0	0	0	0.0	0.0	0.0
Total	1465	216	1681	17.6	23.4	18.4
Wheat	(000 acres)			(bu./acre)		
I,II	27411	889	28300	36.9	77.1	38.2
IIIE,IVE	17107	611	17719	32.8	50.3	33.4
Other III,IV	6449	274	6723	35.0	54.1	35.8
V-VIII	65	2	66	17.3	26.6	17.6
Total	51032	1776	52808	35.3	64.3	36.2
Other hay	(000 acres)			(tons/acre)		
Total	16884	6094	22978	1.7	3.6	2.2
Pasture	(000 acres)			(tons/acre)		
Total	303060	2921	305981	0.6	2.4	0.6

Table 37. Acreage and average yield of crops by land class in the United States with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Barley	(000 acres)			(bu./acre)		
I,II	6148	778	6926	66.9	81.1	68.5
IIIE,IVE	2527	208	2734	51.4	56.5	51.8
Other III,IV	1798	1404	3202	48.9	61.8	54.6
V-VIII	0	0	0	0.0	0.0	0.0
Total	10473	2389	12863	60.1	67.6	61.5
Corn grain	(000 acres)			(bu./acre)		
I,II	45034	1703	46737	124.1	143.4	124.8
IIIE,IVE	4143	139	4283	103.5	85.2	102.9
Other III,IV	3416	87	3503	86.3	95.9	86.5
V-VIII	0	0	0	0.0	0.0	0.0
Total	52593	1930	54523	120.0	137.1	120.6
Corn silage	(000 acres)			(tons/acre)		
I,II	4530	629	5158	13.4	18.8	14.1
IIIE,IVE	146	58	205	10.7	16.8	12.5
Other III,IV	0	40	40	0.0	13.0	13.0
V-VIII	0	0	0	0.0	0.0	0.0
Total	4676	728	5403	13.3	18.3	14.0
Cotton	(000 acres)			(bales/acre)		
I,II	3346	314	3660	1.7	1.7	1.7
IIIE,IVE	858	11	869	1.5	0.9	1.5
Other III,IV	1459	0	1459	1.7	0.0	1.7
V-VIII	0	0	0	0.0	0.0	0.0
Total	5663	325	5988	1.7	1.6	1.7
Legume hay	(000 acres)			(tons/acre)		
I,II	17773	5046	22819	3.8	7.3	4.6
IIIE,IVE	9525	590	10116	3.3	4.0	3.3
Other III,IV	4677	520	5198	3.8	4.9	3.9
V-VIII	9	0	9	2.3	0.0	2.3
Total	31984	6157	38141	3.6	6.8	4.1
Nonlegume hay	(000 acres)			(tons/acre)		
I,II	10215	354	10570	2.2	2.8	2.3
IIIE,IVE	6691	83	6774	2.3	2.1	2.3
Other III,IV	1339	90	1429	2.1	1.3	2.1
V-VIII	149	2	151	1.2	2.0	1.2
Total	18395	529	18924	2.3	2.4	2.3

Table 37. (Continued)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Oats	(000 acres)			(bu./acre)		
I,II	3711	255	3966	71.7	87.7	72.7
IIIE,IVE	1751	33	1784	53.2	46.9	53.1
Other III,IV	234	13	247	61.7	68.2	62.0
V-VIII	36	0	36	13.6	0.0	13.6
Total	5732	301	6033	65.3	82.4	66.1
Sorghum grain	(000 acres)			(bu./acre)		
I,II	4247	1211	5458	68.1	69.9	68.5
IIIE,IVE	1964	374	2338	41.7	68.0	45.9
Other III,IV	1877	106	1983	41.4	61.5	42.5
V-VIII	0	0	0	0.0	0.0	0.0
Total	8088	1692	9780	55.5	69.0	57.8
Sorghum silage	(000 acres)			(tons/acre)		
I,II	4107	428	4535	13.1	19.9	13.7
IIIE,IVE	893	3	896	9.3	13.2	9.3
Other III,IV	266	13	279	10.3	10.6	10.3
V-VIII	0	0	0	0.0	0.0	0.0
Total	5267	443	5710	12.3	19.6	12.9
Soybeans	(000 acres)			(bu./acre)		
I,II	34549	587	35136	43.2	50.0	43.3
IIIE,IVE	6801	114	6915	41.2	41.3	41.2
Other III,IV	5485	25	5510	36.1	46.9	36.2
V-VIII	0	0	0	0.0	0.0	0.0
Total	46835	726	47561	42.1	48.6	42.2
Sugar beets	(000 acres)			(tons/acre)		
I,II	1370	161	1531	17.4	24.8	18.1
IIIE,IVE	0	21	21	0.0	18.5	18.5
Other III,IV	101	31	132	21.4	18.4	20.7
V-VIII	0	0	0	0.0	0.0	0.0
Total	1470	213	1684	17.6	23.3	18.3
Wheat	(000 acres)			(bu./acre)		
I,II	27098	897	27995	37.5	77.8	38.8
IIIE,IVE	15629	618	16246	33.6	50.2	34.3
Other III,IV	6113	274	6387	37.1	54.2	37.8
V-VIII	39	2	41	15.3	26.6	15.8
Total	48878	1791	50669	36.2	64.6	37.2
Other hay	(000 acres)			(tons/acre)		
Total	16908	6094	23002	1.7	3.6	2.2
Pasture	(000 acres)			(tons/acre)		
Total	304614	2921	307535	0.6	2.4	0.6

Table 38. Acreage and average yield of crops by land class in the United States with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Barley	(000 acres)			(bu./acre)		
I,II	3811	883	4694	68.6	84.3	71.6
IIIE,IVE	2549	235	2785	57.5	56.3	57.4
Other III,IV	1948	1416	3364	47.0	61.6	53.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	8309	2533	10842	60.1	69.0	62.2
Corn grain	(000 acres)			(bu./acre)		
I,II	43749	2065	45814	123.5	147.2	124.5
IIIE,IVE	5562	206	5769	111.0	89.3	110.2
Other III,IV	3437	86	3523	89.6	96.0	89.8
V-VIII	0	0	0	0.0	0.0	0.0
Total	52748	2358	55106	119.9	140.2	120.8
Corn silage	(000 acres)			(tons/acre)		
I,II	4954	256	5210	12.8	19.1	13.1
IIIE,IVE	61	26	87	12.0	14.5	12.8
Other III,IV	113	40	153	12.7	13.0	12.8
V-VIII	0	0	0	0.0	0.0	0.0
Total	5128	322	5450	12.8	18.0	13.1
Cotton	(000 acres)			(bales/acre)		
I,II	3488	603	4091	2.0	2.2	2.0
IIIE,IVE	957	11	968	1.7	1.2	1.6
Other III,IV	256	0	256	1.5	0.0	1.5
V-VIII	0	0	0	0.0	0.0	0.0
Total	4701	614	5315	1.9	2.2	1.9
Legume hay	(000 acres)			(tons/acre)		
I,II	19021	4503	23524	3.8	7.2	4.4
IIIE,IVE	9586	453	10039	3.3	4.1	3.3
Other III,IV	5487	542	6029	3.8	4.9	3.9
V-VIII	57	0	57	3.9	0.0	3.9
Total	34152	5497	39649	3.6	6.7	4.0
Nonlegume hay	(000 acres)			(tons/acre)		
I,II	12432	231	12663	2.4	2.7	2.4
IIIE,IVE	5736	155	5891	2.2	2.2	2.2
Other III,IV	2880	105	2986	2.2	1.3	2.2
V-VIII	85	0	85	1.2	0.0	1.2
Total	21133	492	21625	2.3	2.3	2.3

Table 38. (Continued)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Oats	(000 acres)			(bu./acre)		
I,II	4349	332	4682	71.7	84.4	72.6
IIIE,IVE	2022	31	2053	56.4	64.0	56.5
Other III,IV	245	53	298	61.2	70.6	62.9
V-VIII	20	0	20	15.3	0.0	15.3
Total	6637	416	7052	66.5	81.2	67.3
Sorghum grain	(000 acres)			(bu./acre)		
I,II	4062	676	4738	71.4	126.6	79.3
IIIE,IVE	1666	41	1707	50.5	72.1	51.0
Other III,IV	3530	69	3599	41.7	60.9	42.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	9257	786	10043	56.3	118.0	61.1
Sorghum silage	(000 acres)			(tons/acre)		
I,II	2091	211	2301	12.4	25.0	13.5
IIIE,IVE	477	0	477	8.0	0.0	8.0
Other III,IV	41	0	41	12.8	0.0	12.8
V-VIII	0	0	0	0.0	0.0	0.0
Total	2609	211	2820	11.6	25.0	12.6
Soybeans	(000 acres)			(bu./acre)		
I,II	36126	131	36257	44.3	53.9	44.3
IIIE,IVE	4269	6	4275	40.5	35.4	40.5
Other III,IV	4391	0	4391	38.3	0.0	38.3
V-VIII	0	0	0	0.0	0.0	0.0
Total	44786	137	44923	43.3	53.2	43.4
Sugar beets	(000 acres)			(tons/acre)		
I,II	1133	275	1408	17.8	23.7	18.9
IIIE,IVE	0	32	32	0.0	19.4	19.4
Other III,IV	101	71	172	21.4	20.5	21.0
V-VIII	0	0	0	0.0	0.0	0.0
Total	1233	378	1611	18.1	22.7	19.2
Wheat	(000 acres)			(bu./acre)		
I,II	27170	1789	28960	37.8	50.7	38.6
IIIE,IVE	14927	938	15864	33.4	46.4	34.2
Other III,IV	5795	152	5947	39.1	53.5	39.5
V-VIII	66	0	66	16.9	0.0	16.9
Total	47958	2879	50837	36.6	49.4	37.3
Other hay	(000 acres)			(tons/acre)		
Total	17224	6105	23329	1.7	3.6	2.2
Pasture	(000 acres)			(tons/acre)		
Total	310697	708	311406	0.6	2.9	0.6

Table 39. Acreage and average yield of crops by land class in the United States with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Barley	(000 acres)			(bu./acre)		
I,II	5890	819	6709	57.8	91.4	61.9
IIIE,IVE	3366	122	3489	54.8	59.8	55.0
Other III,IV	1686	1423	3110	49.6	61.5	55.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	10943	2364	13307	55.6	71.7	58.5
Corn grain	(000 acres)			(bu./acre)		
I,II	47663	865	48528	124.1	146.7	124.5
IIIE,IVE	5131	173	5303	108.6	86.5	107.8
Other III,IV	4124	86	4210	88.6	96.0	88.7
V-VIII	0	0	0	0.0	0.0	0.0
Total	56917	1123	58041	120.2	133.6	120.4
Corn silage	(000 acres)			(tons/acre)		
I,II	1831	511	2342	16.1	18.9	16.7
IIIE,IVE	0	52	52	0.0	16.6	16.6
Other III,IV	22	33	55	15.6	14.6	15.0
V-VIII	0	0	0	0.0	0.0	0.0
Total	1853	596	2449	16.1	18.5	16.7
Cotton	(000 acres)			(bales/acre)		
I,II	3363	1103	4466	1.8	2.5	1.9
IIIE,IVE	789	11	800	1.3	1.2	1.3
Other III,IV	287	0	287	1.5	0.0	1.5
V-VIII	0	0	0	0.0	0.0	0.0
Total	4439	1114	5553	1.7	2.5	1.8
Legume hay	(000 acres)			(tons/acre)		
I,II	22517	4769	27285	3.9	6.9	4.4
IIIE,IVE	10777	587	11364	3.5	3.8	3.5
Other III,IV	629	695	1324	3.9	4.7	4.3
V-VIII	9	0	9	2.3	0.0	2.3
Total	33932	6051	39982	3.7	6.4	4.1
Nonlegume hay	(000 acres)			(tons/acre)		
I,II	11215	340	11555	2.4	2.8	2.4
IIIE,IVE	8022	163	8186	2.2	1.8	2.2
Other III,IV	1893	62	1955	1.9	1.3	1.9
V-VIII	121	0	121	1.2	0.0	1.2
Total	21251	565	21816	2.3	2.3	2.3

Table 39. (Continued)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Oats	(000 acres)			(bu./acre)		
I,II	6034	293	6327	72.5	89.8	73.3
IIIE,IVE	2516	51	2567	65.3	60.2	65.2
Other III,IV	375	52	426	59.5	71.1	60.9
V-VIII	30	0	30	13.6	0.0	13.6
Total	8955	396	9351	69.7	83.5	70.3
Sorghum grain	(000 acres)			(bu./acre)		
I,II	4826	252	5077	66.7	130.1	69.9
IIIE,IVE	2066	18	2085	32.5	80.6	32.9
Other III,IV	1706	0	1706	43.3	0.0	43.3
V-VIII	0	0	0	0.0	0.0	0.0
Total	8597	270	8868	53.9	126.8	56.1
Sorghum silage	(000 acres)			(tons/acre)		
I,II	2186	293	2478	11.4	25.0	13.0
IIIE,IVE	26	0	26	8.2	0.0	8.2
Other III,IV	279	0	279	8.1	0.0	8.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	2490	293	2783	11.0	25.0	12.5
Soybeans	(000 acres)			(bu./acre)		
I,II	36356	100	36455	44.2	54.8	44.3
IIIE,IVE	2696	0	2696	39.4	0.0	39.4
Other III,IV	5182	0	5182	36.9	0.0	36.9
V-VIII	0	0	0	0.0	0.0	0.0
Total	44233	100	44333	43.1	54.8	43.1
Sugar beets	(000 acres)			(tons/acre)		
I,II	1250	180	1429	17.7	24.4	18.5
IIIE,IVE	0	46	46	0.0	17.4	17.4
Other III,IV	101	71	172	21.4	20.5	21.0
V-VIII	0	0	0	0.0	0.0	0.0
Total	1350	297	1647	18.0	22.4	18.8
Wheat	(000 acres)			(bu./acre)		
I,II	22852	1059	23911	39.4	64.9	40.5
IIIE,IVE	15487	1047	16534	33.7	43.7	34.3
Other III,IV	4721	201	4921	28.4	49.2	29.3
V-VIII	42	0	42	16.2	0.0	16.2
Total	43102	2307	45409	36.1	53.9	37.0
Other hay	(000 acres)			(tons/acre)		
Total	17673	6100	23772	1.7	3.6	2.2
Pasture	(000 acres)			(tons/acre)		
Total	313854	2585	316439	0.6	2.4	0.6

the dryland and irrigated production patterns causes the major increase in overall yield. The changes from the 10 ton restriction to the 3 ton restriction reflect changes in per acre yields on dryland and irrigated production alternatives. These yield increases result from shifts to regions of different productive capacity. Similar shifts in production patterns can be observed for the other crops consistent with their susceptibility to erosion or their relationship to other crops through rotational interactions.

The data in Tables 36, 37, 38 and 39 reflect the acreage of the endogenous crops by land groups. The decline in total acreage as the level of soil restriction is reduced is not reflected equally in the acreage of all crops. Cotton, which has no substitute in the agricultural sector, has a decline in acreage from 6.4 million acres with no soil loss restriction to as low as 5.3 million acres under the 5 ton restriction. These changes are possible because of changes in yield per acre as the cotton is grown on the more productive class I and II lands and as it shifts regions. The most drastic change in acreage occurs in silage, both corn and sorghum. The acreage of silage declines from 13.9 million acres with no soil loss restriction to 5.2 million acres with a 3 ton restriction. The roughage component of the livestock ration provided from silages under the less restrictive soil loss alternatives is satisfied from the greater production of

hays. The nonlegume hay acreage increases from 19 million acres under the unrestricted and 10 ton soil loss limitations to 22 million acres under the 5 ton and 3 ton soil loss restrictions. The projected nonlegume hay acreage represents a decline in total acreage from the 1969 average. The legume hays undergo an increase in acreage from 37 million to 40 million acres. This change contrasts with the present situation where the 1969 acreage of legume hays of 27 million acres was less than the 35 million acres of nonlegume hay crops (35).

Shifts in livestock production

The shift in crop patterns has a direct effect on the feed consumption patterns in the livestock sector. The data in Table 40 indicates the consumption of the crop commodities within the livestock sector. The reduction in the acres of corn and sorghum silage result in a decline in silage fed from 174 million tons under no soil loss restriction to 150 million tons under the 10 ton restriction, to 107 million tons under the 5 ton restriction, and to 76 million tons under the 3 ton restriction. To compensate for the reduction in nutrients from silage, more hay and pasture are used to maintain the balance in roughage and more corn, barley and oats are used to maintain the balance in energy. The substitutions for the silages affect the high protein balance as the legume hays (9-15 percent digestible protein) and the

Table 40. Commodity use in livestock production under alternative soil loss restrictions in 2000

Commodity	Units	Soil loss restrictions			
		unrestricted	10 ton	5 ton	3 ton
Corn	bu.	5552273	5612173	5691554	6023807
Sorghum	bu.	428526	425468	474077	357218
Barley	bu.	558066	577948	461520	565639
Oats	bu.	291832	320820	396728	579533
Wheat	bu.	522816	494016	505341	288741
High protein[a/]	cwt.	743754	726224	699218	681572
Legume hay	tons	154649	160103	163295	167380
Other hay	tons	95386	96038	104197	104450
Silage	tons	173662	149624	107147	75892
Pasture[b/]	tons	207506	209059	212670	215909

[a/] Includes soybean and cottonseed oilmeals and high protein grain supplements, expressed in soybean oilmeal equivalents.

[b/] Expressed in non-legume hay equivalents.

permanent pasture (10-15 percent digestible protein depending on maturity) have a relatively higher protein content than do the silages (2-5 percent digestible protein depending on type). The increase in corn and oats fed offsets the reduced utilization of sorghum and wheat. The increase in utilization of one commodity to the exclusion of some other commodity reflects the lower cost of the former in the nation's total agricultural bill. All shifts in production result because the soil loss restrictions change the relative costs of producing the commodities under the alternative technologies and the model selects the least-cost resource use and production pattern under each soil loss restraint.

Resource use and income distribution

Resource use and cropping patterns reflect the input usage most efficient under each alternative and are consistent with the national, regional and farming practices utilized. The data in Tables 41, 42, 43 and 44 include the value of the inputs used in the production of row crops and close-grown crops under the alternative soil loss restrictions. The value of land and water represents the marginal value product of the last unit utilized as reflected by the shadow prices in the solution. The labor, machinery and pesticide costs are component costs in the cropping system budgets. The "other costs" category includes the cost of fertilizers and the associated miscellaneous items of produc-

Table 41. Value of resource use in crop production by major zones in the United States for unlimited soil loss and 69-71 average exports in 2000 (Model A)[c/]

Zone-item	Land	Water	Labor	Mach	Pest	Other	Total
			($ per acre)				
United States							
Row crops[a/]	18.68	0.34	6.13	34.50	2.82	10.98	73.47
Close crops[b/]	11.42	0.30	3.29	23.99	0.68	3.69	43.40
North Atlantic							
Row crops	6.85	0.00	9.10	56.90	2.62	19.65	95.14
Close crops	4.80	0.00	4.85	31.72	5.67	13.65	60.71
South Atlantic							
Row crops	9.81	0.00	7.68	29.57	4.22	14.80	66.09
Close crops	11.53	0.00	4.75	35.86	0.12	15.39	67.68
North Central							
Row crops	20.81	0.00	5.55	35.20	3.06	12.81	77.44
Close crops	9.74	0.00	3.21	24.45	1.26	5.11	43.79
South Central							
Row crops	19.19	0.24	6.84	34.82	2.32	5.43	68.87
Close crops	16.65	0.10	3.01	23.12	0.16	2.07	45.14
Great Plains							
Row crops	14.66	2.24	6.88	33.93	1.98	6.72	66.43
Close crops	6.19	0.22	3.24	25.57	0.32	-0.83	34.73
North West							
Row crops	6.09	1.47	8.70	14.92	0.73	8.94	40.87
Close crops	11.99	0.49	3.41	21.18	0.99	5.60	43.69
South West							
Row crops	15.24	4.87	5.12	21.36	0.66	1.90	49.17
Close crops	13.75	2.06	3.30	16.95	0.07	5.29	41.44

[a/] Includes corn, cotton, sorghum, soybeans and sugar beets.
[b/] Includes barley, oats and wheat.
[c/] Values are in terms of 1972 dollars.

Table 42. Value of resource use in crop production by major zones in the United States for 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)[c/]

Zone-item	Land	Water	Labor	Mach	Pest	Other	Total
			($ per acre)				
United States							
Row crops[a/]	18.38	0.33	6.17	35.10	4.56	11.40	75.96
Close crops[b/]	11.06	0.31	3.36	24.63	0.81	3.70	43.90
North Atlantic							
Row crops	6.43	0.00	9.19	57.68	4.02	20.25	97.58
Close crops	6.00	0.00	4.66	30.52	7.71	13.88	62.78
South Atlantic							
Row crops	8.67	0.00	8.24	31.81	4.17	14.85	67.76
Close crops	10.88	0.00	5.37	42.24	1.22	17.25	76.98
North Central							
Row crops	20.98	0.00	5.45	34.92	4.91	13.34	79.63
Close crops	9.57	0.00	3.26	24.85	1.32	5.29	44.30
South Central							
Row crops	17.69	0.18	7.05	37.23	5.10	5.63	72.90
Close crops	15.82	0.12	3.22	24.74	0.42	2.18	46.53
Great Plains							
Row crops	14.46	2.12	7.18	35.20	2.39	7.51	68.88
Close crops	5.97	0.22	3.22	25.48	0.34	-0.75	34.49
North West							
Row crops	6.11	1.47	8.37	14.89	0.72	8.79	40.38
Close crops	11.96	0.49	3.42	21.20	0.99	5.60	43.68
South West							
Row crops	13.53	4.90	5.63	23.98	1.08	1.27	50.41
Close crops	13.43	2.05	3.29	16.97	0.07	5.29	41.12

[a/] Includes corn, cotton, sorghum, soybeans and sugar beets.
[b/] Includes barley, oats and wheat.
[c/] Values are in terms of 1972 dollars.

Table 43. Value of resource use in crop production by major zones in the United States for 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)[c/]

Zone-item	Land	Water	Labor	Mach	Pest	Other	Total
			($ per acre)				
United States							
Row crops[a/]	21.14	0.32	6.40	37.19	5.50	11.93	82.51
Close crops[b/]	10.43	0.22	3.36	24.84	0.73	2.53	42.14
North Atlantic							
Row crops	10.74	0.00	9.08	61.56	3.33	18.87	103.60
Close crops	7.43	0.00	6.24	42.27	0.32	14.47	70.74
South Atlantic							
Row crops	8.76	0.00	8.90	38.43	5.93	17.55	79.60
Close crops	12.25	0.00	3.69	31.47	1.32	11.72	60.47
North Central							
Row crops	24.94	0.00	5.35	35.44	5.96	12.83	84.55
Close crops	10.23	0.00	3.14	24.08	1.57	4.27	43.31
South Central							
Row crops	19.89	0.06	7.93	41.33	5.39	7.56	82.18
Close crops	16.07	0.03	3.35	26.25	0.39	2.32	48.43
Great Plains							
Row crops	17.21	1.11	7.38	38.46	4.14	7.24	75.57
Close crops	4.79	0.06	3.24	25.52	0.41	-2.15	31.88
North West							
Row crops	8.74	1.28	9.60	19.95	0.74	15.68	56.01
Close crops	9.13	0.19	3.68	23.57	1.01	3.35	40.94
South West							
Row crops	6.14	6.71	7.02	28.67	2.82	4.52	55.89
Close crops	9.98	1.54	2.96	17.29	0.08	2.55	34.42

[a/] Includes corn, cotton, sorghum, soybeans and sugar beets.
[b/] Includes barley, oats and wheat.
[c/] Values are in terms of 1972 dollars.

Table 44. Value of resource use in crop production by major zones in the United States for 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)[c/]

Zone-item	Land	Water	Labor	Mach	Pest	Other	Total
			($ per acre)				
United States							
Row crops[a/]	23.45	0.33	6.26	37.44	6.48	12.44	86.42
Close crops[b/]	13.61	0.31	3.36	25.16	1.23	2.13	45.83
North Atlantic							
Row crops	10.39	0.00	9.40	59.61	4.13	16.60	100.15
Close crops	10.51	0.00	6.05	40.60	5.50	11.26	73.94
South Atlantic							
Row crops	11.91	0.00	9.00	37.06	6.10	16.36	80.45
Close crops	18.94	0.00	4.11	35.62	0.90	12.99	72.57
North Central							
Row crops	26.58	0.00	5.31	36.62	7.01	13.51	89.06
Close crops	12.42	0.00	3.25	24.56	2.26	4.96	47.47
South Central							
Row crops	22.27	0.11	7.30	40.21	6.45	8.58	84.95
Close crops	18.91	0.04	3.13	25.38	0.55	0.36	48.39
Great Plains							
Row crops	13.09	1.23	6.17	36.84	2.27	3.51	63.14
Close crops	8.67	0.28	3.31	26.52	0.38	-1.19	37.98
North West							
Row crops	7.98	1.55	10.29	15.82	0.71	10.10	46.47
Close crops	13.91	0.47	3.43	21.78	0.98	6.04	46.64
South West							
Row crops	21.52	5.71	10.16	35.36	7.12	12.61	92.51
Close crops	14.63	2.12	3.49	20.06	1.93	0.18	42.42

[a/] Includes corn, cotton, sorghum, soybeans and sugar beets.
[b/] Includes barley, oats and wheat.
[c/] Values are in terms of 1972 dollars.

tion. In some zones, the Great Plains in particular, this component of the cost structure is negative, representing an income to the rotation. This income results as the nitrogen balance restriction forces the disposal of livestock wastes in all areas. In other words, livestock producers would have to pay to dispose of the wastes from their livestock enterprise, reflecting an income or negative cost to the crop sector. This situation results only in certain producing areas of the Great Plains and South Central zones.

At the national level an increase in total per acre resource input is specified for the row crops with each successive reduction in the level of allowable soil loss, Tables 41, 42, 43 and 44. The per acre return from close-grown crops increases for the 10 ton restriction, declines for the 5 ton restriction and increases again under the 3 ton restriction. Most of the decline in value of resource use in close-grown crops under the 5 ton restriction results from reduced fertilizer use as close-grown crops in some producing areas of the Great Plains and South Central zones receive both a "payment" and nitrogen for fertilizer from the livestock sector for disposal of excess wastes. The return to land increases as the land capable of meeting the soil loss restriction at lowest cost becomes relatively more valuable due to the higher prices for the commodities produced. The return to water is relatively unaffected by alternate soil loss re-

strictions and reflects the minor required shifts in the irrigated production patterns. The value of labor utilized increases slightly and reflects the increased requirement associated with the more time-consuming, conservation-tillage practices utilized to meet soil loss restriction. Machinery use per acre also increases for both row crops and close-grown crops as a result of the increased time required for the conservation-tillage practices on more land (which does not offset the reduction in machinery use associated with reduced tillage practices). Per acre expenditures on pesticides increases as the allowable soil loss level is reduced. Chemical methods of control for weeds and insects must be increased under the reduced tillage procedures which are substituted for conventional tillage control methods. At the national level, the "other costs" increase for row crops as the cost of nitrogen increases in line with commercial prices. The close-grown crops, on the other hand, show a decline in "other costs" as the concentration of these crops moves more to the Great Plains and South Central zones where nitrogen is supplied by the livestock enterprises at little or no expense (and in some cases as an income to the crop).

The change in value of resource use under the alternative soil loss restrictions has a direct effect on the distribution of income within the agricultural sector. At the national level, land receives 25.5 percent of the return from

sales associated with row crop production under the no soil loss restriction alternative, water receives 0.5 percent, and labor receives 8.3 percent. Machinery expenses accounted for 47.0 percent, pesticides for 3.8 percent and miscellaneous costs including fertilizer accounted for 14.9 percent, Table 45. Under a 10 ton soil loss restriction the proportion of the total return to row crops attributed to land, water and labor declines, indicating a lower per acre relative return over costs when compared to the unrestricted alternatives. The percentage of the total return attributed to land increases sufficiently under the 5 ton restriction to give a larger share of the return to land, water and labor than under the 10 ton restriction but not enough to equal the proportion received by these sectors in the unrestrained alternative. The increase in the share going to land is sufficient at the 3 ton restriction level to increase the proportion of total returns to land, water and labor above that received under the no soil loss restriction. A similar pattern is followed for the close-grown crops.

The relative shift in proportion of the returns receivable by each sector indicates the shift in the relative income position of each of the sectors. If the landowner is separate from the labor supply, a conflict may arise as conservation programs at a 3 ton restriction level increase the incomes of both but a greater proportion of the total is indi-

Table 45. Percent of the total return in national row crop and close-grown crops production for alternative levels of soil loss restriction in 2000

Restriction/ crop	Total	Land	Water	Labor	Mach	Pest	Other[a]
	($/acre)[b]			(percent)			
Unrestricted							
row crops	73.47	25.5	0.5	8.3	47.0	3.8	14.9
close crops	43.40	26.3	0.7	7.6	55.3	1.6	8.5
10 ton restriction							
row crops	75.96	24.2	0.4	8.1	46.3	6.0	15.0
close crops	43.90	25.2	0.7	7.7	56.1	1.9	8.4
5 ton restriction							
row crops	82.51	25.6	0.4	7.8	45.0	6.7	14.5
close crops	42.14	24.8	0.5	8.0	59.0	1.7	6.0
3 ton restriction							
row crops	86.42	27.1	0.4	7.2	43.4	7.5	14.4
close crops	45.83	29.7	0.7	7.3	54.9	2.7	4.7

[a] Includes fertilizers and miscellaneous production costs.

[b] Values are in terms of 1972 dollars.

cated for the landowner. The labor sector has a higher total return per acre but relative to the land, labor return has declined. With a mild soil loss restriction, 5 or 10 tons per acre, the aggregate farm supply sector receives more of the return and the land and labor (i.e., renters) have less income incentive for undertaking conservation programs. Within the farm supply sector, the pesticide distribution has greater relative income per acre with each successive reduction in allowable soil loss.

The total return to each of the resource sectors under the alternative levels of soil loss restriction is given in Table 46. The return to all sectors at the national level, except pesticides, declines with the initial soil loss restriction, even for those sectors which have an increased return per acre, Tables 41 and 42. The reduction in total return is due to the decline in acreage of row crops from 148 million acres to 141 million acres and of close-grown crops from 76 million acres to 74 million acres. The 5 ton soil loss restriction increases the return to the agricultural sector to 14,314 million dollars, as compared to 14,163 million dollars under the unrestricted alternative. However, the only sectors above the level of the unrestricted model are land and pesticides. The 3 ton restriction increases the value of the returns in the agricultural sector to 14,951 million dollars. Land at 4,144 million dollars and pesticides

Table 46. Returns to the national resource sectors of agriculture from the production of row crops and close-grown crops for alternative levels of soil loss restriction in 2000

Restriction/ crop	Total	Land	Water	Labor	Mach	Pest	Other[a/]
Unrestricted							
row crops	10887	2769	50	908	5114	418	1628
close crops	3276	863	23	249	1812	51	278
total	14163	3632	73	1157	6926	469	1906
10 ton restriction							
row crops	10740	2599	47	873	4964	645	1612
close crops	3260	822	23	250	1830	60	275
total	14000	3421	70	1123	6794	705	1887
5 ton restriction							
row crops	11220	2876	44	870	5059	748	1623
close crops	3094	766	16	247	1825	54	186
total	14314	3642	60	1117	6884	802	1809
3 ton restriction							
row crops	11615	3153	44	842	5033	871	1672
close crops	3336	991	23	245	1832	90	155
total	14951	4144	67	1087	6865	961	1727

[a/] Includes fertilizers and miscellaneous production costs.

[b/] Values are in terms of 1972 dollars.

at 961 million dollars again are the only sectors above the level of the unrestricted soil loss alternative. Hence, persons controlling land on which production remains would gain in both relative income and absolute income over the labor and water sectors. Similarly, the producers of pesticide inputs would gain in relative share of the crop expense dollar.

The data in Table 47 indicate the total value of resources utilized in agricultural production under each soil loss alternative in each of the seven major zones. The North Atlantic zone varies little except under the 5 ton restriction. Its value of resources used then increases to over 600 million dollars from the 400-500 million dollar range under the other three alternatives. The South Atlantic and South Central zones have reduced total resource utilization as the soil loss restriction is lowered and cropped acreage declines. The North Central and Great Plains zones have increased income from the agricultural sector as acreages expand and the more intensive conservation practices increase input utilization, especially pesticides. The two zones in the West increase the value of resources used in agricultural production, especially as the soil loss restriction reaches the 3 ton level.

In general, the more productive lands experience an increase in return while the less productive have a reduced

Table 47. Total returns to the regional agricultural related sectors from the production of row crops and close-grown crops for alternative levels of soil loss restriction in 2000.

Region/crop	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(million dollars)[a/]			
United States				
row crops	10887	10740	11220	11615
close crops	3276	3260	3094	3336
total	14163	14000	14314	14951
North Atlantic				
row crops	353	357	447	336
close crops	103	77	176	154
total	456	434	623	490
South Atlantic				
row crops	706	653	801	687
close crops	217	210	53	53
total	923	863	854	740
North Central				
row crops	7040	6994	7161	7870
close crops	851	846	812	838
total	7891	7840	7973	8708
South Central				
row crops	1973	1924	1996	1689
close crops	936	957	955	962
total	2919	2881	2951	2651
Great Plains				
row crops	499	483	422	436
close crops	562	571	494	694
total	1061	1054	916	1130
North West				
row crops	71	70	110	84
close crops	339	339	317	369
total	410	409	427	453
South West				
row crops	244	258	282	514
close crops	269	261	288	265
total	513	519	570	779

[a/]Values are in terms of 1972 dollars.

relative return, Tables 48, 49, 50 and 51. At the national levels, the marginal value product of an acre of class I or II land under the unrestricted alternative is $20.60. This increases to $25.30 under the 3 ton restriction. The value product of the class V-VIII lands drops, however, from $10.87 per acre to $7.05 per acre as the allowable soil loss level is reduced to 3 tons. All zones have an increase in the value of highly productive class I and II lands as the allowable level of soil loss is reduced. The variation by region and by land class results from the linearity characteristics of the model used, but when the individual regions are weighted together, the national averages indicate the relative shift in income among the owners of acres in the alternate land classes. The change in income distribution among land classes incorporates the fact that 11 million additional acres would be shifted or idled from production as the soil restriction progresses from no restriction to the 3 ton restriction. The reduction in income from idled lands is especially severe in the South Central zone where over 14 million acres of additional idled land results if the 3 ton restriction is implemented. The South Atlantic has an increase of idled land of over 4 million acres from the unrestricted analysis to the 3 ton restriction. Zones increasing land used between the unrestricted and 3 ton restriction alternatives include the Great Plains (about 5 million acres)

Table 48. Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model A)

Zone	Land classes I,II	IIIE,IVE	III-IV	V-VIII	Other[a]	Total[b]
	($ per acre)[c]					
United States	20.60	10.67	12.02	10.87	2.92	17.35
North Atlantic	8.41	0.62	0.00	0.00	3.66	7.50
South Atlantic	14.48	7.38	6.19	0.00	3.84	13.04
North Central	21.71	12.57	10.42	0.00	6.25	19.68
South Central	24.90	12.87	16.06	14.52	3.15	19.41
Great Plains	12.60	5.20	4.10	0.00	2.12	9.55
North West	26.24	10.34	6.80	3.84	2.60	15.37
South West	23.82	8.86	17.78	6.12	1.07	17.24

[a] Other hay and pasture lands.
[b] Excluding other hay and pasture lands.
[c] Values are in terms of 1972 dollars.

Table 49. Shadow prices (marginal value products) of alternative land classes in major zones in 2000 (Model B)

Zone	Land classes I,II	IIIE,IVE	III-IV	V-VIII	Other[a]	Total[b]
	($ per acre)[c]					
United States	20.01	9.95	10.43	5.68	3.02	16.77
North Atlantic	7.94	0.19	0.25	0.00	3.57	7.75
South Atlantic	13.15	5.89	4.52	0.00	3.86	12.07
North Central	21.40	11.45	10.37	0.00	6.78	19.46
South Central	23.44	12.18	12.53	4.21	3.28	17.96
Great Plains	12.57	4.74	4.16	0.00	2.13	9.40
North West	26.22	10.30	6.78	4.68	2.59	15.35
South West	21.74	8.33	18.93	6.12	1.05	16.14

[a] Other hay and pasture lands.
[b] Excluding other hay and pasture lands.
[c] Values are in terms of 1972 dollars.

Table 50. Shadow prices(marginal value products) of alternative land classes in major zones in 2000 (Model C)

Zone	Land classes I,II	IIIE,IVE	Other III-IV	V-VIII	Other[a]	Total[b]
	($ per acre)[c]					
United States	22.47	9.06	9.72	6.72	2.71	18.22
North Atlantic	12.74	0.00	0.80	0.00	1.73	11.03
South Atlantic	13.22	14.17	6.84	0.00	4.09	12.71
North Central	25.08	14.70	13.55	0.00	5.97	23.16
South Central	26.00	11.77	10.33	0.00	3.09	18.97
Great Plains	12.54	2.26	1.77	0.00	1.76	8.43
North West	26.85	5.86	7.10	0.00	2.30	13.66
South West	16.28	3.07	12.14	16.50	0.71	10.59

[a] Other hay and pasture lands.
[b] Excluding other hay and pasture lands.
[c] Values are in terms of 1972 dollars.

Table 51. Shadow prices(marginal value products) of alternative land classes in major zones in 2000 (Model D)

Zone	Land classes I,II	IIIE,IVE	Other III-IV	V-VIII	Other[a]	Total[b]
	($ per acre)[c]					
United States	25.30	11.93	11.24	7.05	3.39	21.07
North Atlantic	12.66	0.00	4.18	0.00	3.66	12.36
South Atlantic	18.84	19.65	16.22	0.00	4.84	18.72
North Central	27.14	14.70	13.29	0.00	7.92	24.46
South Central	30.54	14.00	8.55	5.86	3.27	23.08
Great Plains	14.64	7.03	6.01	0.00	2.56	11.47
North West	32.75	11.03	9.27	8.67	3.19	18.13
South West	25.93	7.85	30.64	7.23	0.96	20.09

[a] Other hay and pasture lands.
[b] Excluding other hay and pasture lands.
[c] Values are in terms of 1972 dollars.

and the North Central (about 2 million acres).

A similar shift in income distribution occurs in the water sector. Total consumptive use of water by agriculture ranges from 55 million acre feet under the unrestricted and 10 ton restriction alternatives, to 49 million acre feet under the 5 ton restriction and back to 53 million acre feet under the 3 ton restriction, Tables 52, 53, 54 and 55. The major river basins most affected by the change in water use include the Arkansas-White-Red with a decline in consumptive use from 4.0 million acre feet under the unrestricted alternative to 2.7 million acre feet under the 3 ton restriction. The California-South Pacific experiences a fluctuation, especially under the 5 ton restriction when water use in the area drops by 6 million acre feet from the less restrictive alternatives and then regains use of 5 million acre feet under the 3 ton restriction.

Nitrogen balances

Utilization of nitrogen provides an additional evaluation of resource use. The nitrogen balance restraints in the model prevent any regional accumulation of livestock wastes and encourages the use of legume crops in rotation with the nonlegume crops. The total utilization of nitrogen increases slightly as the level of soil loss restriction is reduced, Table 56. This is consistent with the higher yields per acre and the higher commodity prices making fertilizer, at a set

Table 52. Withdrawals and consumptive use of water in the western river basins with unlimited soil loss and 69-71 average exports in 2000 (Model A)

River basin	Total 1965[a]	Projected 2000			
		Agriculture	Municipal & industrial[b]	Other[c]	Total
	(000 acre feet per year)				
Withdrawals					
Western basins	151733	72283	51323	7429	131035
Missouri	21668	12961	6172	2218	21351
Ark.-White-Red	10541	5893	8395	0	14288
Texas-Gulf	18382	2182	16890	227	19299
Rio Grande	8165	4104	1222	0	5326
U. Colorado	4500	2174	1079	198	3451
L. Colorado	7774	2815	1457	2085	6357
Great Basin	5730	1736	1034	1276	4046
Col.-N. Pacific	33191	23201	8289	1425	32915
Cal.-S. Pacific	41782	17217	6785	0	24002
Consumptive use					
Western basins	75050	54947	21300	6613	82860
Missouri	11822	10027	1223	2218	13468
Ark.-White-Red	6580	4026	1400	0	5426
Texas-Gulf	8165	1466	7749	227	9442
Rio Grande	4632	1619	557	0	2176
U. Colorado	2220	2557	495	144	3196
L. Colorado	3862	2044	678	1851	4573
Great Basin	2524	1612	445	908	2965
Col.-N. Pacific	11785	17076	7171	1265	25512
Cal.-S. Pacific	23460	14520	1582	0	16102

[a] Source: (35A, Tables 7-3-4 and 7-3-5).

[b] Includes rural domestic, municipal, self-supplied industrial, recreation, mining and thermal electric power.

[c] Includes onsite uses and water exports out of the western basins.

Table 53. Withdrawals and consumptive use of water in the western river basins with 10 ton maximum soil loss and 69-71 average exports in 2000 (Model B)

River basin	Total 1965[a]	Projected 2000 Agriculture	Municipal & industrial[b]	Other[c]	Total
		(000 acre feet per year)			
		Withdrawals			
Western basins	151733	72560	51323	7429	131312
Missouri	21668	13217	6172	2218	21607
Ark.-White-Red	10541	5989	8395	0	14384
Texas-Gulf	18382	2168	16890	227	19285
Rio Grande	8165	4104	1222	0	5326
U. Colorado	4500	2174	1079	198	3451
L. Colorado	7774	2755	1457	2085	6297
Great Basin	5730	1736	1034	1276	4046
Col.-N. Pacific	33191	23205	8289	1425	32919
Cal.-S. Pacific	41782	17212	6785	0	23997
		Consumptive use			
Western basins	75050	55283	21300	6613	83196
Missouri	11822	10199	1223	2218	13640
Ark.-White-Red	6580	4093	1400	0	5493
Texas-Gulf	8165	1458	7749	227	9434
Rio Grande	4632	1619	557	0	2176
U. Colorado	2220	2557	495	144	3196
L. Colorado	3862	2149	678	1851	4678
Great Basin	2524	1612	445	908	2965
Col.-N. Pacific	11785	17078	7171	1265	25514
Cal.-S. Pacific	23460	14518	1582	0	16100

[a] Source: (35A, Tables 7-3-4 and 7-3-5).

[b] Includes rural domestic, municipal, self-supplied industrial, recreation, mining and thermal electric power.

[c] Includes onsite uses and water exports out of the western basins.

Table 54. Withdrawals and consumptive use of water in the western river basins with 5 ton maximum soil loss and 69-71 average exports in 2000 (Model C)

River basin	Total 1965[a]	Projected 2000			
		Agriculture	Municipal & industrial[b]	Other[c]	Total
	(000 acre feet per year)				
Withdrawals					
Western basins	151733	65946	51323	7429	124698
Missouri	21668	12928	6172	2218	21318
Ark.-White-Red	10541	5649	8395	0	14044
Texas-Gulf	18382	2198	16890	227	19315
Rio Grande	8165	4107	1222	0	5329
U. Colorado	4500	2313	1079	198	3590
L. Colorado	7774	2749	1457	2085	6291
Great Basin	5730	1902	1034	1276	4212
Col.-N. Pacific	33191	22505	8289	1425	32219
Cal.-S. Pacific	41782	11595	6785	0	18380
Consumptive use					
Western basins	75050	48622	21300	6613	76535
Missouri	11822	10026	1223	2218	13467
Ark.-White-Red	6580	3740	1400	0	5140
Texas-Gulf	8165	1479	7749	227	9455
Rio Grande	4632	1608	557	0	2165
U. Colorado	2220	2649	495	144	3288
L. Colorado	3862	2152	678	1851	4681
Great Basin	2524	1742	445	908	3095
Col.-N. Pacific	11785	16666	7171	1265	25102
Cal.-S. Pacific	23460	8560	1582	0	10142

[a] Source: (35A, Tables 7-3-4 and 7-3-5).

[b] Includes rural domestic, municipal, self-supplied industrial, recreation, mining and thermal electric power.

[c] Includes onsite uses and water exports out of the western basins.

Table 55. Withdrawals and consumptive use of water in the western river basins with 3 ton maximum soil loss and 69-71 average exports in 2000 (Model D)

River basin	Total 1965[a]	Projected 2000			
		Agriculture	Municipal & industrial[b]	Other[c]	Total
	(000 acre feet per year)				
Withdrawals					
Western basins	151733	69804	51323	7429	128556
Missouri	21668	13336	6172	2218	21726
Ark.-White-Red	10541	3907	8395	0	12302
Texas-Gulf	18382	1740	16890	227	18857
Rio Grande	8165	4114	1222	0	5336
U. Colorado	4500	2307	1079	198	3584
L. Colorado	7774	3189	1457	2085	6731
Great Basin	5730	2073	1034	1276	4383
Col.-N. Pacific	33191	22413	8289	1425	32127
Cal.-S. Pacific	41782	16725	6785	0	23510
Consumptive use					
Western basins	75050	53091	21300	6613	81004
Missouri	11822	10317	1223	2218	13758
Ark.-White-Red	6580	2704	1400	0	4104
Texas-Gulf	8165	1195	7749	227	9171
Rio Grande	4632	1633	557	0	2190
U. Colorado	2220	2638	495	144	3277
L. Colorado	3862	2427	678	1851	4956
Great Basin	2524	1873	445	908	3226
Col.-N. Pacific	11785	16502	7171	1265	24938
Cal.-S. Pacific	23460	13802	1582	0	15384

[a] Source: (35A, Tables 7-3-4 and 7-3-5).

[b] Includes rural domestic, municipal, self-supplied industrial, recreation, mining and thermal electric power.

[c] Includes onsite uses and water exports out of the western basins.

Table 56. Nitrogen sources and use for alternative levels of soil loss restriction in 2000

Nitrogen source	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(million pounds)			
Livestock wastes	8728	8732	8752	8728
Legume crops	8496	8713	8615	8939
Commercial purchase[a/]	6013	6053	6540	6285
Total utilized	23237	23498	23907	23952

[a/] 1970 usage of commercial N fertilizers totaled 14,623 million pounds.

Table 57. Indication of relative farm level prices for some agricultural commodities for alternative soil loss restrictions in 2000

Commodity	Soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
	(unrestricted model = 100)			
Corn	100	100	107	106
Wheat	100	99	103	103
Soybeans	100	101	115	121
Cotton	100	100	112	125
Hay	100	99	101	106
Beef	100	100	104	105
Pork	100	100	105	104
Milk	100	100	100	102

price, a more economically attractive input at lower soil loss levels. Part of the increase in fertilizer nitrogen comes from the increased acreage of legume crops and the crop-supplied nitrogen increases from 8,496 million pounds to 8,939 million pounds. Livestock production of nitrogen-equivalent wastes remains constant near 8,700 million pounds, since the changes in number of livestock is influenced only by changes in productivity (given the equal demands for the livestock products under all alternatives). The trade-off capability of the model is exhibited in the case of the 5 ton restriction when nitrogen from the legume crops declines and the commercial purchase of nitrogen increases to maintain the total utilization of nitrogen in line with trends.

Price Effects

The indications to this point in the analysis suggest a relatively small impact on the agricultural sector at the national level. Regionally, the impacts are more pronounced, especially with regard to regional and inter-resource income distribution. Consumers constitute the remaining group in the system and, in most cases, are also proponents of an improved environment. The results show that a reduced level of soil loss is technically feasible through the imposition of appropriate per acre limits on sheet and rill erosion. The cost to the majority of society is reflected in the changing prices of the agricultural bill. The pricing system reflects

little change in the price of the agricultural bill, as the soil loss limit is initially reduced with a 10 ton restriction, Table 57. A restriction on soil loss at the 5 ton level results in all prices except milk increasing. Soybeans and cotton increase 15 and 12 percent, respectively, above their no soil loss restriction levels. The 3 ton restriction further increases prices on most commodities. Commodities such as soybeans, cotton and corn, which are included in the more highly erosive row crops category, have larger price increases than wheat. The price increases also are closely related to the regional patterns. Cotton and soybeans are grown extensively in the South Atlantic and South Central zones where crop production practices change more extensively than in the other areas when soil loss restrictions are imposed. The increased price of hay is related to the opportunity cost of row crops as the hay is included in rotations competing for the highly productive more erosive lands in the North and South Central zones.

Livestock prices reflect the changes in the prices of the major components of their rations. Beef production uses high levels of corn, hay and some soybeans. Pork production utilizes a large amount of the concentrates and thus its price follows the price of corn. Milk production, on the other hand, utilizes large quantities of the hays and silages and locationally concentrates in the West and Lake States

zones where the close-grown crops are produced. Also contributing to the lower increase in price is the relatively smaller feed cost as a proportion of total cost for dairy as compared to beef and pork.

The soil loss analysis indicates that the assumed demands can be met with little impact on the national agricultural sector and mild regional shifts. What if demand was greater? At what level could the conservation practices still maintain the soil loss restrictions? The next chapter deals with expanded demand possibilities in conjunction with a 5 ton per acre soil loss restriction. Demand is increased through exports for wheat, feed grains and soybeans, and production patterns and soil loss effects again are evaluated.

THE IMPACT OF EXPANDED EXPORTS

The previous section dealt with the impact within agriculture of alternative per acre soil loss restriction levels when agricultural exports were at 1969-71 annual average levels. Experiences in 1972 and 1973 have shown the possibility of greatly expanded levels for the export of feed grains, wheat and soybeans. Hence, two additional alternatives are considered in conjunction with the 5 ton soil loss restriction. Initially, the export levels of feed grains, wheat and oilmeals are doubled from the 1969-71 average annual level. Then they are increased to three times this level, Table 58.

Table 58. The level of export of the feed grains, wheat and oilmeals in 2000, with a 5 ton soil loss restriction.

Commodity (units)	Export alternative			
	69-71 ave	2 * ave	3 * ave	1973[a/]
		(000)		
Corn (bu.)	626333	1252666	1878999	1250000
Sorghum (bu.)	126666	253332	379998	190800
Barley (bu.)	48666	97332	145998	666300
Oats (bu.)	15666	31332	46998	23500
Wheat (bu.)	658719	1317438	1976157	1846600
Oilmeals (cwt.)	276407	552814	829218	317400

a/Represents exports during the 1972-73 crop year.

In formulating a policy encouraging expanded exports, the policy makers must consider alternative impacts similar to the decisions considered in determining the effects of the soil loss restrictions. Trade-offs in environmental quality result as greater output is developed. More land in production means more soil loss in total and possibly per acre if the new lands are not equally capable of receiving erosion control management. Also, greater quantities of inputs must be utilized, thus increasing the application of pesticides and fertilizers on a regional basis, if not on a per acre basis also.

Production Patterns Under Expanded Exports

Agricultural land use increases from 613 million under the 5 ton average export model to 653 million acres acres when exports are doubled and to 702 million acres when exports are tripled, Table 59. Even though the increased exports were of the commodities associated with the row crop and close-grown crop categories, all acreage categories increase as exports are expanded. Rotation roughage crops increase as more erosive land is brought into production and the roughage is grown in rotation with the required crops. Even with the increase in rotation roughage crops the nonrotation or permanent roughage crops also increase in acreage indicating a greater roughage level in livestock rations as some of the grains previously fed are now allocat-

Table 59. National production of row crops, close-grown crops, rotation roughage crops, and permanent roughage crops with a 5 ton soil loss restriction and alternative export levels in 2000.

Land use	Export alternative		
	69-71 ave.	2 * ave	3 * ave
	(000 acres)		
Acres cultivated	258882	295047	337299
row crops	136035	159308	174495
close-grown crops	73478	84411	91746
rotation roughage crops	49369	51328	70988
Permanent roughage crops	334734	349349	354418
Summer fallow and exogenous crops	7788	8197	10316
Total agricultural lands	613310	652593	702033

Table 60. Acreage of cultivated land by region with a 5 ton soil loss restriction and alternative export levels in 2000.

Region	Export alternative		
	69-71 ave.	2 * ave	3 * ave
	(000 acres)		
National[a/]	258882	295049	337299
North Atlantic	6680	8187	10742
South Atlantic	10225	14401	18088
North Central	114340	127725	138711
South Central	66142	70409	78705
Great Plains	35367	46409	59437
North West	11603	12357	14494
South West	14487	15561	17055

[a/] Total does not sum due to rounding in the regional part.

ed to the export market. The summer fallow and exogenous crop category increases, Table 59, and with the fixed level of exogenous crops, this indicates an increase in summer fallow as the expanded agricultural plant moves to areas where summer fallow rotations are advantageous for production.

Land use and irrigated acreage

Regionally, the increased cultivated land concentrates more in the South Atlantic and Great Plains zones, Table 60. Nationally, cultivated acreage increases 14 percent as exports are doubled and an additional 14 percent as exports triple. Given the 5 ton soil loss restriction, the South Atlantic zone would gain the most from a doubling of exports as its cultivated acreage increases by 41 percent compared to 31 percent in the Great Plains, 23 percent in the North Atlantic, and only 12 percent in the North Central zones. Tripling exports of the feed grains, wheat and oilmeals indicates the capacity restraints in most zones, as those zones with the major increases under the doubling export alternative experience a reduced absolute and percentage increase in acreage with the further increase in exports. The North Central zone, where production concentrated under the soil loss restrictions, and the associated lower export levels, increases its acreage only 12 percent as exports double and then only an additional 9 percent as the exports triple.

Similar changes occur in the South Atlantic and Great Plains while the North Atlantic, South Central and Western zones increase proportionately more after exports double, Table 60.

Irrigated lands for all uses increase from 29 million acres under the 5 ton average export model, Table 33, to 30 million acres when exports are doubled, Table 61, and to 33 million acres as exports are tripled, Table 62. This represents only an initial 3 percent and subsequent 10 percent increase in irrigated acreage as exports increase, compared to a 14 percent increase for total cultivated acreage at each subsequent increase of exports. Most of the increase in irrigated acreage is for close-grown crops with minor changes for other cropping uses. The small increase in acreage for the row crops occurs on the class I and II land while the increase in irrigated acreage of close-grown crops occurs on all land classes, with the other III and IV class experiencing the largest percentage increase.

Regionally, the pattern shifts as the increase in irrigated row crops occurs in the Great Plains and the South Central while the Western zones have reductions in irrigated row crop acreage. No zone has a decline in total irrigated acreage. The Great Plains has a reduction in irrigated pasture, moving water to higher valued uses, while the North West has an increase in irrigated pasture as exports of wheat, feed grains and oilmeals increase.

Table 61. Irrigated acreages in major zones with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)

Zone and soil class	Row	Close grown	All hay	Pasture	Other	Total
			(000 acres)			
United States	7096	7874	12341	931	1619	29861
I,II	5517	4096	4906	0	948	15467
IIIE,IVE	579	1412	626	0	205	2822
Other III,IV	976	2364	693	0	444	4477
V-VIII	24	2	0	0	22	48
North Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	2	0	445	0	0	447
I,II	2	0	336	0	0	338
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	109	0	0	109
V-VIII	0	0	0	0	0	0
South Central	1110	995	407	0	92	2604
I,II	952	632	304	0	91	1979
IIIE,IVE	47	70	80	0	1	198
Other III,IV	111	292	5	0	0	408
V-VIII	0	1	0	0	0	1
Great Plains	2939	1525	7042	464	8	11978
I,II	2330	836	2485	0	3	5654
IIIE,IVE	342	451	271	0	3	1067
Other III,IV	261	238	373	0	2	874
V-VIII	6	0	0	0	0	6
North West	1447	2117	2189	420	701	6874
I,II	933	1062	682	0	450	3127
IIIE,IVE	122	467	260	0	100	949
Other III,IV	379	587	193	0	140	1299
V-VIII	13	1	0	0	11	25
South West	1598	3237	2258	47	818	7958
I,II	1300	1566	1099	0	404	4369
IIIE,IVE	68	424	15	0	101	608
Other III,IV	225	1247	13	0	302	1787
V-VIII	5	0	0	0	11	16

[a/] Including other hay and cropland pasture.
[b/] Summer fallow lands and orchards and vineyards.

Table 62. Irrigated acreages in major zones with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)

Zone and soil class	Row	Close grown	All hay[a]	Pasture	Other[b]	Total
			(000 acres)			
United States	7702	9480	12872	1300	1619	32973
I,II	6181	4500	4507	0	948	16136
IIIE,IVE	568	1801	964	0	205	3538
Other III,IV	929	3177	1011	0	444	5561
V-VIII	24	2	3	0	22	51
North Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	0	0	0	0	0	0
I,II	0	0	0	0	0	0
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	0	0	0	0
V-VIII	0	0	0	0	0	0
North Central	20	0	435	0	0	455
I,II	20	0	326	0	0	346
IIIE,IVE	0	0	0	0	0	0
Other III,IV	0	0	109	0	0	109
V-VIII	0	0	0	0	0	0
South Central	1035	1037	447	0	92	2611
I,II	873	671	343	0	91	1978
IIIE,IVE	48	70	81	0	1	200
Other III,IV	114	295	5	0	0	414
V-VIII	0	1	0	0	0	1
Great Plains	3781	1933	6830	470	8	13022
I,II	3201	857	1991	0	3	6052
IIIE,IVE	313	603	537	0	3	1456
Other III,IV	261	473	388	0	2	1124
V-VIII	6	0	1	0	0	7
North West	1356	2945	2819	781	701	8602
I,II	882	1117	681	0	450	3130
IIIE,IVE	132	665	317	0	100	1214
Other III,IV	329	1162	496	0	140	2127
V-VIII	13	1	0	0	11	25
South West	1510	3565	2341	49	818	8283
I,II	1205	1855	1166	0	404	4630
IIIE,IVE	75	463	29	0	101	668
Other III,IV	225	1247	13	0	302	1787
V-VIII	5	0	2	0	11	18

[a] Including other hay and cropland pasture.
[b] Summer fallow lands and orchards and vineyards.

Dryland row crops concentrate on less erosive lands and into regions which have the comparative advantage in their production. The acreage of row crops in the North and South West zones declines as the export levels increase but the total cultivated lands are not decreased as these regions have a substantial increase in the acreage of the close-grown crops, Tables 30, 63 and 64. In the South West, even with the decline in total row crop acreage, there is an increase in acreage of row crops on class I and II lands as exports increase. The acreage of close-grown crops increases in all regions as exports increase. In many zones the largest proportion of the increase is on the IIIE and IVE and other III and IV land groups. This is consistent with the erosive characteristics of the close-grown crops and the erosion potential of the lands.

Average yields

Increased exports and expanded production levels affect yields, since different land classes and regions shift between dryland and irrigated patterns. Average yields of most crops decline as exports increase. With doubled exports, yield increases are experienced by barley as regional shifts put this crop on higher yielding class IIIE and IVE lands, which in turn offset the decline in irrigated yield, Tables 38 and 65. Corn silage also increases in yield as it is

Table 63. Dryland acreages in major zones with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)

Zone and soil class	Row	Close grown	All hay[a/]	Pasture	Other[b/]	Total
			(000 acres)			
United States	152212	76537	74800	312605	6578	622732
I,II	110722	39822	31198	0	1714	183456
IIIE,IVE	20351	26510	17121	0	2023	66005
Other III,IV	20922	9905	8046	0	2600	41473
V-VIII	217	300	231	0	241	989
North Atlantic	5010	3146	2299	6457	295	17207
I,II	3824	2130	577	0	137	6668
IIIE,IVE	265	959	172	0	81	1477
Other III,IV	906	54	109	0	45	1114
V-VIII	15	3	0	0	32	50
South Atlantic	13447	1411	3386	26674	1605	46523
I,II	9655	907	1734	0	229	12525
IIIE,IVE	976	309	389	0	70	1744
Other III,IV	2732	192	29	0	1166	4119
V-VIII	84	3	0	0	140	227
North Central	94839	20828	21267	33279	215	170428
I,II	73184	15593	9546	0	70	98393
IIIE,IVE	11026	3991	4980	0	54	20051
Other III,IV	10603	1226	833	0	70	12732
V-VIII	26	18	0	0	21	65
South Central	26359	20614	26421	107825	782	182001
I,II	14952	8860	10646	0	206	34664
IIIE,IVE	6468	6980	6880	0	221	20549
Other III,IV	4916	4710	5801	0	331	15758
V-VIII	23	64	31	0	24	142
Great Plains	8942	17795	16239	43016	3407	89399
I,II	8146	8909	7281	0	1020	25356
IIIE,IVE	697	6111	2870	0	1429	11107
Other III,IV	72	2718	325	0	958	4073
V-VIII	27	57	0	0	0	84
North West	404	6796	3231	27013	219	37663
I,II	146	1155	1055	0	37	2393
IIIE,IVE	37	4657	515	0	145	5354
Other III,IV	207	968	844	0	23	2042
V-VIII	14	16	23	0	14	67
South West	3211	5947	1957	68341	55	79511
I,II	815	2268	359	0	15	3457
IIIE,IVE	882	3503	1315	0	23	5723
Other III,IV	1486	37	105	0	7	1635
V-VIII	28	139	177	0	10	354

[a/] Including other hay and cropland pasture.
[b/] Summer fallow lands and orchards and vineyards.

Table 64. Dryland acreages in major zones with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)

Zone and soil class	Row	Close grown	All hay[a/]	Pasture	Other[b/]	Total
			(000 acres)			
United States	174495	91746	76233	317889	8697	669060
I,II	117651	41448	23743	0	1953	184795
IIIE,IVE	29079	32865	22039	0	2769	86752
Other III,IV	27363	17071	10123	0	3734	58291
V-VIII	402	362	726	0	241	1731
North Atlantic	7043	3342	3779	6416	295	20875
I,II	4589	1635	438	0	137	6799
IIIE,IVE	611	1397	634	0	81	2723
Other III,IV	1828	307	108	0	45	2288
V-VIII	15	3	0	0	32	50
South Atlantic	16238	1739	4082	28740	1605	52404
I,II	10641	1070	1219	0	229	13159
IIIE,IVE	1521	421	1168	0	70	3180
Other III,IV	3992	245	322	0	1166	5725
V-VIII	84	3	0	0	140	227
North Central	104479	25995	17423	28795	215	176907
I,II	77207	16319	5590	0	70	99186
IIIE,IVE	15040	5636	4656	0	54	25386
Other III,IV	12048	3936	923	0	70	16977
V-VIII	184	104	346	0	21	655
South Central	32258	21799	26933	107087	1575	189652
I,II	16322	8529	9622	0	251	34724
IIIE,IVE	7937	7673	7932	0	518	24060
Other III,IV	7949	5490	6156	0	782	20377
V-VIII	50	107	59	0	24	240
Great Plains	11483	24142	17932	44001	4779	102337
I,II	8026	10409	5619	0	1214	25268
IIIE,IVE	3051	9474	5691	0	1924	20140
Other III,IV	379	4195	832	0	1641	7047
V-VIII	27	64	27	0	0	118
North West	335	7505	3679	29398	173	41090
I,II	77	1275	1044	0	37	2433
IIIE,IVE	37	4708	643	0	99	5487
Other III,IV	207	1506	1156	0	23	2892
V-VIII	14	16	42	0	14	86
South West	2659	7224	2405	73452	55	85795
I,II	789	2211	211	0	15	3226
IIIE,IVE	882	3556	1315	0	23	5776
Other III,IV	960	1392	626	0	7	2985
V-VIII	28	65	252	0	10	355

[a/] Including other hay and cropland pasture.
[b/] Summer fallow lands and orchards and vineyards.

Table 65. Acreage and average yield of crops by land class in the United States with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Barley	(000 acres)			(bu./acre)		
I,II	3463	832	4295	68.9	83.3	71.7
IIIE,IVE	4119	223	4342	63.3	56.5	63.0
Other III,IV	1915	1427	3343	47.5	61.5	53.5
V-VIII	0	0	0	0.0	0.0	0.0
Total	9497	2482	11979	62.2	68.4	63.4
Corn grain	(000 acres)			(bu./acre)		
I,II	48037	1909	49946	120.8	148.0	121.8
IIIE,IVE	8881	154	9036	109.3	89.8	109.0
Other III,IV	6628	91	6719	88.1	97.1	88.2
V-VIII	0	0	0	0.0	0.0	0.0
Total	63546	2155	65700	115.8	141.7	116.6
Corn silage	(000 acres)			(tons/acre)		
I,II	2174	169	2344	14.6	17.4	14.8
IIIE,IVE	184	41	225	12.6	12.9	12.6
Other III,IV	129	61	189	10.9	13.3	11.7
V-VIII	0	0	0	0.0	0.0	0.0
Total	2487	271	2757	14.3	15.8	14.4
Cotton	(000 acres)			(bales/acre)		
I,II	3652	331	3983	1.9	2.1	1.9
IIIE,IVE	1134	11	1145	1.7	1.2	1.7
Other III,IV	415	0	415	1.5	0.0	1.5
V-VIII	0	0	0	0.0	0.0	0.0
Total	5201	342	5543	1.8	2.0	1.8
Legume hay	(000 acres)			(tons/acre)		
I,II	19202	4625	23827	3.8	7.3	4.5
IIIE,IVE	11164	466	11630	3.1	4.1	3.2
Other III,IV	6208	562	6770	3.7	4.8	3.8
V-VIII	36	0	36	4.0	0.0	4.0
Total	36610	5653	42263	3.6	6.8	4.0
Nonlegume hay	(000 acres)			(tons/acre)		
I,II	11995	281	12276	2.4	2.9	2.4
IIIE,IVE	5957	160	6117	2.2	2.3	2.2
Other III,IV	1838	131	1968	2.1	1.4	2.1
V-VIII	194	0	194	1.2	0.0	1.2
Total	19984	572	20556	2.3	2.4	2.3

Table 65. (Continued)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Oats	(000 acres)			(bu./acre)		
I,II	4427	313	4739	73.5	84.7	74.2
IIIE,IVE	2245	31	2276	52.1	63.7	52.3
Other III,IV	569	53	622	64.1	70.6	64.6
V-VIII	46	0	46	14.4	0.0	14.4
Total	7287	396	7683	65.8	81.2	66.6
Sorghum grain	(000 acres)			(bu./acre)		
I,II	6133	869	7001	70.5	128.6	77.7
IIIE,IVE	1638	48	1686	38.1	74.2	39.2
Other III,IV	3838	69	3907	45.4	60.9	45.6
V-VIII	0	1	1	0.0	37.0	37.0
Total	11609	986	12596	57.6	121.1	62.6
Sorghum silage	(000 acres)			(tons/acre)		
I,II	1671	19	1690	11.7	26.0	11.8
IIIE,IVE	349	0	349	10.3	0.0	10.3
Other III,IV	107	7	114	9.0	13.0	9.2
V-VIII	0	0	0	0.0	0.0	0.0
Total	2127	26	2153	11.3	22.6	11.5
Soybeans	(000 acres)			(bu./acre)		
I,II	43370	173	43543	43.8	54.7	43.9
IIIE,IVE	7081	6	7087	38.7	35.4	38.7
Other III,IV	7560	2	7563	37.2	41.1	37.2
V-VIII	0	0	0	0.0	15.9	15.9
Total	58011	182	58193	42.3	53.9	42.4
Sugar beets	(000 acres)			(tons/acre)		
I,II	1072	293	1365	17.9	23.6	19.1
IIIE,IVE	0	36	36	0.0	19.3	19.3
Other III,IV	115	83	198	21.0	20.6	20.8
V-VIII	0	0	0	0.0	0.0	0.0
Total	1187	412	1599	18.2	22.6	19.3
Wheat	(000 acres)			(bu./acre)		
I,II	30086	2661	32747	37.7	63.7	39.8
IIIE,IVE	19353	1137	20490	32.8	45.6	33.5
Other III,IV	6338	278	6616	38.1	52.4	38.7
V-VIII	149	0	149	13.4	0.0	13.4
Total	55926	4076	60003	36.0	57.9	37.5
Other hay	(000 acres)			(tons/acre)		
Total	18205	6117	24321	1.7	3.6	2.2
Pasture	(000 acres)			(tons/acre)		
Total	312605	931	313537	0.6	2.8	0.6

shifted to class I and II lands. The yield increase for silage also occurs as total acreage declines from 5.5 million acres under average exports to 2.8 million acres under doubled exports. Remaining silage production is located on the lands where it is the most productive. Sorghum yields increase as more of it is produced on class I and II lands for both dryland and irrigated production. Yields do not continue to increase as exports move up from double to triple the 1969-71 level, Tables 65 and 66.

Soil loss levels

Increased exports require a greater level of output available only from greater inputs, especially land. Increased use of land results in a higher soil loss level. Under a 5 ton soil loss and average export alternative, national soil loss is 726 million tons, Table 14. This increases to 843 million tons under doubled exports, Table 67, and to 974 million tons under tripled exports, Table 68. Thus, doubling exports increases soil loss by only 16 percent and tripling exports increases soil loss an additional 16 percent. This compares with a 14 percent increase in cultivated acreage as exports initially double and then another 14 percent increase as exports triple.

The regional total soil losses follow closely the regional increases in acreage, except for the North West zone where a decline of 1 million tons of soil loss occurs as

Table 66. Acreage and average yield of crops by land class in the United States with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Barley	(000 acres)			(bu./acre)		
I,II	2522	785	3307	64.8	82.6	69.0
IIIE,IVE	4321	325	4646	58.9	53.3	58.5
Other III,IV	2246	1439	3685	52.3	61.8	56.4
V-VIII	15	0	15	31.9	0.0	31.9
Total	9104	2549	11653	59.0	67.1	60.8
Corn grain	(000 acres)			(bu./acre)		
I,II	50748	2391	53139	120.2	152.8	121.7
IIIE,IVE	12319	141	12460	102.4	95.3	102.3
Other III,IV	9256	81	9337	82.6	90.7	82.7
V-VIII	94	0	94	51.9	0.0	51.9
Total	72417	2613	75030	112.3	147.8	113.5
Corn silage	(000 acres)			(tons/acre)		
I,II	862	72	934	16.0	16.6	16.1
IIIE,IVE	152	30	182	12.9	15.7	13.4
Other III,IV	127	48	174	9.0	12.8	10.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	1141	149	1290	14.8	15.2	14.9
Cotton	(000 acres)			(bales/acre)		
I,II	3720	310	4030	1.9	2.0	1.9
IIIE,IVE	1103	12	1115	1.6	1.1	1.6
Other III,IV	684	0	684	1.1	0.0	1.1
V-VIII	0	0	0	0.0	0.0	0.0
Total	5507	322	5829	1.7	2.0	1.7
Legume hay	(000 acres)			(tons/acre)		
I,II	15557	4150	19707	3.9	7.3	4.6
IIIE,IVE	14954	688	15642	3.1	4.2	3.1
Other III,IV	7771	894	8665	3.6	4.4	3.6
V-VIII	68	3	71	3.8	3.6	3.8
Total	38350	5735	44085	3.5	6.5	3.9
Nonlegume hay	(000 acres)			(tons/acre)		
I,II	8185	358	8542	2.4	2.9	2.4
IIIE,IVE	7084	276	7359	2.0	2.4	2.0
Other III,IV	2353	116	2469	1.9	1.9	1.9
V-VIII	658	0	658	1.4	0.0	1.4
Total	18279	750	19029	2.1	2.5	2.1

Table 66. (Continued)

Crop and land class	Acreage			Yield		
	Dryland	Irrig.	Total	Dryland	Irrig.	Total
Oats	(000 acres)			(bu./acre)		
I,II	3992	313	4306	74.7	84.8	75.5
IIIE,IVE	2975	33	3008	54.5	62.9	54.6
Other III,IV	1145	15	1161	55.2	47.7	55.1
V-VIII	136	0	136	26.4	0.0	26.4
Total	8249	362	8611	63.9	81.2	64.6
Sorghum grain	(000 acres)			(bu./acre)		
I,II	7029	895	7925	72.0	121.1	77.5
IIIE,IVE	2741	44	2785	41.0	71.5	41.5
Other III,IV	3868	73	3941	47.2	61.3	47.5
V-VIII	47	1	48	33.9	37.0	33.9
Total	13685	1013	14699	58.7	114.5	62.5
Sorghum silage	(000 acres)			(tons/acre)		
I,II	1421	10	1432	10.8	26.0	10.9
IIIE,IVE	76	0	76	9.6	0.0	9.6
Other III,IV	54	7	61	13.2	13.0	13.2
V-VIII	0	0	0	0.0	0.0	0.0
Total	1551	17	1568	10.8	20.8	11.0
Soybeans	(000 acres)			(bu./acre)		
I,II	48142	458	48600	43.9	56.5	44.0
IIIE,IVE	11605	6	11610	38.1	35.4	38.1
Other III,IV	11130	2	11132	36.4	41.1	36.4
V-VIII	44	0	45	14.6	15.9	14.6
Total	70920	466	71387	41.7	56.2	41.8
Sugar beets	(000 acres)			(tons/acre)		
I,II	1115	293	1407	17.6	23.3	18.8
IIIE,IVE	0	52	52	0.0	19.6	19.6
Other III,IV	115	54	169	21.0	18.4	20.2
V-VIII	0	0	0	0.0	0.0	0.0
Total	1230	399	1628	17.9	22.2	19.0
Wheat	(000 acres)			(bu./acre)		
I,II	33086	3113	36199	38.3	62.5	40.4
IIIE,IVE	24776	1423	26198	32.1	45.8	32.8
Other III,IV	12596	1118	13714	32.4	51.1	34.0
V-VIII	105	0	105	19.8	32.0	19.8
Total	70563	5654	76216	35.0	56.1	36.6
Other hay	(000 acres)			(tons/acre)		
Total	19602	6387	25990	1.7	3.6	2.2
Pasture	(000 acres)			(tons/acre)		
Total	317889	1301	319190	0.6	2.8	0.6

Table 67. Total soil erosion on cultivated lands in major zones with a 5 ton soil loss restriction and double 1969-71 average level exports in 2000[a/]

Zone	Land Class I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(million tons)				
United States	517	214	111	1	843
North Atlantic	21	6	3	0	30
South Atlantic	36	5	8	0	49
North Central	262	71	32	0	365
South Central	115	80	59	0	254
Great Plains	60	23	3	0	86
North West	6	11	2	0	19
South West	16	19	5	0	40

[a/]For all cultivated crops including rotation hay.

Table 68. Total soil erosion on cultivated lands in major zones with a 5 ton soil loss restriction and triple 1969-71 average level exports in 2000[a/]

Zone	Land Class I,II	IIIE-IVE	other III-IV	V-VIII	Total
	(million tons)				
United States	527	287	156	4	974
North Atlantic	23	11	8	0	42
South Atlantic	36	10	13	0	59
North Central	269	97	36	2	404
South Central	114	94	78	1	287
Great Plains	63	46	10	0	119
North West	6	10	4	0	20
South West	16	18	8	1	43

[a/]For all cultivated crops including rotation hay.

exports levels are doubled, Tables 14 and 67. The decline in the North West occurs while cultivated acreage increases by 754 thousand acres, Table 60. However, the shift from row crop to close-grown crops reduces the per acre soil loss and the total loss in the zone. The Great Plains zone has the largest percent increase in soil loss, 62 percent, as exports are doubled, compared to only a 31 percent increase in acreage, Table 60. When exports increase to three times the average level, soil loss increases only 38 percent in the Great Plains, Table 68, compared to a 28 percent increase in acreage, Table 60.

The increase in total soil loss from land classes IIIE and IVE in most regions is more than proportionate to the increase in acreage on the land class. Land classes I and II do not have proportionate increases in total soil loss. These shifts are consistent with the relative erodibility of soils in the various regions. The IIIE and IVE lands are incorporated into production under higher exports in the South Central, North Central and South Atlantic regions where erosion is already high. The class I and II lands are incorporated in the Great Plains and the North and South West zones where erosion is lower.

On a per acre basis at the national level, soil loss increases by 0.1 tons per acre as exports double. By land class, increase in per acre soil loss occur only on the

class IIIE and IVE (0.1 tons) and class V-VIII (0.3 tons), Tables 20 and 69. This is consistent with the erodibility characteristics of these land classes and the utilization of more of the regionally less productive lands. The declines in per acre soil loss in the North West and the small increase in the South Atlantic and North Central, where large acreages exist, influence the national weighted average such that it reflects very little change in per acre soil loss (0.1 tons per acre).

Tripled exports result in no further increase in average national per acre soil loss, even though a large increase, 1.2 tons per acre, occurs on the V-VIII land class, Tables 69 and 70. The reason for the small change is the relatively small acreage of this land group and the small changes in the other land classes. Regionally, tripled exports reduce average per acre soil loss in the South Atlantic below the doubled export level, Table 71.

The 5 ton soil loss situation in combination with export increases has a major effect on the farming practices utilized for the increased production. Doubling exports increases cultivated acreage by 14 percent but conventional tillage methods increase by only 10 percent, Tables 27 and 72. Within the conventional tillage practices, straight-row farming increases by only 3 percent while contouring increases 16 percent and strip cropping-terracing increases by

Table 69. Per acre soil erosion on cultivated lands in major zones with 5 ton soil loss restriction and double 1969-71 average level exports in 2000

Zone	Land class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Average
	(tons per acre)				
United States	2.7	3.2	2.8	1.8	2.9
North Atlantic	3.5	4.6	3.3	0	3.9
South Atlantic	3.4	3.6	3.5	0	3.4
North Central	2.8	3.6	2.7	0	2.9
South Central	3.2	4.0	4.0	1.1	3.6
Great Plains	2.0	2.0	0.5	0	1.8
North West	1.5	1.9	0.9	2.1	1.6
South West	2.5	3.2	1.9	1.9	2.6

Table 70. Per acre soil erosion on cultivated lands in major zones with 5 ton soil loss restriction and triple 1969-71 average level exports in 2000

Zone	Land class				
	I,II	IIIE-IVE	other III-IV	V-VIII	Average
	(tons per acre)				
United States	2.8	3.2	2.7	3.0	2.9
North Atlantic	3.8	4.3	3.7	0	3.9
South Atlantic	3.1	3.5	3.5	0	3.2
North Central	2.8	3.8	2.2	3.8	2.9
South Central	3.2	4.1	1.9	2.8	3.6
Great Plains	2.1	4.5	1.2	3.1	2.0
North West	1.4	1.8	0.9	3.3	1.4
South West	2.5	3.0	1.8	1.7	2.5

29 percent. In absolute values, conventional tillage increases by 20.6 million acres while the reduced tillage alternatives increase by 15.5 million acres.

Table 71. Average acre soil loss under alternative soil conservation practices with a 5 ton soil loss restriction and alternative export levels in 2000

Conservation practice	Export alternative		
	69-71 ave	2 * ave	3 * ave
	(tons per acre)		
Conventional tillage			
straight row	2.5	2.5	2.4
contouring	3.1	3.1	3.1
strip crop-terracing	3.3	3.3	3.1
Reduced tillage			
straight row	2.7	2.9	3.0
contouring	3.7	3.7	3.8
strip crop-terracing	2.9	3.0	3.3

Tripled exports increase cultivated acreage by a further 14 percent and conventional tillage by an additional 11 percent, Table 73. Within the conventional tillage practices straight row farming does not increase, contouring increases 12 percent and strip cropping-terracing increases by 42 percent. Under reduced tillage practices straight row acreages increase 17 percent, contouring 20 percent and strip cropping-terracing by 42 percent.

Regional and land class land-use patterns do not necessarily follow the national pattern. Under the doubling of grain exports, the increase in straight row farming occurs mostly on the other III and IV land class, while most of the

Table 72. Acreages under conservation practices in major zones with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)[a/]

Zone and soil class	Conventional tillage			Reduced tillage		
	Str. row	Contour only	S. crop terrace	Str. row	Contour only	S. crop terrace
	(000 acres)					
United States	133449	43103	45304	28354	25743	19094
I,II	85140	28753	23747	20151	20169	10928
IIIE,IVE	29092	11441	10013	5740	4215	5545
Other III,IV	18791	2909	11544	2463	1359	2621
V-VIII	427	0	0	0	0	0
North Atlantic	2614	1751	3098	154	252	318
I,II	2011	1463	2144	141	252	0
IIIE,IVE	246	66	652	0	0	318
Other III,IV	358	222	302	14	0	0
V-VIII	0	0	0	0	0	0
South Atlantic	2536	4436	3474	1520	676	1759
I,II	2293	3593	1958	1120	200	1719
IIIE,IVE	113	103	847	320	0	39
Other III,IV	130	740	669	80	476	0
V-VIII	0	0	0	0	0	0
North Central	48297	18808	3789	23822	17332	15677
I,II	37237	16175	2271	16548	15211	8524
IIIE,IVE	6156	1340	609	4928	2121	4559
Other III,IV	4903	1293	910	2347	0	2594
V-VIII	0	0	0	0	0	0
South Central	26865	12782	21506	1191	6724	1341
I,II	17450	5127	7439	690	3747	684
IIIE,IVE	5386	7003	4664	489	2094	629
Other III,IV	3943	653	9403	12	883	28
V-VIII	85	0	0	0	0	0
Great Plains	28904	2709	12371	1667	758	0
I,II	15947	1910	9935	1653	758	0
IIIE,IVE	8575	798	2176	4	0	0
Other III,IV	4383	0	260	10	0	0
V-VIII	0	0	0	0	0	0
North West	9366	1925	1066	0	0	0
I,II	4258	0	0	0	0	0
IIIE,IVE	2766	1925	1066	0	0	0
Other III,IV	2317	0	0	0	0	0
V-VIII	26	0	0	0	0	0
South West	14868	693	0	0	0	0
I,II	5945	486	0	0	0	0
IIIE,IVE	5851	207	0	0	0	0
Other III,IV	2756	0	0	0	0	0
V-VIII	316	0	0	0	0	0

[a/] For all cultivated crops including rotation hay.

Table 73. Acreages under conservation practices in major zones with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)[a/]

Zone and soil class	Conventional tillage			Reduced tillage		
	Str. row	Contour only	S. crop terrace	Str. row	Contour only	S. crop terrace
	(000 acres)					
United States	133298	48190	64500	33289	30839	27113
I,II	74528	29400	29318	22826	23010	11830
IIIE,IVE	30350	14322	18567	7090	5524	11698
Other III,IV	27902	4403	16615	3305	1783	3584
V-VIII	518	64	0	68	522	0
North Atlantic	2593	2996	4256	382	139	376
I,II	1565	1770	2453	216	139	0
IIIE,IVE	421	319	1466	5	0	318
Other III,IV	608	907	337	161	0	58
V-VIII	0	0	0	0	0	0
South Atlantic	1142	4548	4301	3654	1532	2911
I,II	592	3371	2283	1886	762	2631
IIIE,IVE	251	215	1201	1008	0	185
Other III,IV	300	961	818	759	769	95
V-VIII	0	0	0	0	0	0
North Central	42764	21357	8604	24856	20440	20690
I,II	32460	17351	3924	17023	17490	8520
IIIE,IVE	3167	2553	1849	5583	2332	9577
Other III,IV	7137	1454	2831	2181	96	2594
V-VIII	0	0	0	68	522	0
South Central	25757	14444	26708	1489	7659	2648
I,II	15856	4989	9183	922	3565	680
IIIE,IVE	4771	8499	5695	490	3191	1130
Other III,IV	4976	926	11831	77	902	838
V-VIII	153	30	0	0	0	0
Great Plains	33060	2254	19656	2910	1069	488
I,II	13755	1461	11476	2780	1054	0
IIIE,IVE	12523	605	7381	4	0	488
Other III,IV	6781	155	799	126	16	0
V-VIII	1	34	0	0	0	0
North West	11594	1925	975	0	0	0
I,II	4301	0	0	0	0	0
IIIE,IVE	3254	1925	975	0	0	0
Other III,IV	3994	0	0	0	0	0
V-VIII	45	0	0	0	0	0
South West	16388	667	0	0	0	0
I,II	6000	459	0	0	0	0
IIIE,IVE	5963	207	0	0	0	0
Other III,IV	4106	0	0	0	0	0
V-VIII	318	0	0	0	0	0

[a/] For all cultivated crops including rotation hay.

increase in the acreage for the other land classes occurs in the contouring and strip cropping-terracing alternatives. The South Atlantic and South Central zones have a reduction in conventional tillage-straight row farming as exports expand. The decrease is offset by an increase in reduced tillage and the conservation techniques, Tables 27, 72 and 73. The conventional tillage-straight row farming practices increase in the Great Plains, North West and South West. Also, in these zones erosion is not as great a hazard and the increased straight row farming occurs on all land classes. In these three zones with the tripling of exports, reduced tillage only amounts to 3.7 million acres, up from the 1.2 million acres under average exports.

Resource use patterns

Nationally, total per acre resource input for row crops increases from $82.51 under the average level export alternative, Table 43, to $91.68 under double exports, Table 74, and to $120.38 when exports are tripled, Table 75. Costs increase at an increasing rate as the marginal product of the variable inputs declines and the implied return to the more productive fixed inputs increases. Close-grown crops do not increase to a similar dollar level, but on a percentage basis the increase in return for the close-grown crops is greater than for row crops (16.5 percent compared to 11.1 percent as exports double and 56.4 percent compared to 45.9 percent when

Table 74. Value of resource use in crop production by major zones in the United States for 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)

Zone-item	Land	Water	Labor	Mach	Pest	Other	Total
			($ per acre)[c/]				
United States							
Row crops[a/]	29.64	0.20	6.10	38.52	5.71	11.48	91.68
Close crops[b/]	15.96	0.20	3.50	25.61	0.89	2.92	49.11
North Atlantic							
Row crops	14.18	0.00	9.19	62.11	3.20	17.59	106.28
Close crops	13.40	0.00	6.41	42.82	1.96	14.88	79.48
South Atlantic							
Row crops	13.41	0.00	8.34	42.15	6.86	19.18	89.95
Close crops	18.44	0.00	4.45	36.32	1.95	15.33	76.51
North Central							
Row crops	35.93	0.00	5.22	36.34	6.37	12.25	96.13
Close crops	18.28	0.00	3.32	24.97	1.88	4.11	52.58
South Central							
Row crops	30.43	0.05	7.35	41.75	5.21	6.51	91.32
Close crops	23.96	0.03	3.35	26.40	0.51	1.06	55.34
Great Plains							
Row crops	12.25	0.86	5.87	40.72	3.68	8.69	72.09
Close crops	6.20	0.07	3.21	26.03	0.35	0.28	36.16
North West							
Row crops	9.56	1.37	9.29	18.24	0.42	13.53	52.44
Close crops	16.14	0.18	4.17	24.86	1.03	4.83	51.22
South West							
Row crops	13.30	3.69	6.19	30.69	2.07	3.03	59.00
Close crops	12.71	1.45	3.05	17.56	0.06	2.33	37.18

[a/] Includes corn, cotton, sorghum, soybeans and sugar beets.
[b/] Includes barley, oats and wheat.
[c/] Values are in terms of 1972 dollars.

Table 75. Value of resource use in crop production by major zones in the United States for 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)

Zone-item	Land	Water	Labor	Mach	Pest	Other	Total
			($ per acre)[c]				
United States							
Row crops[a]	56.38	0.27	6.03	39.94	6.13	11.60	120.38
Close crops[b]	31.51	0.22	3.53	26.03	0.95	3.62	65.89
North Atlantic							
Row crops	31.88	0.00	10.09	68.60	3.74	19.10	133.43
Close crops	34.42	0.00	7.08	46.63	1.88	15.14	105.18
South Atlantic							
Row crops	36.15	0.00	8.09	44.03	8.35	19.32	115.95
Close crops	39.59	0.00	4.66	36.97	4.18	16.68	102.11
North Central							
Row crops	67.21	0.00	5.15	36.61	6.62	12.11	127.70
Close crops	37.88	0.00	3.34	25.22	1.92	4.53	72.92
South Central							
Row crops	53.83	0.04	7.13	44.31	5.33	6.63	117.30
Close crops	41.03	0.03	3.35	26.69	0.52	1.61	73.26
Great Plains							
Row crops	34.80	1.52	5.53	41.47	5.06	9.31	97.72
Close crops	18.29	0.07	3.19	26.43	0.32	2.12	50.45
North West							
Row crops	14.94	1.46	7.53	15.37	0.25	13.07	52.65
Close crops	34.69	0.26	4.39	25.61	1.05	5.57	71.60
South West							
Row crops	21.21	5.51	5.78	28.75	2.12	3.72	67.11
Close crops	22.70	1.57	3.08	17.86	0.08	1.78	47.08

[a] Includes corn, cotton, sorghum, soybeans and sugar beets.
[b] Includes barley, oats and wheat.
[c] Values are in terms of 1972 dollars.

exports increase from average to triple).

Most of the increase in return per acre results from the increased return to land. For row crops and as exports double, the $9.17 increase in per acre resource use results from an $8.50 increase in the return to land, leaving only $0.67 as the increase in return to other factors. Water receives a smaller return per acre mostly as a result of the large increase in total cultivated acres over which a small increase in water is allocated. In the zones where water is used, the per acre return to water reflects its greater use and value as its return increases.

Regional increases in return per acre for row crops varies as exports are increased. When exports double the regional percent increase in return per acre varies from -4.6 percent in the Great Plains to 13.7 percent in the North Central zone and 13.0 percent in the South Atlantic. The North Central and South Atlantic have almost equal percentage increases in total returns; however, in the North Central $10.99 of the $11.58 increased total return goes to land while in the South Atlantic only $4.65 of the $10.35 total increase goes to land. The remainder of the South Atlantic's increased return goes to the machinery, pesticide and other (fertilizer) categories. As exports of the feed grains, wheats and oilmeals increase, the Great Plains brings enough land into production to utilize the livestock wastes such

that the return to the other category increases and for close-grown crops is no longer negative as occurred with the average export alternative. This indicates a surplus demand situation for nitrogen wastes as opposed to the surplus supply situation which existed under the average exports and 5 ton soil loss restriction.

Shifts in returns among resources

The total return to each of the resources utilized in the agricultural sector increases as exports are expanded, except water when exports are doubled, Table 76. The reduced value of water results as land class and regional patterns shift the high-valued row crops out of the irrigated areas and substitute the lower-valued, close-grown crops. Also as land use increases the regional competitive advantage shifts to place more of the return on the productive land and if water is not the scarce resource, the returns are bid away from the water sector, causing a lower per unit value and a lower total return to the water sector. As exports triple, the demand for water increases further as essentially all irrigated land is utilized. Water then becomes a scarce resource in some regions. Returns to all agriculturally related sectors increase by 31 percent in total as exports double and 100 percent as they triple.

Land is the relatively larger gainer in return as exports are increased. The return to land increases by 66

Table 76. Returns to the national resource sectors of agriculture from the production of row crops and close-grown crops with a 5 ton soil loss restriction and alternative levels of exports in 2000.

Export level crop	Land	Water	Labor	Mach	Pest	Other	Total
			(million dollars)				
Ave. 1969-1971							
row crops	2876	44	870	5059	748	1623	11220
close crops	766	16	247	1825	54	186	3094
total	3642	60	1117	6884	802	1809	14314
2 * average							
row crops	4722	32	972	6137	910	1829	14605
close crops	1347	17	295	2162	75	246	4145
total	6069	49	1267	8299	985	2075	18750
3* average							
row crops	10272	49	1099	7277	1117	2113	21933
close crops	3190	22	357	2635	96	366	6670
total	13462	71	1456	9912	1213	2479	28603

percent as exports double and by 270 percent as exports triple. The pesticide sector receives the next largest relative gain with a 22 percent increase with doubled exports and a 51 percent increase if exports triple. Total returns for the labor sector increases by only 13 percent as exports double and by only 30 percent if exports triple. Returns to all agriculturally related sectors increase by 31 percent in total as exports double and 100 percent as they triple. Similarity in returns to labor, machinery, pesticide and "other" sectors results from their fixed per acre value. Increases in their share of the return results from increased acreages and shifts among regions, land classes, and conservation tillage methods. Land and water price, and returns are determined internally by the solution procedure. Hence, their returns are directly affected by commodity prices under the different export levels. Thus, as exports increase, the return to land and water is affected proportionally by price changes as well as by their respective levels of use.

Regionally, increases in returns range from 10 percent in the South West as exports double to 206 percent in the Great Plains as exports triple (Table 77). The large increase in the Great Plains results from the increased acreage as well as the increased per acre return from higher prices. Other zones, such as the North Central, South Central, and South West, have more modest increases since their acreage

Table 77. Total returns to the regional agricultural related sectors from the production of row crops and close-grown crops with a 5 ton soil loss restriction and alternative export levels in 2000

	Export alternative		
	69-71 ave	2 * ave	3 * ave
	(million dollars)[a/]		
United States			
row crops	11220	14605	21933
close crops	3094	4145	6670
total	14314	18750	28603
North Atlantic			
row crops	447	532	940
close crops	176	250	352
total	623	782	1292
South Atlantic			
row crops	801	1210	1883
close crops	53	108	178
total	854	1318	2061
North Central			
row crops	7161	9117	13345
close crops	812	1095	1896
total	7973	10212	15241
South Central			
row crops	1996	2508	3905
close crops	955	1196	1673
total	2951	3704	5578
Great Plains			
row crops	422	857	1492
close crops	494	699	1315
total	916	1556	2807
North West			
row crops	110	97	89
close crops	317	457	748
total	427	554	837
South West			
row crops	282	284	280
close crops	288	341	508
total	570	625	788

[a/] Values are expressed in terms of 1972 dollars.

expansions are not large under increased exports. In absolute terms the North Central zone has the largest increase in returns, from $7,573 million to $10,212 million as exports double and to $15,241 million as exports triple.

Individual land classes all have increases except the V-VIII class where the return per acre drops as more of it is used and the marginal return per acre is reduced, Tables 50, 78 and 79. With the 5 ton soil loss restriction and average exports, the class V-VIII lands have a $6.72 per acre rent (attributed mostly to the $16.50 return in the South West). Doubling exports increases the return to all lands except the V-VIII class in the South West. In the South Central and North West zones, the return to the V-VIII lands increases and is above the return to these lands in the South West. The return declines in the South West as V-VIII lands are now used to produce relatively more close-grown crops and hays, Table 60.

Use of water and nitrogen

Consumptive use of water for agriculture increases from 48.6 million acre feet under average exports to 50.3 million acre feet under doubled exports and to 55.4 million acre feet under tripled exports, Tables 54, 80 and 81. The Missouri and Texas-Gulf basins have no significant change in water use under increased exports but all other basins do have. The Lower Colorado basin has a decline in consumptive use of wa-

Table 78. Shadow prices(marginal value products) of alternative land classes in major zones in 2000 (Model E)

Zone	Land classes					
	I,II	IIIE,IVE	Other III-IV	V-VIII	Other[a]	Total[b]
	($ per acre)[c]					
United States	32.25	14.00	15.22	2.06	3.24	25.83
North Atlantic	20.00	0.00	5.39	0.00	1.84	15.27
South Atlantic	20.71	10.99	4.49	0.00	4.40	17.39
North Central	38.39	19.02	18.17	0.00	5.78	33.49
South Central	38.38	18.80	18.94	4.47	3.99	28.58
Great Plains	12.70	4.76	1.80	0.00	2.48	9.63
North West	37.16	10.86	13.29	8.81	2.86	20.37
South West	26.82	5.89	17.89	0.85	1.05	16.56

[a] Other hay and pasture lands.
[b] Excluding other hay and pasture lands.
[c] Values are expressed in terms of 1972 dollars.

Table 79. Shadow prices(marginal value products) of alternative land classes in major zones in 2000 (Model F)

Zone	Land classes					
	I,II	IIIE,IVE	Other III-IV	V-VIII	Other[a]	Total[b]
	($ per acre)[c]					
United States	61.33	30.48	29.66	6.07	4.14	47.72
North Atlantic	46.16	15.80	20.10	0.00	2.96	33.99
South Atlantic	51.27	22.11	26.16	0.00	4.12	41.52
North Central	71.45	41.81	41.30	2.61	7.14	62.26
South Central	65.35	39.36	33.60	19.82	4.77	49.51
Great Plains	34.10	14.01	9.49	0.00	4.54	23.72
North West	67.47	29.64	22.99	19.18	4.28	39.00
South West	44.95	17.07	17.87	3.34	1.60	27.57

[a] Other hay and pasture lands.
[b] Excluding other hay and pasture lands.
[c] Values are expressed in terms of 1972 dollars.

Table 80. Withdrawals and consumptive use of water in the western river basins with 5 ton maximum soil loss and double 69-71 exports in 2000 (Model E)

River basin	Total 1965[a]	Projected 2000			
		Agriculture	Municipal & industrial[b]	Other[c]	Total
	(000 acre feet per year)				
Withdrawals					
Western basins	151733	68207	51323	7429	126959
Missouri	21668	12958	6172	2218	21348
Ark.-White-Red	10541	6061	8395	0	14456
Texas-Gulf	18382	2231	16890	227	19348
Rio Grande	8165	3989	1222	0	5211
U. Colorado	4500	2554	1079	198	3831
L. Colorado	7774	2707	1457	2085	6249
Great Basin	5730	2136	1034	1276	4446
Col.-N. Pacific	33191	22986	8289	1425	32700
Cal.-S. Pacific	41782	12585	6785	0	19370
Consumptive use					
Western basins	75050	50343	21300	6613	78256
Missouri	11822	10013	1223	2218	13454
Ark.-White-Red	6580	4002	1400	0	5402
Texas-Gulf	8165	1490	7749	227	9466
Rio Grande	4632	1528	557	0	2085
U. Colorado	2220	2823	495	144	3462
L. Colorado	3862	2128	678	1851	4657
Great Basin	2524	1908	445	908	3261
Col.-N. Pacific	11785	17035	7171	1265	25471
Cal.-S. Pacific	23460	9416	1582	0	10998

[a] Source: (35A, Tables 7-3-4 and 7-3-5).

[b] Includes rural domestic, municipal, self-supplied industrial, recreation, mining and thermal electric power.

[c] Includes onsite uses and water exports out of the western basins.

Table 81. Withdrawals and consumptive use of water in the western river basins with 5 ton maximum soil loss and triple 69-71 exports in 2000 (Model F)

River basin	Total 1965[a]	Projected 2000			
		Agriculture	Municipal & industrial[b]	Other[c]	Total
	(000 acre feet per year)				
Withdrawals					
Western basins	151733	74390	51323	7429	133142
Missouri	21668	13313	6172	2218	21703
Ark.-White-Red	10541	6413	8395	0	14808
Texas-Gulf	18382	2246	16890	227	19363
Rio Grande	8165	4506	1222	0	5728
U. Colorado	4500	2883	1079	198	4160
L. Colorado	7774	2827	1457	2085	6369
Great Basin	5730	2308	1034	1276	4618
Col.-N. Pacific	33191	26518	8289	1425	36232
Cal.-S. Pacific	41782	13376	6785	0	20161
Consumptive use					
Western basins	75050	55458	21300	6613	83371
Missouri	11822	10174	1223	2218	13615
Ark.-White-Red	6580	4228	1400	0	5628
Texas-Gulf	8165	1505	7749	227	9481
Rio Grande	4632	1903	557	0	2460
U. Colorado	2220	3069	495	144	3708
L. Colorado	3862	2069	678	1851	4598
Great Basin	2524	2042	445	908	3395
Col.-N. Pacific	11785	20500	7171	1265	28936
Cal.-S. Pacific	23460	9968	1582	0	11550

[a] Source: (35A, Tables 7-3-4 and 7-3-5).

[b] Includes rural domestic, municipal, self-supplied industrial, recreation, mining and thermal electric power.

[c] Includes onsite uses and water exports out of the western basins.

ter for agriculture as more is transferred to the California-South Pacific basin for use in high return alternatives. The remaining river basins increase consumptive use of water as their acreage of irrigated lands increase.

Nitrogen use increases proportionate to the export levels, Table 82. Livestock production of nitrogen increases only slightly as rations, feeding period and regional production patterns adjust to changed exports. Legume-produced nitrogen increases in proportion to increased acreages, with an adjustment for the reduced yields resulting as the greater demands require use of the less productive lands. The major source for the increased fertilizer demand is associated with the commercial fertilizer sector. Its production increases from 6.5 billion pounds to 8.0 billion as exports double, then to 9.6 billion pounds of purchased fertilizer as exports triple.

Price and consumer impacts of export-increasing policies

Farm level prices under the greater export levels are indicated in Table 83. With a doubling of exports from the 1969-71 average level, soybeans undergo the largest percent increase in price. The shift in prices follows the comparative advantage in production. Cotton is not affected greatly since its demand is not increased and the areas producing cotton have a definite advantage for it (i.e., land is not among most productive for substitute crops). Soybeans are

Table 82. Nitrogen sources and use with a 5 ton soil loss restriction and alternative levels of export in 2000

Nitrogen source	Export alternative		
	ave. 69-71	2 * ave	3 * ave
	(million pounds)		
Livestock wastes	8752	8759	8795
Legume crops	8615	9491	9945
Commercial purchase	6540	7980	9626
Total utilized	23907	26230	28366

Table 83. Indication of relative farm level prices for some agricultural commodities with a 5 ton soil loss restriction and alternative levels of export in 2000

Commodity	Export alternative		
	ave. 69-71	2 * ave	3 * ave
	(ave. 69-71 prices=100)		
Corn	100	105	126
Wheat	100	109	158
Soybeans	100	139	219
Cotton	100	101	107
Hay	100	109	132
Beef	100	106	119
Pork	100	106	122
Milk	100	103	111

grown in competition with corn and in a more confined region. Hence, as markets become more advantageous for corn, soybeans must pay a greater cost to bid land from corn. Similarly for wheat, expanded exports increase the demand for corn and soybeans grown on larger acreages in the North Central and South Central zones. Wheat formerly grown in these regions then must relocate to the relatively less productive areas where it has higher per unit costs.

Livestock prices increase in relation to their ability to adjust rations to lower priced feeds. Beef and pork prices increase by 6 percent as exports double but 22 percent and 19 percent, respectively, as exports triple. Pork is not able to substitute legume hays for the oilmeals in the manner of dairy, beef cows and beef feeding sectors as land use shifts to match higher grain exports (Table 84).

Starting from a level of surplus capacity, as exports double farm level commodity prices increase by less than 10 percent, except for soybeans. However, as exports triple, price increases become more commodity specific and reach a 19 percent increase for soybeans.

Table 84. Commodity use in livestock production with a 5 ton soil loss restriction and alternative export levels in 2000.

Commodity	Unit	Export alternative		
		ave 69-71	2*ave	3*ave
		(000)		
Corn	bu.	5691554	6071780	6302504
Sorghum	bu.	474077	522068	525620
Barley	bu.	461520	498455	397970
Oats	bu.	396728	417232	446362
Wheat	bu.	505341	199564	82863
High protein[a/]	cwt.	699218	666981	636069
Legume hay	tons	163295	172265	175074
Other hay	tons	104197	102269	99792
Silage	tons	107147	64731	36521
Pasture[b/]	tons	212670	215912	222273

[a/] Includes soybean and cottonseed oilmeals and high protein grain supplements all expressed in soybean oilmeal equivalents.

[b/] Expressed in non-legume hay equivalents.

SUMMARY AND IMPLICATIONS

This study, made under a grant from the National Science Foundation's RANN program (Research Applied to National Needs), emphasizes the development and application of a 223 region model of soil loss control as a means of environmental improvement. A soil loss restraint and a nitrogen balance equation were developed and implemented in each of the 223 producing regions. The model also incorporates 51 water supply regions, 30 market regions, a transportation submodel, crops and livestock submodels and includes all of the agricultural land and irrigation water of the nation.

The model analyzes changes required in land and water uses of individual regions, agricultural commodity production, interregional production shifts, regional and national soil loss, required conservation practices by regions, commodity prices, resource returns and other relevant parameters as (a) soil loss is first unrestrained and then restrained to 10, 5 and 3 tons per acre, and (b) as commodity exports are at the 1969-71 levels, then doubled and tripled from this level.

The major objective of the study was to develop and test a model capable of (a) simulating changes in the level of

allowable sheet and rill erosion from cultivated lands, and (b) determining the national and regional impacts of such restrictions. Within the 223 producing areas, the dryland and irrigated cultivated lands were each allocated to 9 land groups based on their erodability characteristics. Activities were defined within each producing area and land group to simulate rotations producing alternative crop combinations under alternative conservation and tillage practices. Each rotation had a specific level of associated gross field soil loss, as determined from the Universal Soil Loss Equation.

The results indicate that agriculture can contribute to a reduced gross field loss of soil with only small increases in the farm level prices of the agricultural commodities. Total soil loss can be reduced significantly through the shift to conservation practices and reduced tillage in the crop management systems utilized. Some shift in crops grown is indicated as the less-erosive crops are substituted for the more-erosive crops, especially the silages.

Regionally, the shifts in production patterns are more pronounced in the South Central, South Atlantic and North Central regions. The regions in the West, where runoff is lower, gain in production of the agricultural products. In all regions, the more-erosive crops are incorporated into less-intensive rotations and on the less-erosive lands.

The environmental impacts associated with the reduction in soil loss are compounded by the increased use of the pesticides to control the insects and weeds formerly controlled by mechanical tillage. Fertilizer use is distributed somewhat more widely as the less-intensive rotations do not concentrate the high-fertilizer use crops.

Erosion And Erosion Control Methods

Table 85 presents a summary of the soil loss and farming practice data for the four soil loss alternatives analyzed. Erosion per acre with no restriction averages 9.9 tons per acre and declines to 4.3 tons per acre with a 10 ton restriction, to 2.8 tons per acre with a 5 ton restriction and to 1.9 tons per acre with a 3 ton restriction. The initial restriction results in a 58 percent reduction in total soil loss from the 2,677 million tons under the unrestricted model. Thereafter, the lower restrictions encourage lower percentage reductions in soil loss as the 5 ton restriction reduced total soil loss by a further 36 percent and the 3 ton restriction by a further 33 percent.

The method of controlling erosion and bringing about the reduction in soil loss is through a shift to reduced tillage from conventional tillage, and within the tillage methods, a shift away from straight row cultivation to conservation practices. Under the unrestricted alternative, 92.1 percent of the lands are farmed under conventional tillage. This

Table 85. Summary of erosion and acres under alternative conservation practices with the alternative soil loss restrictions in 2000

Item(unit)	Per acre soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
Erosion per acre (tons)	9.9	4.3	2.8	1.9
Total erosion (million tons)	2677	1132	727	483
Total acres cultivated (000)	269113	261564	258882	258058
Percent of acres by tillage method				
conventional	92.1	83.1	77.7	71.7
reduced	7.9	16.9	22.3	28.3
Percent of acres by conservation practice				
contouring	4.6	17.3	21.6	25.2
strip crop-terracing	1.2	8.7	18.9	26.0
straight row	94.2	74.0	59.5	48.8

practice drops to 71.7 percent for the 3 ton restriction. With respect to tillage methods, 94.2 percent of the utilized land is cultivated under straight row techniques when no soil loss restriction is imposed. The percentage declines to 48.8 under the 3 ton restriction. Concurrently, the use of contouring is increasing from 4.6 percent under no restriction to 25.2 percent of the acreage under the 3 ton restriction. Strip cropping and terracing undergo the largest percentage increases and are mostly associated with conventional tillage. The use of strip cropping or terracing on lands increases from 1.2 percent of all lands under the unrestricted model to 8.7 percent with the 10 ton restriction, 18.9 percent with the 5 ton restriction and to 26.0 under the 3 ton model.

Land and Water Allocations

The unrestrained soil loss model utilizes 586 million acres of land in 2000, down 366 million acres from the 1967 actual acreage, Table 86. This reduction is largely due to a decline of 311 million acres of pasture lands and 28 million acres of land in fallow or allocated to exogenous crops. The remaining 26 million acre reduction is mostly associated with a smaller acreage of close-grown crops as wheat moves to land not required for the row crops in the less arid acres of the North Central and South Central zones. Irrigated land declines by 8.6 million acres as depletion of groundwaters re-

Table 86. Summary of land, water and nitrogen fertilizer allocation in agriculture under alternative soil loss restrictions in 2000

Item	1967 level[a]	Per acre soil loss restriction			
		unrestricted	10 ton	5 ton	3 ton
		(million acres)			
Total dryland	952.5	586.3	580.3	584.6	588.6
row crops	143.9	139.0	132.6	128.5	127.9
close crops	93.8	70.2	68.9	66.7	66.8
all hay	65.5	66.3	67.3	72.5	72.9
pasture	614.3	303.1	304.6	310.7	313.9
other[b]	35.0	7.7	6.9	6.2	7.1
Total irrigated	40.0	31.4	31.5	28.6	29.4
row crops	16.1	9.2	8.8	7.5	6.5
close crops	6.8	5.3	5.4	6.7	6.0
all hay	12.1	12.4	12.8	12.1	12.7
pasture	3.0	2.9	2.9	0.7	2.6
other[b]	2.0	1.6	1.6	1.6	1.6
Unused lands	---	413.4	419.5	418.0	415.1
cultivated	---	97.4	105.0	107.7	108.4
other land	---	316.0	314.5	310.3	306.7
		(million acre feet per year)			
Water[c]					
withdrawals	151.7	131.0	131.3	124.7	128.6
consumptive use	76.0	82.9	83.2	76.5	81.0
		(million pounds)			
N fertilizer	---	23237	23498	23907	23952

[a] Source (3).

[b] Includes exogenous crops and summer fallow.

[c] For agricultural uses only.

duces the water availability in the western area of the Great Plains zone.

The imposition of a 10 ton soil loss restraint further reduces the land used by 6 million acres. Most of the reduction occurs in row crops categories as these commodities are shifted to more productive lands. Further reductions in the level of allowable soil loss reduces the acreage of row crops and increases the acreage of irrigated close-grown crops, dryland and irrigated hays and dryland pasture. As the soil loss restraint is reduced to 5 and 3 tons, the total agricultural land base increases as low-erosion and low-productivity native pastures and hayland are used for field crops. Silage acreage declines from 13.9 million acres under the unrestricted model to 5.2 million acres under the 3 ton soil loss restriction. The decline in silages results from their erosion characteristics.

Regionally, the imposition of soil loss restrictions reduces the level of the cultivated land base (row crops and close-grown crops) in the South Atlantic, South Central and North Central zones, Table 87. The North Central and South Atlantic zones especially have an increase in hay and pasture land to compensate for shifts in cultivated lands. The more arid zones, including the Great Plains, North West and South West, have increases in close-grown crops. The North West and South West also increase row crop acreage.

Table 87. Summary of agricultural land use by the major zones under alternative soil loss restriction levels in 2000

Zone/land use	Per acre soil loss restriction			
	unrestricted	10 ton	5 ton	3 ton
North Atlantic				
row crops	3713	3661	4318	3359
close crops	1698	1225	2491	2089
hayland	1616	1608	2043	2247
pasture	6806	6888	7098	8315
South Atlantic				
row crops	10691	9647	10065	8549
close crops	3201	2729	870	736
hayland	2007	2006	2686	2913
pasture	23592	23632	25222	25615
North Central				
row crops	90926	87843	84714	88372
close crops	19440	19117	18756	17652
hayland	17190	18054	20421	23523
pasture	29775	30304	33820	35810
South Central				
row crops	28666	26401	24305	19883
close crops	20716	20569	19720	19885
hayland	27447	27648	27722	23304
pasture	110694	111368	108031	105322
Great Plains				
row crops	7512	7017	5593	6904
close crops	16192	16549	15510	18292
hayland	21051	21385	22443	24775
pasture	41860	41949	41999	45579
North West				
row crops	1740	1734	1981	1811
close crops	7763	7762	7751	7906
hayland	5679	5631	5598	5986
pasture	26896	27033	27833	28872
South West				
row crops	4978	5112	5059	5562
close crops	6498	6358	8380	6253
hayland	3747	3737	3689	2826
pasture	66357	66361	67404	66925

The use of water by agriculture varies directly with the shifts in irrigated acreage, Table 86. The consumptive water use is above the level estimated for 1965 even though irrigated acreages are down. This is possible as the regional distribution of the irrigated crops affects the water requirements.

Agriculture and Environmental Improvement

The results of the alternative soil loss analysis indicates that agriculture has the productive and technological capacity to contribute to environmental improvement without serious implications for domestic food prices when exports are at average levels. Soil erosion can be substantially reduced through the use of per acre restrictions. This reduction in gross field erosion could reduce the contribution of agriculture to the level of sediment in the waterways, given the delivery and transport characteristics of the area. There is, however, a trade-off in environmental quality: as erosion is controlled, the level of pesticide and fertilizer application increases as farmers shift to reduced tillage methods. Thus, policy makers must consider the implications of increased use of these two commodity groups and their contributions to pollution.

Increases in production levels brought about by expanded export levels increases the per acre soil loss from 2.8 to

2.9 tons per acre for either of the two levels considered. The increased per acre soil loss results from the inclusion of a higher proportion of the more erosive lands among the acres brought into production to meet expanded demands. Total soil erosion increases 16.0 percent as exports double and a further 15.5 percent as exports are tripled, Table 88. This corresponds to the 16 percent increase in acreage for each of the increases in export level. Exports thus, can increase without significantly increasing the per acre soil loss levels, given the 5 ton restriction, with total soil loss increasing proportionately to acreage.

Table 88. Summary of erosion and percent of acres by conservation practice with the 5 ton per acre soil restriction and the alternative export levels in 2000

Item(unit)	Export alternative		
	69-71 ave	2 * ave	3 * ave
Erosion per acre (tons)	2.8	2.9	2.9
Total erosion (million tons)	727	843	974
Total acres cultivated (000)	258882	295047	337299
Percent of acres by tillage method			
conventional	77.7	75.2	72.9
reduced	22.3	24.8	27.1
Percent of acres by conservation practice			
straight row	59.5	54.8	49.4
contouring	21.6	23.3	23.4
strip crop-terracing	18.9	21.9	27.2

The increased acreage required for larger exports concentrates increasingly on the lands farmed under the reduced tillage methods.

Increased exports necessarily require more land for agricultural production or a more intensive use of the lands already farmed. Increased exports of feed grains, wheat and the oilmeals directly influences the acreage of the row crops and close-grown crops, Table 89. These exports also influence the acreage of hays, pasture and other crops as livestock rations allow for changes in the feeds consumed. Use of the dry and irrigated lands does not decline as the substitutions and expanded exports readjust the market. The only significant quantity of lands available for expansion of agriculture, above the tripled export level, is in pasture lands from which the livestock has been removed.

Water and nitrogen use increase nearly in proportion to the increased acreage for greater exports. Water use changes reflect limits on water and irrigable land availability. Shifts in nitrogen use reflect the productivity of the fertilizers used in the various regions and on the several land classes.

The double and triple export levels were accompanied with rather wide shifts in crop production among land classes and agricultural regions and in the conservation practices used. However, the model indicates that with imposition of

Table 89. Summary of resource use in agriculture under a 5 ton soil loss restriction and alternative export levels in 2000

Item (units)	1967 level[a]	Export alternative		
		69-71 ave	2 * ave	3 * ave
Total dryland	952.5	584.6	622.7	669.1
row crops	143.9	128.5	152.2	174.5
close crops	93.8	66.7	76.5	91.7
all hay	65.5	72.5	74.8	76.2
pasture	614.3	310.7	312.6	317.9
other[b]	35.0	6.2	6.6	8.7
Total irrigated	40.0	28.6	29.9	33.0
row crops	16.1	7.5	7.1	7.7
close crops	6.8	6.7	7.9	9.5
all hay	12.1	12.1	12.3	12.9
pasture	3.0	0.7	0.9	1.3
other[b]	2.0	1.6	1.6	1.6
Idle lands		418.0	378.6	329.1
cultivatable	---	107.7	71.5	29.3
pasture	---	310.3	307.1	299.8
		(million acre feet per year)		
Water[c]				
withdrawals	151.7	124.7	127.0	133.1
consumptive use	76.0	76.5	78.3	83.4
		(million pounds)		
N fertilizer	---	23907	26230	28366

[a] Source (3).

[b] Includes exogenous crops and summer fallow.

[c] For agricultural uses only.

soil loss restraints, export levels equal to triple the 1969-71 level could be attained while both (a) environmental improvement is attained through regionally and nationally imposed limits on soil loss, and (b) commodity prices are increased only modestly. The nation's agricultural plant apparently has sufficient capacity and flexibility to allow simultaneous attainments in environmental improvement, expanded exports and reasonable farm commodity prices. The analysis does not, however, relate to exports as high as those experienced in 1972 and 1973.

Agricultural Technological Requirements

Erosion apparently can be controlled by means of the technologies currently available to agriculture with little impact on the sector's potential to meet the agricultural demands and modest export increases in the year 2000.

The analysis indicates that the appropriate level of erosion control might be attained through (a) a rather large-scale shift in crop production to contouring and strip cropping (with little terracing), (b) utilizing conventional tillage methods, and (c) through a shift of acreage to reduced tillage methods.

Agricultural Returns and Farm Price Levels

The return to labor and water declines slightly with the imposition of the soil loss restraints used in this study.

Land returns increase greatly. The reduced labor return results from the decline in total acreage cultivated. The reduced water return results from a shift of production to the lower-valued, close-grown crops and away from higher-value row crops on irrigated land.

For the model's agricultural capacity and export levels analyzed, price levels increase only as the allowable soil loss level becomes low. A reduction in soil loss can be attained with only minor increases in farm prices levels. As soil loss is lowered, and export levels are increased, commodities associated with more erosive land use patterns and the highly erosive areas of the nation experience the greater price increases. At the 5 ton soil loss restriction level (2.8 tons per acre actual soil loss) price increases are only about 5 percent when exports are at the 1969-71 level. If exports of the feed grains, wheat and oilmeals are increased, however, price increases are greater. While exports larger than triple the 1969-71 level are not analyzed, greater demand magnitudes imply high commodity prices with restraining soil loss restrictions. An increase in exports to three times the 1969-71 level exhausts the capacity of the agricultural plant as all land available, given the 5 ton soil loss restriction, is used. Further expansion of the demand would bring forth large price increases and little increase in supply. Commodity supplies can be increased with modest price

increases, up to the export level where the available land base is fully utilized. Beyond this level, supply can increase only with substantial increases in prices unless more intensive production is used.

REFERENCES

1. Ayres, G.E. ISU suggestions for 1972 crop production tillage alternatives-machine oriented. Extension Handout, Iowa State University, Ames, 1971. (Mimeo.)

2. Dean, G.W., G.A. King, H.O. Carter, and C. Richard Shumway. Projections of California agriculture to 1980 and 2000. California Agricultural Experiment Station Bulletin 847, Berkeley, Sept. 1970.

3. Conservation Needs Inventory Committee. National inventory of soil and water conservation needs 1967. U.S. Department of Agriculture, Statistical Bulletin 461, Washington, D.C., Jan. 1971.

4. Consumer and Marketing Service. Grain Market News. U.S. Department of Agriculture, (Independence, Missouri) 15(3) (Jan. 20, 1967).

5. Doster, D.H., and J.A. Phillips. Costs, inputs and returns: Humid and subhumid areas. Conservation tillage. Proceedings of a National Conference. Soil Conservation Society of America, Ankeny, Iowa, 1973.

6. Economic Research Service. Selected U.S. crop budgets: Yields, inputs and variable costs, Volume III, Great Plains region. U.S. Department of Agriculture, Washington, D.C., ERS459, 1971.

7. Economic Research Service. Selected U.S. crop budgets: Yields, inputs, and variable costs, Volume V, South Central region. U.S. Department of Agriculture, Washington, D.C., ERS461, 1971.

8. Eyvindson, R.H. A model of interregional competition in agriculture incorporating consuming regions, producing areas, farm size groups and land classes. Volumes I through V. Unpublished Ph.D. dissertation. Iowa State University, Ames, 1965.

9. Heady, E.O., Howard C. Madsen, Kenneth J. Nicol, and Stanley H. Hargrove. Agricultural water demands. National Technical Information Service, Report No. PB 206-790, Springfield, Virginia, Nov. 1971.

10. Heady, E.O., Howard C. Madsen, Kenneth J. Nicol, and Stanley H. Hargrove. Agricultural water policies and the environment. Center for Agricultural and Rural Development, CARD Report 40T, Iowa State University, Ames, 1972.

11. Ibach, D.B., and T.W. Adams. Fertilizer use in the United States by crops and areas. Economic Research and Statistical Reporting Service, Statistical Bulletin No. 408, Washington, D.C., Aug. 1967.

12. Kamprath, E.J., W.V. Chandler, and B.A. Krantz. Winter cover crops. North Carolina Agricultural Experiment Station Technical Bulletin 129, Raleigh, March 1958.

13. McClure, W.R., S.H. Phillips, and J.W. Herron. No-tillage experiences in Kentucky. University of Kentucky, Lexington, Paper No. 68-144, 1968.

14. Miner, J.R. Farm animal waste management. North Central Regional Publication 206, Iowa State Agriculture and Home Economics Experiment Station, Ames, May 1971.

15. Missouri River basin, comprehensive framework study, The. Volume VII, Appendix, Plan of development and management of water and related land resources. Missouri Basin Inter-agency Committee, Omaha, Nebraska, Final Draft, June 1969.

16. Movers, C.A. The effects of various legumes on the yield of corn. Tennessee Agricultural Experiment Station Bulletin No. 142, College Station, Feb. 1930.

17. National Academy of Sciences. Nutrient requirements of domestic animals: Number 2, Nutrient requirements of swine. Sixth rev. ed. NAS, Washington, D.C., 1968.

18. National Academy of Sciences. Nutrient requirements of domestic animals: Number 3, Nutrient requirements of dairy cattle. Fourth rev. ed. NAS, Washington, D.C., 1971.

19. National Academy of Sciences. Nutrient requirements of domestic animals: Number 4, Nutrient requirements of beef cattle. Fourth rev. ed. NAS, Washington, D.C., 1970.

20. Ngoddy, D.P.O., et al. Closed system waste management for livestock. Water Pollution Control Research Series 13040 DKP, U.S. Environmental Protection Agency, Washington, D.C., June 1971.

21. Pacific Southwest Interagency Committee, Lower Colorado Region State-Federal Interagency Group. Lower Colorado region, comprehensive framework study. Appendix V, Water resources. San Francisco, Preliminary Field Draft, Nov. 1970.

22. Ritchie, Wayne. Tillage for row crops-improving on the tried and true. Doane's Agricultural Report, Business Issue 30(29), Oct. 8, 1967.

23. Shrader, W.D. Legumes-How much N do they provide? Iowa Cooperative Extension Service EC-810t, Ames, Jan. 1973.

24. Shrader, W.D., and R.D. Voss. Soybeans may supply 50 pounds of nitrogen for next years corn. Wallaces Farmer 97(Sept. 23, 1972): 42-43.

25. Shrader, W.D., W.A. Fuller, and F.B. Cady. Estimation of a common nitrogen response function for corn (Zea mays) in different crop rotations. Agronomy Journal 58(1966): 397-404.

26. Soil Conservation Service, Engineering Division. Procedure for computing sheet and rill erosion on project areas. Soil Conservation Service Technical Release No. 51, Washington, D.C., Sept. 1972.

27. Stoecker, A. A quadratic programming model of U.S. agriculture in 1980: Theory and application. Unpublished Ph.D. dissertation. Iowa State University, Ames, ca. 1974.

28. U.S. Army Corps of Engineers. Agriculture, Appendix N. Upper Mississippii River Comprehensive Basin Study. Des Moines, Iowa, USACE, 1969.

29. U.S. Department of Agriculture. Agricultural statistics, 1972. Washington, D.C. 1972.

30. U.S. Department of Commerce, Bureau of Economic Analysis. The economic base of selected geographic areas, historical and projected 1929 to 2020. Preliminary Report to the Water Resources Council, Washington, D.C., 1968.

31. U.S. Department of Commerce. Bureau of the Census. U.S. census of agriculture, 1950, Volume I, Counties and state economic areas. U.S. Govt. Printing Office, Washington, D.C., Dec. 1952.

32. U.S. Department of Commerce, Bureau of the Census. U.S. census of agriculture, 1954, Volume I, Counties and state economic areas. U.S. Govt. Printing Office, Washington, D.C., Dec. 1956.

33. U.S. Department of Commerce, Bureau of the Census. U.S. census of agriculture, 1960, Volume I, Counties and state economic areas. U.S. Govt. Printing Office, Washington, D.C., Oct. 1962.

34. U.S. Department of Commerce, Bureau of the Census. U.S. census of agriculture, 1964, Volume I, Statistics for the states and counties. U.S. Govt. Printing Office, Washington, D.C., 1967.

35. U.S. Department of Commerce, Bureau of the Census. U.S. census of agriculture, 1969, Volume I, Statistics for the states and counties. U.S. Govt. Printing Office, Washington, D.C., 1971.

35A. U.S. Water Resources Council. The Nation's Water Resources. U.S. Govt. Printing Office, Washington, D.C., Nov. 1968.

36. U.S. Water Resources Council. Water resources regions and subregions for the national assessment of water and related land resources. U.S. Govt. Printing Office, Washington, D.C., July 1970.

37. Vanderholm, D.H. Area needed for land disposal of beef and swine wastes. Iowa State University Cooperative Extension Service, Ames, PM-552, Jan. 1973.

38. Wischmeier, Walter H., and Dwight D. Smith. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agriculture Handbook No. 282, Washington, D.C., May 1965.

APPENDICES

Appendix 1. Exogenous Crop Sector

The exogenous crop sector defines the allocation of land by region and land class, fertilizer nitrogen, and water for use by the crops not endogenously allocated by the model. These crops include broomcorn, buckwheat, cowpeas, dry beans, dry peas, flax, hops, orchards and vineyards, peanuts, potatoes, proso-millet, rice, rye, safflower, sugar cane, sunflowers, sweet potatoes, tobacco, and vegetables. Soil loss from lands utilized by these crops is not considered in the total accumulation of soil loss as data, and alternative cropping patterns are not available.

Water allocation for the exogenous crop sector is determined directly from the water use coefficients developed in Agricultural Water Demands (9). These per acre water use rates were applied to all acres and this value entered as the requirements for the exogenous crops. The allocation of land and nitrogen fertilizer are outlined in the following sections.

Acreages allocated for use by exogenous crops

The acreage defined for use by land class is adjusted to reflect the requirement for the production of the exogenous crops in 2000. The 1969 production and the projected production in 2000 by state for most of the exogenous crops are obtained from the OBERS work of the Economic Research Service.[1] Acreages by state for each crop in 1969 are obtained from the Census of Agriculture (35) and an average state yield in 1969 is determined.[2] Dean et al. (2) reports yields for the exogenous crops produced in California in 1969 and projected yields for each of the crops in 2000.[3] The ratio yield in 2000/yield in 1969 is determined for each crop in the California study (2). It is assumed that the yields in each state will increase proportionately to those in California, and the above ratios are used to adjust all state yields from 1969 to 2000. Acreage requirements for the year 2000 are

---

[1]The 1972 OBERS Report backup materials were obtained through private communication with Dr. Melvin L. Cotner, Director, NRED, U.S. Department of Agriculture, March 1973.

[2]For crops not included in the E.R.S. data it is assumed that the acreage required in the year 2000 will be the same as required in 1969 with the production differential being made up by increases in yield per acre.

[3]Yields for the crops not included in Dean's study (2) were obtained by extending the 1949-1969 yield trend from the Agriculture Census (32, 33, 34, 35) to the year 2000.

computed by dividing the estimated production by the projected yields per acre.

All projections in the exogenous crop sector are made at the state level. The acreage is allocated to the counties within the state on the basis of the proportion of each crop grown in the county as reported in the 1964 Census of Agriculture (34).[1] The acreages of each of the exogenous crops in each producing area is determined by summing the projected acreage of the relevant crops in the producing area over the subset of counties consistent with the definition of the producing area.

Within each producing area the exogenous crops are grouped into three categories according to their method of cultivation. These categories are row crops, close-grown crops and orchards and vineyards. Acreages of these three categories are then allocated to the different land groups in proportion to the calculated acres of other row crops, close-grown crops and orchards and vineyards as determined by land class in the National Inventory (3). This same procedure is used for both dryland and irrigated acreages. If the projected acreage requirement for the exogenous crops is greater

---

[1]The 1964 Census of Agriculture (34) was used for the state to county allocation as not all 1969 state summaries were published at the time of calculation. State data for 1969 was available from the National Summary (35).

than the acreage available for the land group, the excess acres are allocated either to the land group next closest in erosion hazard characteristic or to the same land group in an adjoining producing area depending on the agronomic characteristics of the land groups, producing areas and cropping patterns required to produce the exogenous crops.

Nitrogen for the exogenous crops

The use of nitrogen by the exogenous crops represents a significant demand for nitrogen especially in the Gulf and West Coast areas. The amounts of nitrogen required by the specific crops are determined from the work of Ibach and Adams (11). The quantity used per acre for each of the exogenous crops is multiplied by the acres calculated in the region. The assumption is made that by 2000 the application rate for all acres will be equal to the application rate on the acres fertilized in Ibach and Adams data.[1] The region's nitrogen requirement for the exogenous crops is determined as:

$$RN(i) = \sum_{m} A(i,m)\, N(i,j)$$

where:

A(i,m) is the projected acreage of crop m in producing

---

[1]This assumption is used as time series estimates of the percent of acres receiving fertilizer are not available for most of the exogenous crops.

computed by dividing the estimated production by the projected yields per acre.

All projections in the exogenous crop sector are made at the state level. The acreage is allocated to the counties within the state on the basis of the proportion of each crop grown in the county as reported in the 1964 Census of Agriculture (34).[1] The acreages of each of the exogenous crops in each producing area is determined by summing the projected acreage of the relevant crops in the producing area over the subset of counties consistent with the definition of the producing area.

Within each producing area the exogenous crops are grouped into three categories according to their method of cultivation. These categories are row crops, close-grown crops and orchards and vineyards. Acreages of these three categories are then allocated to the different land groups in proportion to the calculated acres of other row crops, close-grown crops and orchards and vineyards as determined by land class in the National Inventory (3). This same procedure is used for both dryland and irrigated acreages. If the projected acreage requirement for the exogenous crops is greater

---

[1]The 1964 Census of Agriculture (34) was used for the state to county allocation as not all 1969 state summaries were published at the time of calculation. State data for 1969 was available from the National Summary (35).

than the acreage available for the land group, the excess acres are allocated either to the land group next closest in erosion hazard characteristic or to the same land group in an adjoining producing area depending on the agronomic characteristics of the land groups, producing areas and cropping patterns required to produce the exogenous crops.

Nitrogen for the exogenous crops

The use of nitrogen by the exogenous crops represents a significant demand for nitrogen especially in the Gulf and West Coast areas. The amounts of nitrogen required by the specific crops are determined from the work of Ibach and Adams (11). The quantity used per acre for each of the exogenous crops is multiplied by the acres calculated in the region. The assumption is made that by 2000 the application rate for all acres will be equal to the application rate on the acres fertilized in Ibach and Adams data.[1] The region's nitrogen requirement for the exogenous crops is determined as:

$$RN(i) = \sum_{m} A(i,m)\, N(i,j)$$

where:

A(i,m) is the projected acreage of crop m in producing

---

[1]This assumption is used as time series estimates of the percent of acres receiving fertilizer are not available for most of the exogenous crops.

area i in 2000;

N(i,m) is the projected per acre use of nitrogen by crop m in producing area i in 2000;

RN(i) is the total projected fertilizer nitrogen equivalent of all crops in producing area i in 2000.

Appendix 2. Development of the Livestock Sector

The equilibrium of the livestock sector is partially determined exogenous and partially endogenous to the model. The dairy, pork and beef production sectors are endogenous while the poultry, sheep and other livestock are allocated exogenous to the model.

The exogenous livestock sector

Rations for the exogenous livestock are determined as outlined in Agricultural Water Demands (9).[1] The rations give the quantity of each of the commodities required per unit of the livestock class. These quantities are withdrawn from the consuming region commodity markets at a level consistent with the projected level of the relevant livestock class. The water requirements of the exogenous livestock, in

---

[1]Activities are defined to create the commodity needs for the production of broilers, turkeys, eggs, sheep and lambs and a general category for other animals, such as horses, mules, ducks and zoo animals.

the regions of the west, are also obtained from Agricultural Water Demands (9).

The use of the commodities, except oilmeals, by each class of exogenous livestock represents a direct demand on the regional commodity markets. The oilmeal demand is adjusted to reflect the amount of high protein animal feed produced as a by-product from the slaughter of the exogenous livestock.[1]

The quantity of nitrogen equivalent wastes produced by broilers is determined as described later and a comparable production of nitrogen waste is calculated for the other poultry classes based on feed consumption and commodity production relative to broilers. Sheep and lamb wastes are calculated from the coefficients of the endogenous ruminants based on the waste production per unit of output. A more detailed explanation of the nitrogen waste calculation is included in the nitrogen wastes section.

The endogenous livestock sector

Activities for the production of pork, milk, feeders and fed beef are defined in each of the 223 producing areas. The

---

[1]The quantity of high protein oilmeal equivalent provided by the exogenous livestock is determined by evaluating the relationship between slaughter wastes and total animal protein supplements consumed and the waste is allocated to the classes of livestock based on the proportion of wastes from all animals which originated from the given class.

activity costs and output levels are based on the work of Eyvindson (8) and are weighted into the 223 producing areas and projected to 2000 using the procedure outline in Agricultural Water Demands (9).

A modified system of ration determination is used for this analysis. Rather than allow for nutrient transfers from the commodities to the livestock rations as has been done in previous models (8, 9, 10), this model allows alternative rations for the livestock activities which draw directly from the commodity balance rows. Under the nutrient transfer system balanced rations are determined endogenous to the model, but it is possible to have rations which, because of the commodities included, are not palatable to the livestock units. An example is to provide the energy component of a beef feeding ration from wheat which under normal management systems is not a feasible alternative. All rations provided for each of the livestock groups are balanced in separate mathematical formulations based on the nutrient requirements specified by the National Academy of Sciences (17, 18, 19). The rations are formulated to provide alternative levels of substitution between grains, between roughages and grains, and between the roughages given a grain component. These rations reflect research-based recommendations which approximate an optimal level of feeding efficiency. In order to account for the "inefficiency" of actual production, the rations are

adjusted to set the level of total nutrient consumption at the level of projected consumption in Agricultural Water Demands (9). By providing these alternative rations a linear combination of them provides the system with a sufficiently large number of possible rations with which to minimize the feed costs of the respective livestock group.

In the rations the oilmeal requirements are based on the total demand for soybean meal equivalent high protein supplements. Part of this requirement is satisfied by high protein grain by-products or from animal scraps. An adjustment is made to define the high protein requirement in terms of soybean oilmeal equivalent only. The historic consumption patterns of animal and "grain" protein are related to slaughter and milling, respectively, and the consumption level per unit of processing determined is assumed to hold to 2000. Livestock production has its high protein demands reduced by the expected production from each type of livestock and the milling production is adjusted for as the per capita consumption for the grain commodities is determined.

Livestock production of nitrogenous wastes

Livestock wastes historically have served as a ready source of plant nutrients. With the advance of technology and the resulting concentration of large numbers of livestock in localized feeding facilities, the disposal of the waste products has become of concern to the operators of the facil-

ities and the community. All livestock activities considered in the model are subject to the restriction that the nitrogen wastes, using the "conventional" system of handling, must be utilized in the cropping sector. Data expressing the daily production of nitrogen wastes for the different classes of livestock (14, 20) are adjusted for the efficiency of the handling system and for the feeding time and pattern of the activity (37). The calculated per unit production of nitrogen, Table 90, is used as the activities coefficient for interacting with the nitrogen sector.

Table 90. Nitrogen fertilizer equivalent wastes from livestock

Type	Unit	Period	Lbs. of nitrogen per unit of livestock
Beef cows	Head	Year	58.0
Beef feeding (1.5)[a]	Head	Day	.102
Beef feeding (2.25)[a]	Head	Day	.103
Beef feeding (3.0)[a]	Head	Day	.105
Dairy	Head	Year	142.0
Hogs	Cwt. L.W.	Prod'n period	2.8
Poultry[b]	1000 lbs. r.c.w.	Prod'n period	28.0
Eggs	1000 doz.	Prod'n period	20.5
Sheep	Cwt. Carc. wt.	Prod'n period	2.17

[a]Rates are expected daily gain of the feeders while in the lot.

[b]Poultry represents the production of broilers or turkeys.

Appendix 3. Determination of the Soil Loss Coefficients

Gross soil loss represents the average number of tons of soil leaving the field over a one year period. This measurement of soil loss does not represent the amount reaching the stream or bodies of water as some of the soil particles settle out or are diverted as the runoff passes through grassed areas or onto flatter terrain, thereby changing the waters capacity to transport soil particles. Two separate procedures were used to determine the gross soil loss per acre. For the areas east of the mountains the "Universal Soil Loss Equation" as described by Wischmeier and Smith (38) is used to develop the gross soil loss coefficients. The soil loss equation is represented by:

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

where:

A is the average annual per acre soil loss;

R is a rainfall erosive factor based on the local area;

K is a soil erodibility factor for the specific soil determined from its erosion under continuous fallow on a nine percent slope, 72.6 feet long;

L is the slope length factor relative to a 72.6 foot slope length,

S is the slope gradient factor relative to a nine percent slope;

C is the crop management factor which relates to a particular crop rotation and tillage practice and

P is the erosion control practice factor which relates to the conservation practice.[1]

For details on the factors and on the computational procedures used see Wischmeier and Smith (38) and "Technical Release 51" (6). For the areas east of the Rocky Mountains, the above variables are defined as the dominate value existing on each soil class and subclass in the area of reporting. The soil loss is then computed by Land Resource Area for each feasible combination of crop rotation, conservation practice, tillage method and soil class defined from the SCS data questionnaire.

The soil loss defined above for the relevant of the 29 major soil classes and subclasses is aggregated using weighting functions determined from the National Inventory (3) to get soil loss by the nine soil classes. The soil loss by cropping management system is weighted to the producing area from the SCS data area as follows;

---

[1]The data for this equation are obtained from tables in Wischmeier and Smith (38) and the regional data given for the soil classes in a questionnaire completed in conjunction with the Soil Conservation Service, USDA.

$$S(i,j,m) = \sum_{n} SL(i,j,k)\, A(j,k,n,m) / A(j,m)$$

i = 1, ..., the number of crop management systems defined in the producing area,
j = 1, ..., 18 for the soil groups,
k = 1, ..., 165 for the relevant set of SCS data,
m = 1, ..., 223 for the producing area,
n = 1, ..., the number of sets of SCS data included in the producing area,

where:

S(i,j,m) is the soil loss for crop management system i on soil group j in producing area m;

SL(i,j,k) is the soil loss for crop management system i on soil group j consistent with SCS data area k;

A(j,k,n,m) is the acres of tillable soil group j in part n of producing area m and is consistent with SCS data area k and;

A(j,m) is the total tillable acres of soil group j in producing area m.

These coefficients are attached to the appropriate crop production activity and reflect the severity of erosion for the conditions on which the cropping management system is defined.

For those agricultural lands in the mountain valleys and on the west coast, the data required for the soil loss equation have not been completely developed and an alternative procedure is used to estimate the soil loss from these lands.

The SCS data questionnaire (Appendix 3) asked for crop management systems consistent with the production possibilities of the SCS data area. The SCS personnel estimated the tons of soil loss associated with the crop management system on each of the land class and subclasses defined in the SCS data area. These estimates are, for purposes of this model, treated as if they were developed from the same equation from which the estimates in the eastern area are computed. This "assumed consistency" allows the soil losses from each SCS data area to be treated equally in weighting to the producing areas in the model. This capability is required as some producing areas overlap the SCS data areas in which the soil loss is developed using the eastern procedure and other areas which have the soil loss estimated with the western procedure. Each of the activities representing the production of irrigated crops is considered to have a soil loss similar to the corresponding dryland activities. The assumptions which are needed to enable this transformation include good management of the irrigation system, a larger quantity of residue left from crops receiving irrigation which will help to "bind" the soil during the subsequent applications of water, and the heavier growth resulting from irrigation increases the canopy protection of the soil by the plants reducing dislodging during rainfalls. The soil loss coefficients form the first of the bank of total coefficients required to com-

pletely define each activity.

Appendix 4. Development of the Crop Yield Coefficients

A unique yield is determined for each of the irrigated and dryland crops as a function of the producing area, the soil class, the crop rotation, the conservation practice and the tillage method. The development of the yields progressed from a system of state functions capable of projecting to the future, a transformation into producing area functions, and finally the projected yields adjusted for crop rotation, land class and conservation and tillage practice.

Yield determination

The state projection functions are modifications of the functions developed by Stoecker (27). For a given crop the function is of the form:

$$Y(t) = Yo(t) + A(1-.8^{**}x(t))*PF(t)$$

where:

Y(t) is the estimated average per acre yield in year t;

Yo(t) is the estimated average yield per acre on unfertilized land in year t, developed from a linear trend function;

A is the maximum response obtainable from fertilization;

X(t) is the number of units of fertilizer applied per acre in year t;

PF(t) is the proportion of the acreage receiving fertilizer in year t, developed from a linear trend of the proportion of crop acres receiving fertilizer and;

t is years after 1949.

The X(t) defined above represents:

$$X(t) = PO(t)*(LN(PX/PC) - LN(a) - (LN(LN .8)))/LN .8$$

where:

ln is the natural log of base e;

Px is the weighted price of a unit of fertilizer;

PC is the price of a unit of crop c;

PO(t) is a linear estimate of the proportion of the optimum rate of fertilizer applied in year (t).

The last multiplicative factor in the above equation represents an estimate of the optimum application of fertilizer obtained by solving the marginal conditions of a profit maximization system.

The second step in the determination of yields is to weight the state functions by the proportion of the acres in each producing area and aggregate the producing area parts into functions which can predict the yield on a producing area basis. The weights are developed from the 1964 Census

of Agriculture (34) and are represented by:

$$W(i,m,k) = \sum_{j} A(i,n,j\ m) / \sum_{m} A(i,k,m)$$

i = 1, ..., 15 for the crop number,
j = 1, ..., for the counties in state n,
k = 1, ..., 233 for the producing areas,
m = 1, ..., for the producing area part in state n,
n = 1, ..., 48 for the continental states,

where:

W(i,m,k) is the weight for crop i in part m of producing area k;
A(i,n,j m) is the acres of crop i in county j of state n included in part m of producing area k;
A(i,k,m) is the acres of crop i in part m of producing area k.

These weights are multiplied by each of the function coefficients and summed over m for each i and k to give the producing area yield predition equation. This procedure is used to transfer the yield, proportion of acres fertilized and proportion of optimal fertilizer applied functions into the producing areas.

The producing area yield is calculated for each crop based on the functions developed and the projected levels of fertilizer use. If the rotation in which any crop is defined includes a legume crop the carry-over nitrogen from these sources is included in predicting the yields. The fertilizer value of the legume crops will be covered in the fertilizer use part of this Appendix. In many instances the legumes, especially alfalfa hay, produced more fertilizer equivalent

nitrogen than would have been applied commercially. When this occurred, the fertilizer equivalent nitrogen from the legume is used in the yield equation giving a larger yield than under trend fertilizer uses.

The next step in determining the yields for the cropping system is to adjust for land class, conservation practice and tillage method. The data obtained in the SCS questionnaire included a set of ratios giving the relative land class yields as compared to the most productive land class of the area. These ratios are used with the acreages by crop type[1] by land class reported in the National Inventory (3) to develop a set of ratios which relate each land class to the producing area average crop yield. These ratios are then used to adjust the projected producing area yields for land class.

The conservation and tillage ratios, from the SCS data, are used equally on each land class and the yields are adjusted for both conservation and tillage effects. For the adjustment ratios if data was missing the national average is used as a proxy. This substitution is only used where that practice or land class exists in the producing area and the specific data needed was not included on the SCS data forms.

---

[1]Crop types reflect the row crops, close-grown crops and hay and pasture as reported in the National Inventory (3).

These adjustments completed the calculation of yields as determined from the response function of the area, the land class, the rotation, the conservation practice and the tillage method.

Fertilizer use coefficients for the crops

The fertilizer coefficients developed from the functions were independent of the land class, the conservation practice or the tillage method. The functions developed by Stoecker (27) provided the basis for determining the level of nitrogen supplementation required. The level of commercial fertilization required to meet the projected yields were determined by taking the optimum level of fertilizer use as determined from the function and subtracting the amount provided by the legumes, if any, in the rotation. The legume nitrogen data was developed from results reported in agronomy publications (16, 23, 25) and through consultation with William Shrader.[1] An estimate of a function was developed which related nitrogen fertilizer equivalent carry-over of the legume as a function of the yield of the legume. Only those legumes which offer the potential of high nitrogen production are included when developing the function. This selectivity allowed for the switch to equal yielding but higher management legume va-

---

[1]Professor of Agronomy, Iowa State University, Ames, Iowa.

rieties in order to harvest the carry-over nitrogen. The legume hays provided carry-over for a two year period after a good yielding stand and functions relate the first and second year production of nitrogen. The first year function is

$$N1 = 50.0 * Y - 5.0Y^{**}2 + 0.2Y^{**}3$$

and the second year function is

$$N2 = 81.5 - (81.5).8^{**}Y$$

where N1 and N2 are the pounds of nitrogen supplied by the legume for the crop following the first and second year after plowing, respectively, and Y represents the annual yield in tons of dry weight hay equivalent of the legume hay during the years it is harvested. The effect of legumes does not include a green manuring response but rather only the response coming after a legume hay crop. This type of relationship allows for the utilization of the roughage for feed and also the nitrogen carry-over.

A similar functional relationship has been developed for nitrogen carry-over from soybeans. Shrader and Voss (24) have shown that soybeans provide approximately one pound of nitrogen equivalent per bushel of soybeans yield as a carry-over for the crop during the following year. After adjusting the fertilizer use, determined by optimizing the production relationships, for the amount supplied by the previous years legume crop, the nitrogen coefficient for the cropping management system is determined.

The sources of supply for the nitrogen requirement is determined endogenously in the nitrogen sector of the model. The nitrogen can be obtained from purchase of commercial nitrogen fertilizer or through the use of livestock wastes. The non-nitrogen fertilizer required to satisfy the calculated optimum application rate is purchased and the costs are included in with the rest of the production costs to give the exogenous variable costs of production for the system.

Appendix 5. Development of the Crop Management System Costs

The source of the basic data used in determining the costs of production is Eyvindson (8). The machinery, labor, pesticide, non-nitrogen fertilizer and miscellaneous costs of Eyvindson are weighted to the 223 producing areas for each of the 11 endogenous crops[1] using county acreages as the weights and the following relationship:

$$C(i,j,k) = \sum_{m \epsilon k} C(i,j,m) * A(j,m)/A(j,k)$$

i = 1, ..., 5, for machinery, labor, pesticides, fertilizer and miscellaneous costs,
j = 1, ..., 11 for the endogenous crops,
k = 1, ..., 223 for the producing areas,
m = 1, ..., number of counties in producing area k.

---

[1]The endogenous crops are barley, corn, corn silage, cotton, nonlegume hay, legume hay, oats, sorghum, sorghum silage, soybeans and wheat.

where:

C(i,j,k) is the cost i for crop j in producing area k;

C(i,j,m) is the cost i for crop j in county m;

A(j,m) is the acres of crop j in county m;

A(j,k) is the acres of crop j in producing area k.

Each county in one of Eyvindson's regions is assumed to have the costs of that region. The acreages used as the weights are from the Census of Agriculture (34). Labor costs were adjusted to account for the increases in technology as outlined in Agricultural Water Demands (9). Each cost is then projected to 2000 using the assumption of constant per unit costs.

Adjustments for conservation practice and tillage method are determined from the SCS data questionnaire. A base of straight row cropping is used for conservation practices and adjustments are made in machinery and labor efficiency for contouring, strip cropping and terracing. Similarly, adjustments are made for the tillage practices where conventional tillage with no residue management serves as the base. The variations included conventional tillage with residue management and reduced tillage.

A further adjustment is made for reduced tillage operations to reflect the tradeoff between tillage operations and the use of herbicides for weed control. In areas which are

not moisture deficient,[1] Figure 12, a direct tradeoff has been determined with the saving in machinery cost being equally offset by increased herbicide costs (1, 3, 13, 22). In arid areas the adjustment consisted of a $3.00 increase in herbicide costs for each $1 reduction in nonherbicide costs. This is consistent with the extensive farming methods used resulting in a much reduced weed problem.

The costs reflect regional average costs of production and a response to summer fallow is required for those crops normally grown in a summer fallow rotation. From the Selected U.S. Crop Budgets (6, 7) a relative use of fertilizer and herbicides was obtained for the plains area where summer fallowing is common (Figure 13). The adjustments reflected a 4 percent reduction in pesticide after summer fallow and an increase of 50 percent if summer fallow is not part of the rotation. The wide variation in the adjustments results from the average being close to the after summer fallow data as a result of the large percent of all acres in a summer fallow rotation. A similar adjustment is made for fertilizer use with crops in summer fallow rotations receiving .92 of the average and continuous cropping sequences receiving 1.18 times the average.

---

[1]Being moisture deficient indicates an excess of potential evapotranspiration over precipitation.

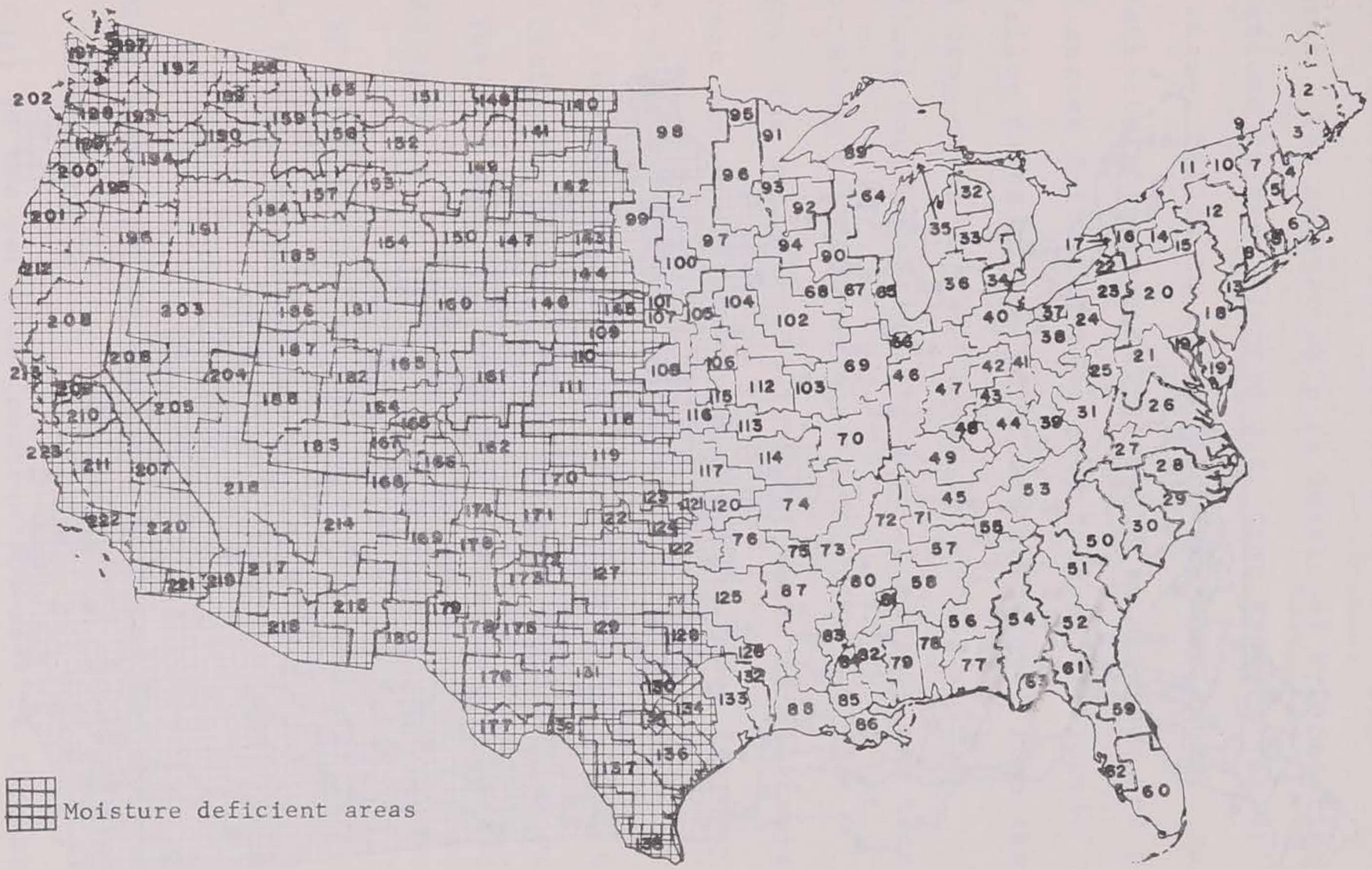


Figure 12. Moisture deficient areas of the nation

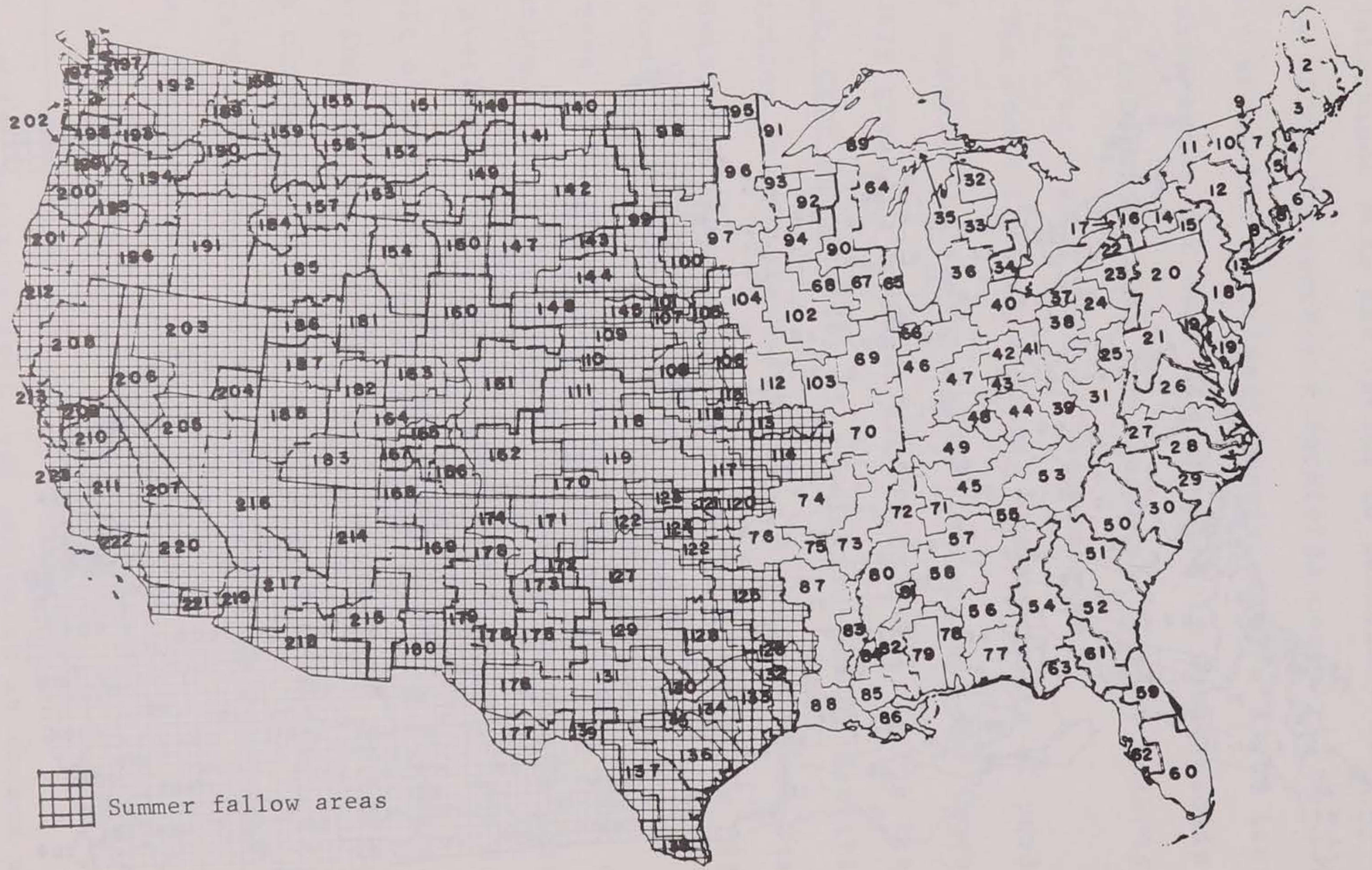


Figure 13. Summer fallow areas of the nation

Summer fallowing costs are treated as a separate "crop" in the area. The relationship is developed by comparing the crop rotations in the Selected U.S. Crop Budgets (6, 7) which include summer fallow to those which are continuous. In this way an estimate of summer fallow costs is obtained and a ratio of summer fallow cost to crop cost is developed. The summer fallow costs in the model are calculated from the determined crop costs and the developed ratios.

A final cost adjustment is made to reflect the terracing costs for those cropping systems defined to include terracing. The SCS data provided estimates of the coefficients required to calculate construction costs for terraces. The data is provided only for those classes on which terracing is a feasible alternative and other lands do not have terracing as one of their alternate conservation practices. The average terracing cost per acre is calculated by producing area as:

$$TC(i) = .1\ (CC(i) + PW(i)W(i) + PT(i)T(i))PLT(i)$$

$$i = 1, \ldots, 9 \text{ for the land classes,}$$

where:

TC(i) is the per cultivated acre terracing costs on land class i;

CC(i) is the per acre construction cost of terraces on land class i;

PW(i) is the proportion of acres of land class i terraced having grassed waterways for drainage;

W(i) is the cost per terraced acre for grassed waterways consistent with the terraces on land class i;

PT(i) is the proportion of acres of land class i terraced having tiled outlets for drainage;

T(i) is the cost per terraced acre of tiling and drainage consistent with the terraces on land class i;

PLT(i) is the the proportion of all land in class i which is feasible to terrace;

.1 is the factor to adjust for a 10 year amortized life of the terrace.[1]

From the many cost components the final production cost is determined for each cropping management system as:

$$C(i,j,k) = \sum_{m}(M(i,j,m) + L(i,j,m) + P(i,j,m) + F(i,j,m) + MS(i,j,m))\ R(i,j,m)) + TC(j,k)$$

i = 1, ..., the number of crop management systems in the producing area,
j = 1, ..., 223 for the producing areas,
k = 1, ..., 18 for the land classes, 1, ..., 9 dryland, and 10, ..., 18 irrigated,
m = 1, ..., the number of crops in the cropping system,

---

[1]A 10-year amortized life for terraces represents a tradeoff with a longer amortization period and inclusion of repair and maintenance costs.

where:

C(i,j,k) is the cost per acre for crop management system i in producing area j on land class k;

M(i,j,m) is the the projected per acre machine cost for crop m in crop system i in producing area j;

L(i,j,m) is the the projected per acre labor cost for crop m in cropping system i in producing area j;

P(i,j,m) is the the projected per acre pesticide cost for crop m in cropping system i in producing area j;

F(i,j,m) is the projected per acre non-nitrogen fertilizer cost for crop m in cropping system i in producing area j;

MS(i,j,m) is the projected per acre other costs for crop m in cropping system i in producing area j;

R(i,j,m) is the rotation weight for crop m in cropping system i in producing area j;

TC(j,k) is the per cultivated acre terracing costs on land class k in producing area j.

Appendix 6. Determination of the Land Base

The land base represents the major constraint on the productive capacity of the system. The number of acres of dryland and irrigated cropland for use by the endogenous

crops,[1] nonrotation hays and nonrotation pastures are determined by aggregating the county acreages as determined from the National Inventory (3).

Land base for the endogenous crops

The National Inventory (3) reports the acres of 18 land uses in each of the 29 class-subclass categories classified according to the severity of different conservation hazards. The major classes are from one through eight and the subclasses defined within each of the major classes, except one, reflect four conservation hazards. The hazards include erosion, subsoil exposure, drainage problems, and climatic restrictions preventing normal crop production. Class one lands have no subclass designations and the acres in this category are considered to be adequately treated and reflect no hazards under normal cultivation practices.

The county data reported in the National Inventory (3) are aggregated to the producing areas and the 29 class-subclass groups defined for dryland and irrigated are aggregated to give nine land groups which exhibit a range in erosion hazard, yield and farming alternatives. The land base used for the endogenous dryland or irrigated crops rep-

---

[1]The endogenous crops include barley, corn, corn silage, cotton, legume hay, nonlegume hay, oats, sorghum, sorghum silage, soybeans, sugar beets and wheat.

resents the sum of those lands in the component land classes of the National Inventory designated as being used for row crops, close-grown crops, summer fallow, rotation hay and pasture, land in conservation base, and land used for fruits and vegetables with an adjustment for the land used for the exogenous crops.

Projected increases in irrigated lands in the western United States are added to the irrigated acreages in each of the relevant producing areas. Only those irrigation projects which have been approved for construction before 1980 are considered. A more detailed discussion on the location of these projects and the procedure used is given in Agricultural Water Demands (9).

Acreage available for the noncultivated hays and pastures

The noncultivated land base is divided into three land use categories based on the acreages from the National Inventory (3). Dryland nonrotation pasture and rangeland from the National Inventory are combined into an upper bound for the improved or managed pasture activity by producing area. The yields and costs for these activities are obtained from the "pasture on farms" activities as described in Agricultural Water Demands (9). A similar procedure gives the activities for the irrigated improved pasture.

Bounded activities are also defined for dryland and irrigated non-rotation hay. These acres represent wild hay and

other hayland which is continuous except for infrequent interruptions to re-establish a stand. The cost and yield coefficients for these activities are determined by weighting together the respective "wild hay" and "improved hay" activity coefficients from Agricultural Water Demands. A final set of bounded activities is defined, on dryland only, to represent the grazing of forest and bush lands. Coefficients for this set of activities are determined from the "pasture not on farms" activities described in Agricultural Water Demands.

ADDITIONAL COPIES of this publication can be ordered by writing the Center for Agricultural and Rural Development, 578 East Hall, Iowa State University, Ames, Iowa 50010. Price is $3 per copy. A complete listing of all Center publications is available free upon request.

Barcode Inside