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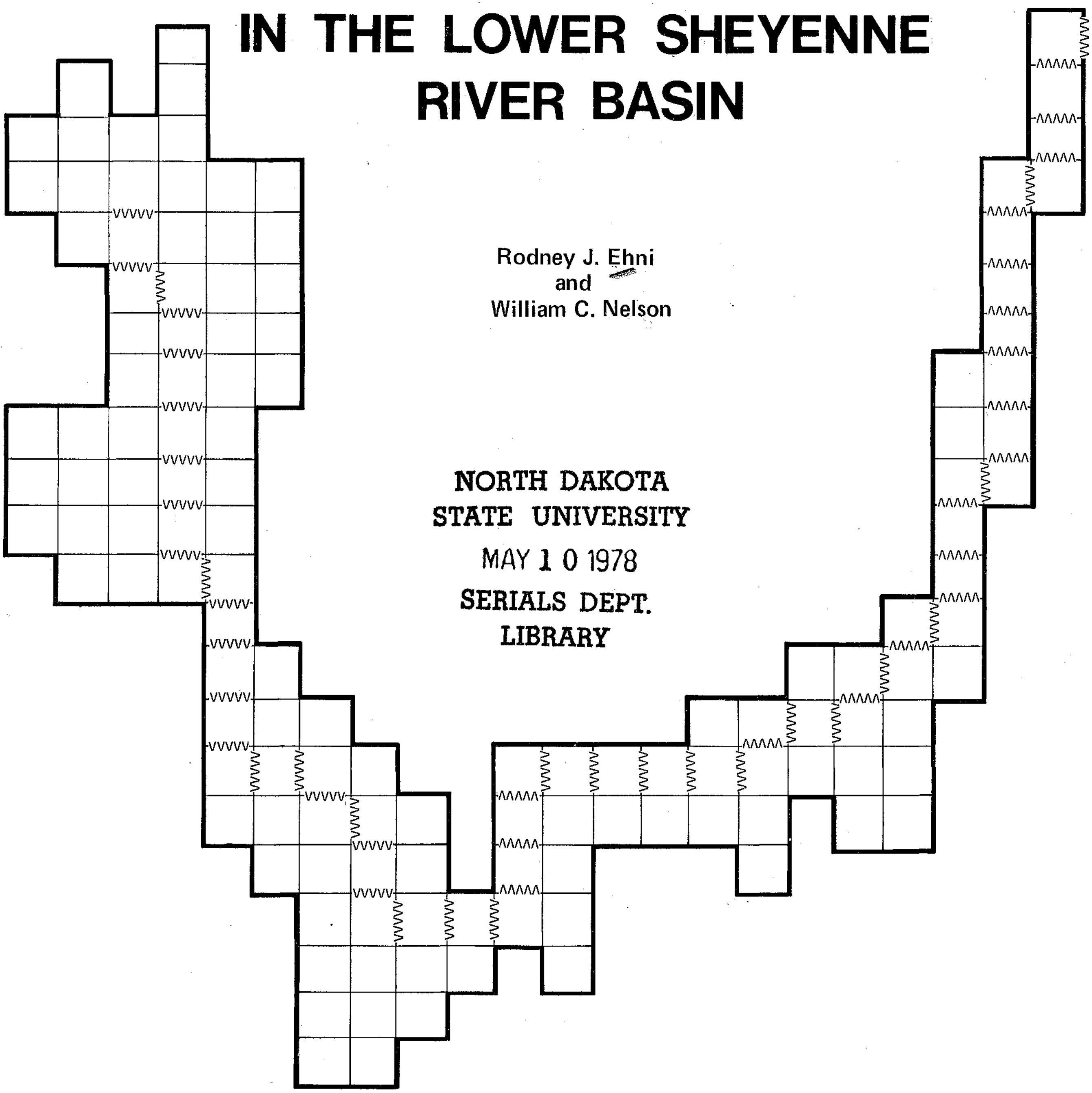
ECONOMIC AND ENVIRONMENTAL EFFECTS OF AGRICULTURAL MANAGEMENT DECISIONS IN THE LOWER SHEYENNE RIVER BASIN



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FOREWORD

Land use and water quality are two topics which individually receive much attention, yet are very interdependent. The purpose of this report is to analyze the relationship between land use and water quality and evaluate the economic consequences of this relationship.

We extend our appreciation to the following persons for their comments and information:

Donald Scott, Assistant Professor, Agricultural Economics, North Dakota State University.

George Pfeiffer, Research Associate, Agricultural Economics, North Dakota State University.

Timothy Petry, Assistant Professor, Agricultural Economics, North Dakota State University.

William Barker, Associate Professor, Botany, North Dakota State University.

Roger Johnson, Professor, Agricultural Economics, North Dakota State University.

Donald Patterson, Associate Professor, Soils, North Dakota State University.

The research for this report was part of a project on land use and water quality in the Lower Sheyenne River Basin. The research is being conducted by a multidisciplinary team composed of William C. Nelson, Agricultural Economics; William T. Barker, Botany; Mary C. Bromel, Bacteriology; John A. Brophy, Geology; Delmer L. Helgeson, Agricultural Economics; and William D. MacKeller, Chemistry. The research was supported with funds from:

North Dakota Agricultural Experiment Station

North Dakota Water Resources Research Institute

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HIGHLIGHTS

The objectives of this study were to examine the effects of agricultural production decisions on the economy and environment of the Lower Sheyenne River Basin, and to develop a simulation model to represent the agricultural sector of the Lower Sheyenne River Basin.

The Lower Sheyenne River Basin is made up of parts of Barnes, Cass, Ransom, Richland, and Sargent counties in North Dakota. Data collected included soil productivity indicies, soil information for the Universal Soil Loss Equation, and cost/revenue information. The data base included information on current land use, soil associations, and slope.

A simulation model was developed to compare four alternative sets of farm management decisions. The model calculated costs and revenues, economic impact, soil losses, and sediment contributed to the Sheyenne River for each of the alternatives. The management alternatives were: profit maximization with and without soil loss restrictions, and typical management in 1973 with and without soil loss restrictions.

Profit maximization without soil loss restrictions yielded the highest returns while adding a low level of sediment compared to other alternatives. Typical 1973 management practices yielded the highest levels of sediment while typical 1973 management practices with soil loss restrictions generated the lowest economic returns.

The results indicate soil loss can be reduced and, consequently, the water quality of the Sheyenne River can be improved due to lower sediment levels. This can be accomplished by eliminating summer fallow, limiting row crop acreage, and emphasizing small grain and hay production. Economic losses to the decision maker are not expected to occur as a result of these practices. In fact, these practices increase farm income as well as reducing sediment entering the river based on data used in this study.

ECONOMIC AND ENVIRONMENTAL EFFECTS OF AGRICULTURAL MANAGEMENT DECISIONS IN THE LOWER SHEYENNE RIVER BASIN

by

Rodney J. Ehni and William C. Nelson

Agriculture possesses a great potential for affecting the quality of the nation's water resources. In fact, agriculture's potential for changing surface water quality appears greater than the total of all other industries in the United States.[1] Soil erosion by surface runoff produces four billion tons of sediment each year.[2] Three-fourths of this sediment comes from agricultural land.[3] Each ton of sediment carries about one pound of phosphorus and 10 percent of this phosphorus is available for plant use, thereby promoting algae growth in lakes and rivers.[4] This potential for water quality degradation has generated demands to assess the effects of agricultural pollution on the total environment.[5]

The 1972 amendments to the Federal Water Pollution Control Act require each state to prepare areawide plans which include "a process to (1) identify, if appropriate, agriculturally related nonpoint sources of pollution, including runoff from manure disposal areas and from land used for livestock and crop production; and (2) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources."[6] The Iowa

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[1]Timmons, J. F., "Economic Aspects," in _Agricultural Practices and Water Quality_, Iowa State University Press, Ames, 1970, p. 377.

[2]Wadleigh, C. H., _Wastes in Relation to Agriculture and Forestry_, Miscellaneous Publication No. 1,065, United States Department of Agriculture, Washington, D.C., 1968, p. 10.

[3]_Ibid._, p. 6.

[4]Robinson, A. R., "Sediment: Our Greatest Pollutant?" _Agricultural Engineering_, Vol. 53, No. 8, August, 1971, p. 406.

[5]Federal Water Pollution Control Act, Amendments of 1972, Section 208, Public Law 92-500, 86 Stat. 816, October 18, 1972.

[6]_Ibid._

state legislature has legally established soil loss limits on agricultural land at one to five tons per acre per year, depending on soil association.

Land use planning in North Dakota will need to consider the water quality implications of land use. To meet the need for information in this area, the North Dakota Agricultural Experiment Station and Water Resources Research Institute are sponsoring a study of the relationship between land use and water quality in the Lower Sheyenne River Basin. The purpose of this report is to examine and evaluate economic and water quality conditions related to agriculture and their effects of the Lower Sheyenne River Basin.

I. Lower Sheyenne River Basin

The origin of the Sheyenne River is near the geographic center of North Dakota. The river flows east for 100 miles, turns south near McVille for another 100 miles, and then reverses its direction to the northeast at Lisbon for another 50 miles where it joins the Red River north of Fargo.

The Sheyenne River is the longest river which is completely within North Dakota's boundaries, making it subject to state control. It has a narrow and well-defined basin and is representative of other river valleys in the Great Plains in terms of municipalities, agriculture, and recreational use. There are several major water developments (Garrison Diversion, Kindred Lake, Fargo Diversion) under way or being planned that will affect the river basin. The Sheyenne River has been identified as one of the principal areas of water pollution in the United States.[7]

The lower one-third of the river basin, from the Bald Hill Dam north of Valley City to the river's mouth on the Red River above Fargo, was selected as the study area. This section of the river basin is referred to as the Lower Sheyenne River Basin (LSRB). This area consists of approximately 1,100 square miles along the Sheyenne River in Barnes, Ransom, Sargent, Richland, and Cass counties.[8] Sixty-nine percent of the land area is cultivated and

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[7] Water Atlas of the United States, Water Information Center, Inc., Port Washington, New York, 1973, Plate 51.

[8] Unpublished data interpreted from aerial photographs by technical members of the Lower Sheyenne River Basin Research Team.

22 percent of the land area is pasture or grassland.[9] The basin lies in a relatively deep, narrow valley in the Drift Prairie Region for the first one-third of its distance and then drops through the Sheyenne Delta Region into the Red River Valley.

The LSRB was divided into four regions (Figure 1). Region 1 is the Barnes County portion of the Drift Prairie. Region 2 consists of the portions of Sargent and Ransom counties which are in the Drift Prairie. Region 3 is made up of the Sheyenne Delta Region located in portions of Ransom and Richland counties. Region 4 is in the Lake Agassiz or Red River Valley portion of Cass County.

Regions 1 and 2 consist of about 70 percent cropland and 15 to 20 percent pasture. The Sheyenne Delta Region (Region 3) contains nearly equal percentages of cropland and pasture. Cropland is the major land use (92 percent) in the Red River Valley Region (Region 4) of the basin (Table 1).

TABLE 1. ACREAGE DISTRIBUTION IN THE LOWER SHEYENNE RIVER BASIN

Region	Crop Acres	Pasture Acres	Other Acres[a]	Total Acres
1	207,146	57,868	21,706	286,720
2	171,614	33,708	25,078	230,400
3	50,438	57,113	15,969	123,520
4	56,774	275	4,391	61,440
TOTAL	485,972	148,964	67,114	702,080

[a]Woodland, water, wetlands, and land in urban and residential use.

SOURCE: Unpublished data compiled and interpreted by technical members of the LSRB team.

The average growing season in the basin is between 120 and 129 days, except in the Red River Valley. The growing season in this area is 130 to

[9]*Ibid.*

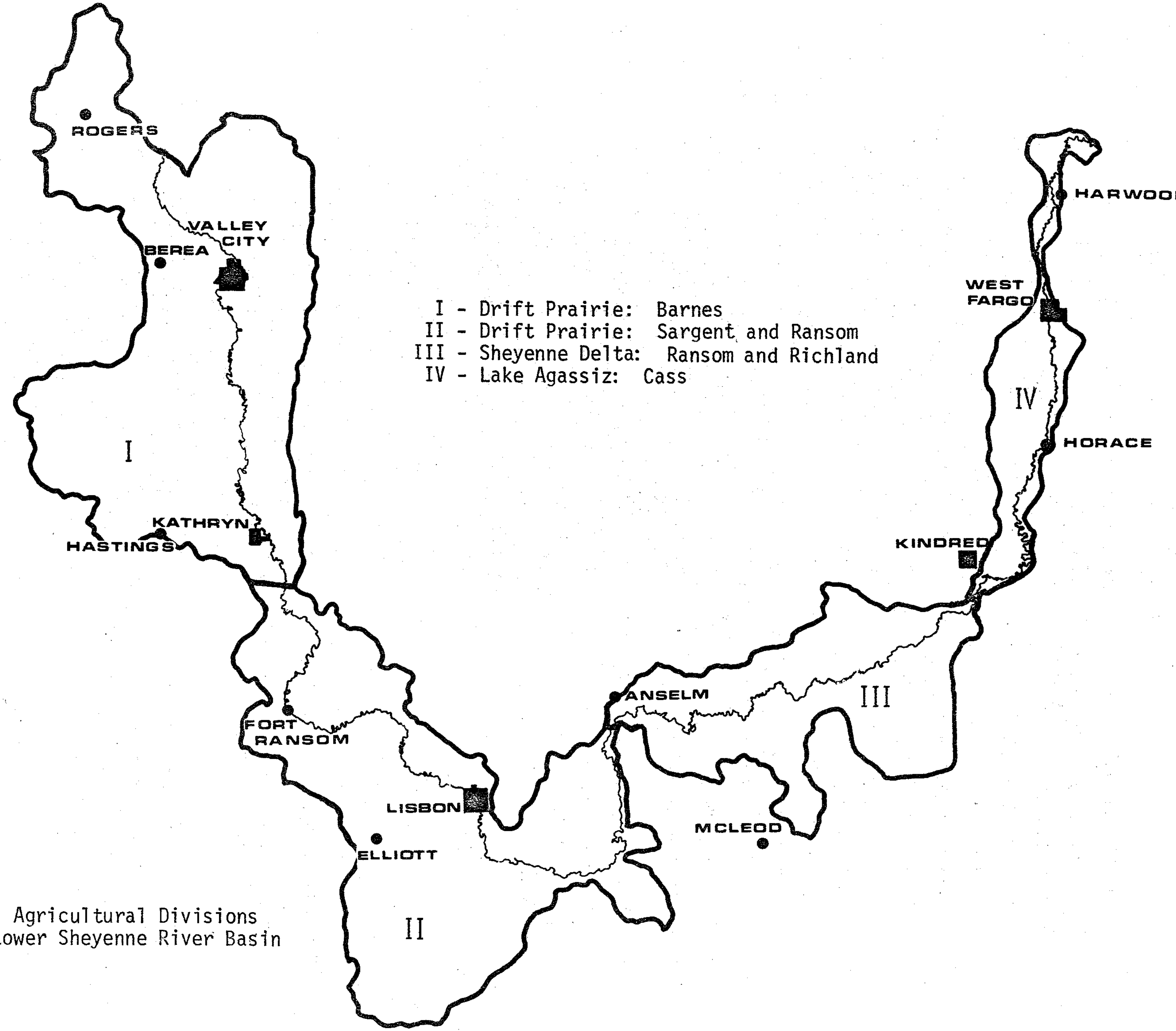

Figure 1. Agricultural Divisions of the Lower Sheyenne River Basin

150 days.[10] The average yearly temperature for the basin is 41°F.[11] The basin's average annual precipitation is 20 inches per year.[12]

Small grain production is the dominant agricultural enterprise in the counties which contain the Lower Sheyenne River Basin.[13] In 1973, small grains made up 58 percent of the tillable acres (Table 2). Row crops made up 21 percent of the tillable acres while 13 percent was summer fallowed and 8 percent was in hay.

II. The Model and the Data Base

A simulation model (LSRB Agricultural Sector Model) was developed to represent the basin. The model is a descriptive simulation model which utilizes Fortran IV as its source language. The environmental effects of the agricultural sector model are evaluated by examining the quantity of sediment from sheet and rill erosion which is deposited in the Lower Sheyenne River. Agricultural income is estimated from cost and revenue data. The input-output analysis estimates the impact of agricultural sales on the regional economy.[14]

The model uses a physical data base and a management decision data base. The physical data base describes the land use, the soil association, the generalized slope, and the generalized length of slope for each section, (parcel).[15] It identifies the watershed (subbasin) and the county to which the section belongs and identifies sections which are adjacent to the river.

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[10] North Dakota Crop and Livestock Statistics, Annual Summary, 1975, Agricultural Statistics No. 38, Statistical Reporting Service, United States Department of Agriculture in cooperation with the Department of Agricultural Economics, North Dakota State University, Fargo, May, 1976, p. 44.

[11] Ibid., p. 42.

[12] Ibid., p. 43.

[13] Agricultural data for the LSRB are available only on a county basis.

[14] The impact of agricultural sales affects more than just the five-county area comprising the basin.

[15] Each section (parcel) is assumed to be a separate 640 acre farm.

TABLE 2. AGRICULTURAL PRODUCTION IN THE LOWER SHEYENNE RIVER BASIN, 1973

	County					
	Barnes	Ransom	Sargent	Richland	Cass	Total
			thousands			
Planted Acres						
Wheat on Fallow	175.8	45.0	36.4	67.7	129.6	454.5
Barley on Fallow	37.5	13.2	11.0	13.0	12.5	87.2
Wheat	60.2	34.0	45.6	110.3	225.4	475.5
Barley	98.5	31.8	31.0	59.0	153.5	373.8
Oats	60.0	49.0	46.0	79.0	58.0	292.0
Durum	16.0	5.0	11.5	2.0	14.0	48.5
Flax	35.0	8.0	18.0	16.0	19.0	96.0
Corn for Grain	3.0	18.2	17.1	97.8	22.2	158.3
Sugarbeets	0.0	0.0	0.0	5.0	9.7	14.7
Corn Silage	11.1	9.8	14.6	11.9	8.7	56.1
Sunflowers	38.0	9.0	4.0	42.0	99.0	192.0
Soybeans	0.0	1.5	4.0	90.0	105.0	200.5
Alfalfa	33.0	38.0	29.0	29.0	20.0	149.0
Other Tame Hay	8.0	11.0	20.0	10.0	9.0	58.0
Summer Fallow	175.0	33.0	44.0	61.0	99.0	412.0
TOTAL ACRES	751.1	306.5	332.2	693.7	984.6	3,067.7
Number						
All Cattle	58.0	47.0	64.0	64.0	47.0	280.0
Milk Cows	3.3	2.0	1.9	3.7	2.3	13.2
Sheep	3.7	9.8	6.4	6.0	11.4	37.3
Hogs	10.8	12.0	19.1	46.8	39.8	128.5
Chickens	35.0	6.0	17.0	105.0	40.0	203.0

SOURCES: North Dakota Crop and Livestock Statistics, Annual Summary, 1973, Agricultural Statistics No. 32, Statistical Reporting Service, United States Department of Agriculture in cooperation with the Department of Agricultural Economics, North Dakota State University, Fargo, May, 1974.

North Dakota Crop and Livestock Statistics, Annual Summary, 1974, Revisions, 1973, Agricultural Statistics No. 35, Statistical Reporting Service, United States Department of Agriculture in cooperation with the Department of Agricultural Economics, North Dakota State University, Fargo, May, 1975.

The management decision data base describes the cropping strategies and erosion control practices for each section. Selected levels of rainfall can be assumed and influence revenue and soil erosion.

There are 1,097 sections in the basin. Region 1 (in Barnes County) is the largest with 448 sections. Region 2 (in Ransom and Sargent counties) has 360 sections. The Delta (Region 3) consists of 193 sections. Region 4 (in Cass County) is the smallest region with 96 sections. There are 186 watershed (subbasins) in the basin ranging in size from one square mile (one section) to 35 square miles. Each contributing watershed has one outlet (river section) to the river. Five hundred and ten of the 1,097 sections are in these watersheds. These are the areas which influence water quality degradation. The other 587 sections drain to lakes and depressions within the basin under normal conditions. These sections do not affect the quantity of sediment entering the Lower Sheyenne River under normal conditions.

The model contains three parts: the pollution generator, the revenue generator, and the main model.[16] The pollution generator calculates soil movement on a given parcel. The revenue generator calculates costs and returns for each parcel. The parcels are aggregated to watershed and region totals in the main model. Sediment levels and economic returns are calculated for each watershed and region. Economic impact is estimated for the basin only. A general flowchart is presented in Figure 2.

Pollution Generator

The pollution generator estimates the amount of soil eroded (soil moved) on each parcel, and supplies this information to the main model using the Universal Soil Loss Equation to estimate the amount of soil moved.[17]

The Universal Soil Loss Equation measures sheet and rill erosion. The equation is of the form:

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

where A is the predicted average annual soil loss in tons per acre per year.

R (the rainfall factor) is a measure of the erosive force of a specified rainfall distribution over one year. It is the number of erosion-index units in a normal year's rainfall. There are 75 erosion index units (R = 75) in the LSRB during a normal year.

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[16]Computer program and data base may be obtained by contacting either of the authors at the following address: Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota 58102.

[17]Detailed information on the pollution generator is presented in Appendix A--Calculation of Soil Loss and Sediment by Pollution Generator.

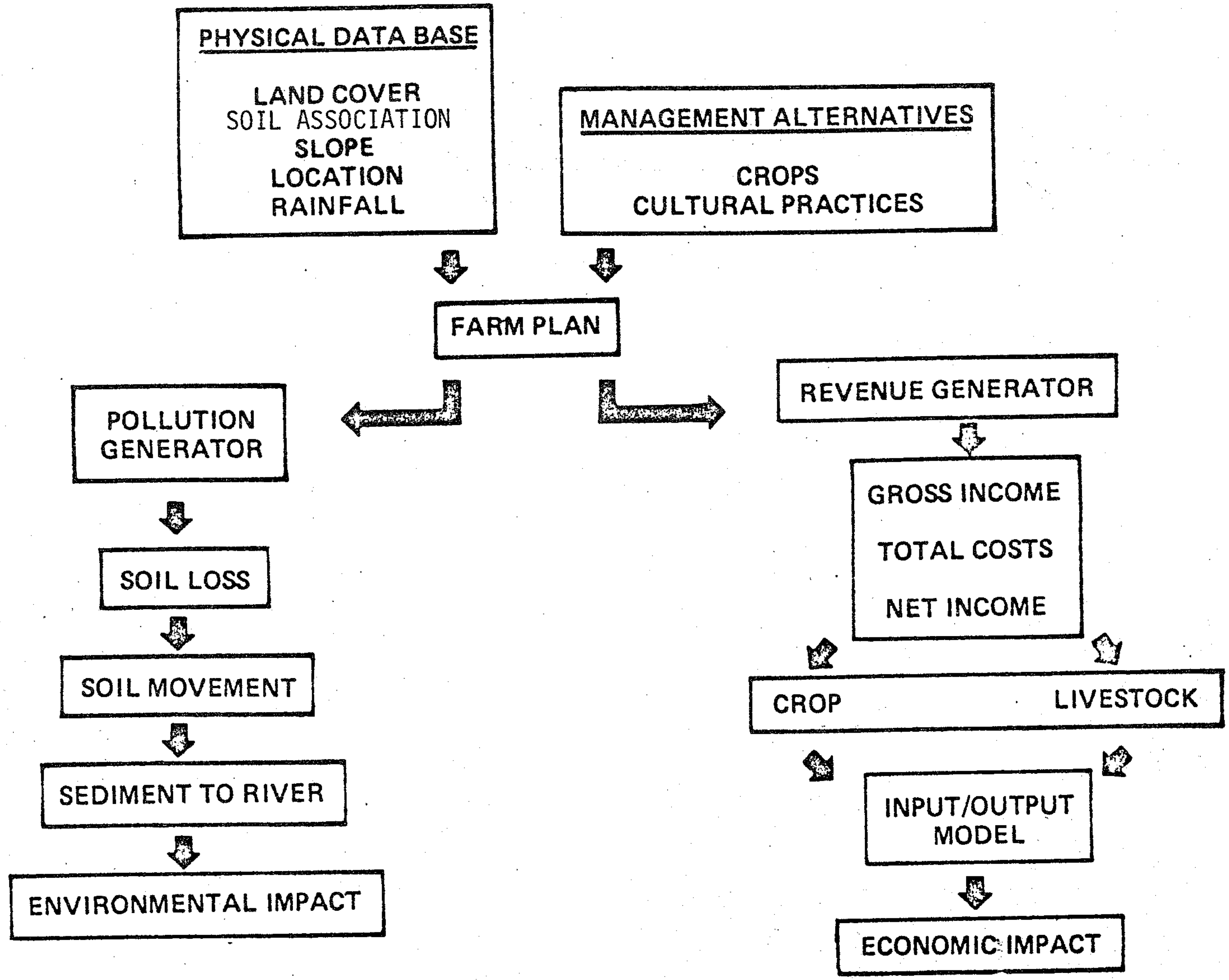

Figure 2. General Flowchart of the Agricultural Sector Simulation Model

K is the soil-erodibility factor. It is the erosion rate per unit of erosion-index for a specified soil in cultivated, continuous fallow on a 9 percent slope, 72.6 feet long. Soil properties that influence sheet and rill erosion are those that affect the infiltration rate, permeability, and total water capacity; and those that resist the dispersion, abrasion, transporting, and splashing forces of the rainfall and runoff.

The slope length (L) and slope gradient (S) factors are combined in equation form to find the expected ratio of soil loss (LS) on a field slope to the corresponding loss from a 9 percent slope, 72.6 feet long. Slope length is the distance from the point of origin of overland flow to either the point where deposition of sediment begins or where runoff enters a defined channel. The relationship between soil loss and slope gradient is affected by density of vegetal cover and soil particle size.

Soil and water management are important in determining soil loss. The cropping management factor (C) and erosion control practice factor (P) reflect management decisions in the equation. The cropping management factor is the ratio of soil loss from a field with a specified cropping and management or plant cover to soil loss from the fallow condition on which the K factor is evaluated. This measures the combined effect of all the interrelated cover and management variables including the stage of growth and vegetal cover at the time of the rain. The erosion control practice factor (P) is the ratio of soil loss with contouring, strip-cropping, or terracing to the soil loss from plowing up and down the slope.[18]

The Universal Soil Loss Equation computes gross sheet and rill erosion, but does not predict sediment yield.[19] Much of the material which is eroded often moves only a short distance before it is deposited in areas which are remote from any stream system. The actual sediment yield from a watershed is found by multiplying the gross sheet and rill erosion in a watershed by the delivery ratio for that watershed. The sediment delivery ratio for a watershed is defined as the fraction of gross sheet and rill erosion which is delivered to a point in a stream system from the drainage area above that point. It is based on the size of drainage area.

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[18]USDA-Soil Conservation Service, "Estimating Soil Loss Resulting from Water and Wind Erosion in North Dakota," Bismarck, North Dakota, March, 1975.

[19]Sediment yield equals the gross erosion minus the material deposited enroute to the point of measurement.

Multiplying the delivery ratio times gross sheet and rill erosion in calculating sediment yield is the method used by the Soil Conservation Service in estimating yield at points downstream.[20]

Revenue Generator

The revenue generator calculates the total revenue, total costs, and net revenue for crops and livestock by section.[21] This information is then passed to the main model. The prices used in this study are the 1963-1972 average prices adjusted to 1973-1974 price and cost relationships.

The LSRB Agricultural Sector Simulation Model assumes that all inputs are fixed in optimal combinations for each crop on a per acre basis. Land becomes the proxy for all variable resources and has a constant cost for each acre of land used. Combining all inputs in the optimal proportions for each acre of land implies that a 1 percent change in the quantity of land used will yield a 1 percent change in the amount of all inputs and output. When all factors other than land are given for the optimal allocation of inputs and land is considered the variable resource for the production function, the relationship between the input and the quantity of output is linear.

The total revenue function for this production relationship is linear when price is constant. The total cost function also is linear. The average revenue and cost per acre and per unit of output are constant; therefore, net revenue per acre and per unit of output is also constant for each crop.

The Agsim Model

The pollution generator and the revenue generator calculate information for each individual section. The main model takes this information and aggregates to watershed, region, and basin totals. The main model calculates sediment levels and gross business volume is estimated by using the interdependence coefficients of the North Dakota input-output model.

Before any computations are made, the main model insures that the number of acres planted on a section does not exceed the number of available

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[20] USDA Soil Conservation Service, "Sedimentation," National Engineering Handbook, Section 3, Washington, D.C., 1971.

[21] Detailed information on revenue generator is presented in Appendix B--Calculation of Revenue and Cost Estimates by Revenue Generator.

cropland acres, and the number of animal unit months required by livestock does not exceed the potential animal unit months available on a section.

Total revenue, total cost, and net revenue for crop activities, livestock activities, and agricultural activities are summed to region and basin totals. Total revenue from crops, total costs from crops, and net crop revenue are divided by the number of crop acres for each of the four regions and for the basin to find the average total revenue, the average total cost, and the average net revenue from crop activities for each of the regions and for the basin.

The impact of agriculture on the economy is estimated using the input-output model. Total revenue from crops and total revenue from livestock are assumed to represent final demand payments to the agriculture-crop and agriculture-livestock sectors. These payments are multiplied by the respective gross receipts multipliers to estimate the gross business volume generated as a result of revenue from crops and livestock.

The Data Bases

The LSRB model uses two data bases: the physical data base and the management decision data base. They describe the physical characteristics and the management decisions for each of the 1,097 sections (parcels) in the basin.

The physical data base describes land use, soil associations, the generalized length of slope and percent slope, the watershed and county to which the section belongs, and a code for river sections. If the section contains urban land, the data base indicates the city or town. Each section has a unique identification which defines its location in the basin. The township, range, and section number are given for reference.

The information describing land use gives the percent of land in crops, pasture, woodland, water and marsh, and urban use. These data were developed from aerial photographs. The generalized length of slope and the watershed groupings were taken from topographic maps. Soil associations were interpreted from the county general soil maps.

Each watershed has one parcel which is a river parcel. This indicates that the river flows through this parcel and it is the point where runoff from the watershed enters the river.

The management decision data base describes the cropping strategies and erosion control practices. Four alternative management decisions are assumed and include: (1) typical management reflecting 1973 decisions without restrictions on soil loss, (2) typical management with restrictions on soil loss, (3) profit maximization without restrictions on soil loss, and (4) profit maximization with restrictions on soil loss.

Each of the five counties was divided into two areas: contributing areas that are likely to add to water quality degradation in the Lower Sheyenne River and noncontributing areas which normally do not affect water quality degradation. The management decisions determine the percentage of the crop or livestock activity to be allocated to each of these areas.

All available cropland was divided into fields which were nearly equal in size. Crop activities were allocated to these fields to reflect the percentage of each crop for the particular management alternative.[22] Livestock allocated to pasture reflected the percentage distribution of livestock species produced under each of the four alternatives.[23]

The erosion control practices also reflected the needs of each area. Steep, hilly land used intensive erosion control methods. Areas with a relatively low percent slope did not require erosion control practices.

Alternative I reflected typical management without soil loss restrictions. The alternative was based on 1973 plantings in the respective counties.[24] There was a large amount of summer fallow and more land in row crops and hay than in the profit maximizing alternative (alternative III).

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[22]The total crop acres on a parcel were classified into different size groups and then were divided into fields. This method was used to allocate crop acres into fields of similar sizes. Small amounts of crop acres were left unused and were treated as summer fallow. Crops were assigned to individual fields by a random number generator which forced the aggregate crop distribution to reflect county patterns for each management alternative.

[23]In assigning livestock to pasture, the pasture acres were first assigned to a species of livestock by using the random number system. The number of that species was allocated by finding the number that could be supported on the pasture under normal rainfall. The assignments made insure that the available pasture acreage is not overgrazed. The number of head was assigned in groups of five to eliminate partial numbers. If an area could not support at least five additional head, the pasture carrying capacity was left underutilized.

[24]North Dakota Crop and Livestock Statistics, Annual Summary 1974, Agricultural Statistics No. 35, Statistical Reporting Service, United States Department of Agriculture in cooperation with the Department of Agricultural Economics, North Dakota State University, Fargo, May, 1975.

Alternative II described typical 1973 management decisions with soil loss restrictions. The noncontributing areas used the same crop distribution as in alternative I. In contributing areas, summer fallow was eliminated, plantings of row crops were reduced, and plantings of small grains and hay were increased.

Management alternative III reflected a profit maximization plan without soil loss restrictions. This alternative had a large percentage of small grains and eliminated summer fallow. Range cattle were the main livestock activity. This alternative was based on mathematical programming studies which attempted to determine cropping patterns which maximized profit in areas containing the Lower Sheyenne River Basin.[25]

Alternative IV described the profit maximization plan with soil loss restrictions. Areas which did not contribute to water quality were permitted the same crop and livestock distributions as alternative III. Contributing acres were planted exclusively in small grains (especially wheat) and hay. Summer fallow was eliminated to reduce erosion.

The crop and livestock distributions for these alternatives are shown in Appendix C.

An Example of the Model

The preceding sections describe the data and the procedures used in the agricultural sector model.[26] This section works through the model for one parcel to illustrate the relationships of the model. The model calculates revenue and soil loss for each parcel; however, estimates are not necessarily reliable at the individual parcel level. The estimates are aggregated to region and basin totals and the averages are used. The predictions gain reliability when aggregated over a large number of parcels.

This example uses parcel number 1413, located in northwestern Barnes County. It is one of 13 sections in subbasin 167. The dominant soil association on this parcel is Gardena-Glyndon with a glacial till substratum (soil association = 13). The K factor (erodibility) for Gardena-Glyndon is 0.28.

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[25]Herman, W. D., An Analysis of Optimum Farm Enterprise Organization in Southeast Central North Dakota, unpublished M.S. thesis, Department of Agricultural Economics, North Dakota State University, Fargo, 1975.

Anderson, J. D., Analysis of Optimum Farm Organization in the Red River Valley, unpublished M.S. thesis, Department of Agricultural Economics, North Dakota State University, Fargo, 1970.

[26]Data and relationships used in this example are presented in Appendicies A and B.

The parcel is nearly level with a generalized slope of 2 percent and the generalized length of slope being 30 feet (LS factor = 0.116). Eighty-two percent (525 of 640 acres) of the land is cropland, 15 percent (96 acres) is pasture, 2 percent (13 acres) is woodland, and 1 percent (6 acres) is water or marsh. Rainfall is assumed to be one inch above normal during the critical growing season (rainfall code = 5 and the R factor = 79).

There are assumed to be two 260-acre fields containing continuously cropped wheat and sunflowers. Twenty head of beef cattle are grazed on the pasture. The operator uses contour plowing and strip cropping as erosion control practices (P = 0.30).

The model finds that 520 of the 525 acres of cropland are cropped.[27] The model also checks pasture requirements and finds that 88.6 of the 96 pasture acres are needed for subsistence by the cattle.

The pollution generator finds the total soil moved on this parcel. The soil erosion is computed by using the Universal Soil Loss Equation (A = R•K•LS•C•P). The C factor for continuous wheat is 0.19. The soil loss from the wheat field is 0.147 tons per acre (79 x 0.28 x 0.116 x 0.19 x 0.03 = 0.147 tons per acre) or 38.14 tons (0.147 x 260 acres = 38.15). Soil losses from the sunflower field are 0.309 tons per acre (80.29 total tons). Total soil lost from the pasture (C factor = 0.013) is .96 tons. Soil loss from woodland (C = 0.02) is .66 tons. Soil losses from unused cropland totals 3.7 tons. The total soil moved on this parcel is 123.75 tons. Of this total, 122.13 tons are eroded from cropland.

Calculation of cost and revenue data for the parcel requires that yields be estimated. The average wheat yield for Barnes County is 24.1 bushels per acre. The added inch of rainfall increases the yield by 2.1 bushels per acre. The productivity index for Gardena-Glyndon till substratum is 90. The Barnes County productivity index is 73. Applying the productivity index and the rainfall effects to the average yield gives a wheat yield of 32.3 bushels per acre [(90/73) (24.1 + 2.1) = 32.3]. The average sunflower yield for Barnes County is 1,020 pounds per acre. The added inch of rainfall increases this by 120 pounds per acre. After applying the productivity index, the yield for sunflowers on this parcel is 1,405 pounds per acre.

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[27]The model divides the available cropland into fields of similar sizes. This process leaves small amounts of cropland unused. Unused acres are treated as summer fallow.

The price of wheat of $3.50 per bushel times 32.3 bushels per acre times 260 acres results in $29,394.22 of revenue from wheat. With a price of $.11 per pound, revenue from sunflowers is $40,196.69. Total crop revenue is $69,590.91.

Production costs are $52.09 per acre for wheat and $60.57 per acre for sunflowers. The return to land (land rent) for Barnes County is $18.53. When adjusted by the productivity index to reflect the value of this parcel [(90/73) (18.53) = $22.86], the rent is $22.86 per acre. The average cost per acre of wheat is $74.94 and the average cost per acre for sunflowers is $83.43. Total cost for wheat is $19,486.35 and $21,691.15 for sunflowers. Total crop costs sum to $41,177.50. The cost from the unused cropland is $173.82.[28] Net revenue from cropland is $28,239.59.

A livestock unit contains one cow and nine-tenths of one calf with a 90 percent calf crop. Beef cattle production (20 head/1.9 = 10.53 livestock units) on this parcel accounts for $2,449.38 in revenue ($232.61/l.u. x 10.53). Total costs of beef production are $2,303.44 ($218.75 x 10.53) which includes the cost of land. Net revenue from livestock is $145.94.

Total revenue generated on this parcel is $72,040.29. Total costs of production are $43,654.76. Net revenue on this parcel is $28,385.53.

This parcel contributes 123.75 tons of the soil moved (0.19 tons per acre) in subbasin 167. A total of 1,897 tons of soil (0.23 tons per acre) is moved in the 13 parcels of subbasin 167. To find the amount of sediment contributed to the river from subbasin 167, the delivery ratio of 0.168 (13 square miles) is multiplied times the soil moved. This results in 318.70 tons of sediment (0.04 tons per acre) contributed to the river from this watershed.

III. Results

The economic results of the simulation model are gross revenue; total cost; and net revenue for crop activities, livestock activities, and the sum of crop activities and livestock activities. The results are given both as totals and as averages per acre. The per acre results from the crop

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[28]Rental costs are $114.30 (5 x 22.86) plus $59.52 of summer fallow costs.

activities are given for crop acres. Results from livestock activities are given for pasture acres. Combined crop and livestock results are given for the crop and pasture acres in the basin.[29]

The environmental results are gross soil loss from contributing acres, soil loss per contributing acre, total sediment reaching the river, and sediment per contributing acre. Environmental results are given as tons contributed per acre and in total tons contributed. All results are computed for each of the four regions in the basin and summed or averaged for the basin.

Effects Based on Normal Rainfall

Soil Loss and Sediment

Typical management decisions (alternative I) yielded 133,060 tons of eroded soil annually (Table 3). An estimated 29,200 tons of soil reach the river in the form of sediment. This was an average of 0.59 tons of eroded soil per contributing acre and 0.09 tons of sediment reaching the river per contributing acre.

TABLE 3. SOIL LOSS AND SEDIMENT REACHING THE LOWER SHEYENNE RIVER FROM CONTRIBUTING ACRES

Management Alternative	From Contributing Acres		Per Contributing Acre	
	Soil Loss	Sediment	Soil Loss	Sediment
		tons		
I-Typical	133,060	29,200	0.59	0.09
II-Typical w. Restric.	68,930	15,135	0.29	0.05
III-Profit	84,070	18,425	0.36	0.06
IV-Profit w. Restric.	70,100	15,400	0.29	0.05

The typical decisions with soil loss restrictions (alternative II) yielded 68,930 tons of soil annually from sheet and rill erosion. An estimated

[29]Detailed economic results are presented in Appendix D--Effects of Management Decisions on Revenues.

15,135 tons of soil reached the river in the form of sediment. This was an average of 0.29 tons of eroded soil per contributing acre and 0.05 tons of sediment reaching the river per contributing acre.

The profit maximizing decisions (alternative III) estimated 84,070 tons of eroded soil annually (soil moved from its original position) due to sheet and rill erosion. Most of this soil was deposited in depressions before reaching the river, but an estimated 18,425 tons of eroded soil in the form of sediment entered the Sheyenne River. This was an average of 0.36 tons of eroded soil per contributing acre and 0.06 tons of sediment reaching the river per contributing acre.

The profit maximizing decisions with soil loss restrictions (alternative IV) resulted in 70,100 tons of soil eroded annually due to sheet and rill erosion. Over 15,000 tons of this soil reached the river in the form of sediment. This was an average of 0.29 tons of eroded soil and 0.05 tons of sediment reaching the river per contributing acre.

Validity of Estimated Soil Loss

Soil losses from sheet and rill erosion in North Dakota were small relative to other North Central States according to the Center for Agricultural and Rural Development in a study on land use in the North Central Region.[30] The average soil loss per acre for all classes of land in the North Central States was 4.11 tons per acre. The average annual soil loss estimated for all classes of land ranged from 0.63 tons per acre in North Dakota to 9.52 tons per acre in Missouri.

Annual soil losses in North Dakota from class II land[31] were estimated to be 0.39 tons per acre. With soil loss abatement programs, this decreased to 0.35 tons per acre. Average annual soil loss from class III and class IV land was 1.39 tons per acre, and 1.60 tons per acre when a soil loss abatement alternative was used. The soil loss increased for classes III and IV since more erosive cropland in North Dakota was placed into production in order to decrease soil losses in other states and in the entire North Central Region.

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[30]Huemoeller, W. A., et al., Land Use: Ongoing Development in the North Central Region, Center for Agricultural and Rural Development, Iowa State University, Ames, September, 1976, pp. 220-223.

[31]The Soil Conservation Service land classification is used. Classes I and II are good cropland. Classes III and IV are fair to poor cropland susceptible to erosion. Classes V and above are not used for cropland. North Dakota does not contain class I land due to climatic conditions.

The average annual soil loss for all classes of land was 0.63 tons per acre in North Dakota. Under the soil loss abatement alternative, the soil loss increased to 0.66 tons per acre annually because of the use of the more erosive cropland in North Dakota in order to decrease soil loss in other states.[32]

Economic and Environmental Effects

A comparison of results from a simulation will not necessarily give the "best" or optimum strategy on an absolute basis. However, the best decision relative to the limited set of decisions under consideration may be determined. This section evaluates the alternatives using sediment, net revenue, and total economic impact as indicators.

Alternative III (profit maximization) generated $22,277,000 of net revenue (Table 4). Alternative I (typical) generated $15,386,000 of net revenue. Alternative IV (profit maximization with restrictions) generated $19,944,000 of net revenue and alterantive II (typical with restrictions) generated 14,805,000 of net revenue. As expected the unrestricted profit maximizing alternative generated the highest net revenue.

TABLE 4. SEDIMENT FROM CONTRIBUTING ACRES, NET REVENUE, AND GROSS BUSINESS VOLUME RESULTING FROM THE MANAGEMENT ALTERNATIVES IN THE LOWER SHEYENNE RIVER BASIN

Management Alternative	Sediment From Contributing Acres	Net Revenue	Gross Business Volume
	tons	*1,000 dollars*	
I-Typical	29,200	15,386	192,629
II-Typical w. restric.	15,135	14,805	194,131
III-Profit	18,425	22,277	222,733
IV-Profit w. restric.	15,400	19,944	211,535

The largest economic impact (measured in terms of gross business volume) was also generated by alternative III. Alternative III generated $222,733,000 in gross business volume; alternative I, $192,629,000; alternative IV,

[32] Huemoeller, W. A., et al., op. cit., pp. 221-224.

$211,535,000; and alternative II, $194,131,000. Gross business volume under the profit maximizing alternatives was substantially greater than the typical alternatives because of the larger amounts of agricultural sales.

Total sediment reaching the river from alternative III was 18,425 tons, while alternative I contributed 29,200 tons. The restricted alternatives (II and IV) contributed 15,135 tons and 15,400 tons of sediment, respectively.

There was a substantial difference between the net revenue generated by the profit maximizing alternatives and the typical alternatives (Table 5). Eliminating summer fallow and increasing the production of wheat in the basin resulted in net revenue of $35.09 per acre from alternative III as opposed to $24.23 from alternative I. The soil loss abatement alternatives decreased the per acre net revenue to $31.41 under profit maximization (alternative IV) and to $23.32 for typical practices (alternative II).

TABLE 5. SEDIMENT PER CONTRIBUTING ACRE, NET REVENUE PER ACRE, AND THE VALUE OF LAND PER ACRE RESULTING FROM MANAGEMENT ALTERNATIVES IN THE LOWER SHEYENNE RIVER BASIN

Management Alternative	Sediment Per Contributing Acre	Net Revenue Per Acre
	tons	*dollars*
I-Typical	0.09	24.23
II-Typical w. Restric.	0.05	23.32
III-Profit	0.06	35.09
IV-Profit w. Restric.	0.05	31.41

Sediment levels of 0.05 tons and 0.06 tons per contributing acre occurred annually under the profit maximizing alternatives with and without soil loss abatement programs, respectively. The typical alternative with soil restrictions yielded 0.05 tons of sediment per contributing acre annually. Sediment contribution under the typical alternative without soil loss restrictions was 0.09 tons per acre.

Although the unrestricted profit maximizing alternative did not reflect the best management practices in terms of erosion control, there was little difference between this alternative and the two alternatives which restricted soil erosion. The elimination or reduction of summer fallow was a major cause of this decrease in sediment.

The maximization of profit will lead to the improvement of water quality in the Lower Sheyenne River by reducing soil loss via the elimination of summer fallow and selected row crops on contributing acres. In turn, with less soil eroded within the basin, less sediment can be expected to be found in the river.

Farmers are reducing land in summer fallow. In 1973, total land in summer fallow in the five-county area comprising the basin was 412,000 acres (Table 6). In 1976, the land in summer fallow in this area was reduced to 218,000 acres. Each county comprising the basin exhibited the same trend with fewer summer fallow acres in 1976 than in 1973. There was nearly a 50 percent decrease in the number of acres in summer fallow over this three-year period. The land in summer fallow was artificially high in 1973 because of the farm programs which were discontinued in 1972. The adjustment of converting land in summer fallow to cropland is taking place.

TABLE 6. LAND IN SUMMER FALLOW IN THE LOWER SHEYENNE RIVER BASIN

County	Acres in Fallow	
	1973	1976
Barnes	175,000	106,000
Ransom	33,000	23,000
Sargent	44,000	18,000
Richland	61,000	30,000
Cass	99,000	41,000
TOTAL	412,000	218,000

SOURCE: North Dakota Crop and Livestock Statistics, Annual Summary 1976, Agricultural Statistics No. 40, Statistical Reporting Service, United States Department of Agriculture in cooperation with the Department of Agricultural Economics, North Dakota State University, Fargo, May, 1977.

Increases in prices of small grains relative to row crop prices and to production costs would reduce the amount of land in summer fallow and in row crops. This would result in lower levels of soil loss and sediment in the LSRB. A return to government programs which require summer fallow would produce higher levels of soil loss. Low prices for small grains and livestock also would tend to increase soil erosion due to land being summer fallowed or transferred from grain and forages to row crops.

IV. Summary and Conclusions

Summary

This study was conducted to develop a model to examine the effects of agricultural management decisions on the environment and the economy of the Lower Sheyenne River Basin.

The profit maximizing management alternatives generated substantially higher revenues and substantially lower soil loss than the typical alternatives. Profit maximization without soil loss restrictions resulted in $35.09 of net revenue per acre as opposed to $24.23 of net revenue per acre for the typical alternative. The profit maximizing alternative yielded only .36 tons of soil loss annually per contributing acre as compared to the annual per acre soil loss of .59 tons from the typical alternative.

The profit maximizing alternative eliminated summer fallow and emphasized the production of small grains. The elimination of summer fallow accounts for most of the reduction in the quantity of soil moved. The crop management factor for summer fallow is 1.0; whereas, the crop management factor for wheat and other small grains is .19 (small grains can be expected to contribute only 19 percent as much soil loss as summer fallow). Row crops generally have a C factor of about .40 (they contribute about twice as much eroded soil per acre as small grains). The elimination of summer fallow also increases the amount of land used for crop production. The increase in production leads to an increase in sales and revenue.

There is little difference in the amount of soil eroded under the two profit maximizing alternatives. The soil loss restrictions limit sugarbeet acreage which is a more profitable crop than wheat. Since the sugarbeet acreage is limited by contract, there are only minor differences between the alternatives. The only difference between the two profit maximizing alternatives is that row crops are not allowed on contributing acres when restrictions are used.

The results indicate soil loss can be reduced, and consequently, the water quality of the Sheyenne River can be improved because of lower sediment levels. This can be accomplished by eliminating summer fallow, limiting the acres of row crops that are planted, and emphasizing the production of small grains and hay. Economic losses are not expected from these practices. In fact, the economic situation of the decision maker should improve under the cost and revenue conditions used in this study.

Conclusions

Conferences and meetings with farmers and ranchers to present information on nonpoint pollution would aid in reducing the quantity of soil loss and sediment entering the Sheyenne River. Illustrations of how summer fallow generates five times the amount of soil loss as small grains and 2.5 times more than row crops annually may stimulate voluntary changes in farm plans. If those changes also increase net farm income as they do under 1963 to 1972 average price relationships, voluntary action to reduce soil loss should be successful.

Soil loss under normal conditions is low in North Dakota (0.63 tons/acre) when compared to the average in 12 north central states (4.11 tons/acre).[33] This is primarily due to climatic conditions, topography, and cropping patterns (lower percent of row crops) in North Dakota than states such as Iowa, South Dakota, and Illinois. The initial lower quantity of soil loss may enable the achievement of satisfactory soil loss levels in North Dakota through voluntary and incentive measures rather than strictly enforced regulations and accompanying penalties.

National agricultural policy can have substantial effects on soil erosion through price and acreage reduction programs. Programs which require land to be held fallow will lead to substantial increases in soil loss and sediment. If land taken out of crop production is required to be seeded with cover crops, soil losses will be reduced.

Prices of small grains and forage crops relative to row crops have a major effect on farm enterprise combinations and, therefore, soil loss. High prices of small grains and forages (including pasture via high livestock prices) relative to row crops will probably lead to lower soil losses; whereas, high row crop prices relative to small grains will lead to increased soil losses. Therefore, rational agricultural price policy should be formulated to consider the environmental effects of its target and loan prices. Combined costs of agricultural products and good quality surface water can be much

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[33]Huemoeller, W. A., et al., op. cit., pp. 220-221.

lower for consumers through a coordinated program than agricultural programs which indirectly increase soil loss via stimulating row crop production and requiring summer fallow and costly environmental programs to increase water quality.

Limitations of Study

The data used in this study have a definite effect on the outcome of the model. The model used 1963-1972 cost and price relationships adjusted to 1973 levels. These relationships may not hold at future dates. If this is the case, the model's results would differ from the actual situation.

The physical features of the data base are given for each 640 acre section. These data may differ from the actual characteristics of a particular section as the soil associations were obtained from county general soil maps and the percent slope and length of slope were generalized for each section. The results for a particular section may be incorrect; however, the information from each section is summed to a regional total and averaged. The estimates gain reliability when summed over a large area.

Some assumptions made for the livestock sector in the model need refinement. Rainfall affects the growth of forage and the growth of calves; however, this is not programmed into the model. Data are needed to provide better estimates of the relationship between rainfall, forage production, and weight gain of livestock.

Need for Further Research

The LSRB agricultural sector simulation model provides a description of the economic and environmental effects of agricultural management decisions. The model could be improved to be a more useful aid in the decision-making process for state and local officials by refining the model and examining other agricultural pollutants.

The model examines the quantity of sediment added to the Sheyenne River. Pollutants, such as nitrogen, phosphorus, and pesticides, are not specifically examined, and the model is limited in evaluating policies concerning fertilizer and pesticide use. In addition to predicting surface runoff from these pollutants, the model could be modified to examine groundwater flows and the leaching of nitrogen.

The components of the Universal Soil Loss Equation should also be evaluated. The accuracy of the erodibility factor, K, has been questioned by soil scientists.[34] The length (L) and slope (S) factors are generalized for each parcel and can be refined to more accurately reflect the physical conditions of the parcel. The relationship between the rainfall factor and increments in rainfall was assumed to be linear. This relationship should be analyzed for its validity. Crop rotations, residue handling, and tillage methods should be incorporated into the crop management factor.

New methods are being developed to estimate soil losses. Data required by these predictive models for large geographic areas are not available.[35] Users of the LSRB model should remain aware of these soil loss estimators and implement them when the models and data become available.

The agricultural sector model does not include feedlots of any kind. Feedlots contribute waste and bacteria to the river but generate business volume in the regional economy. The pollutants from feedlots and the revenue generated from feedlots should be included in the basin totals.[36]

The most important addition to the model which could be implemented is a statistical analysis section. This section would check the results of the model against actual conditions for statistical significance. This analysis would provide proper checks on the validity of the model and would allow the user to place confidence limits on the results of the model.

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[34] Gee, G. W., J. E. Gilley, and Armand Bauer, "Use of Soil Properties to Estimate Soil Loss by Water Erosion on Surface-Mined Lands of Western North Dakota," North Dakota Farm Research, November-December, 1976, pp. 40-43.

[35] Heitzenrater, P. R., project leader, Loading Functions for Assessment of Water Pollution from Nonpoint Sources, U.S. Environmental Protection Agency, Washington, D.C., May, 1976.

Meyer, L. D., and W. H. Wischmeier, "Mathematical Simulation of the Process of Soil Erosion by Water," Transactions of the American Society of Agricultural Engineers, Vol. 12, No. 6, November-December, 1969.

[36] A feedlot model was incorporated into the LSRB simulation model in October, 1976.

APPENDICIES

APPENDIX A

APPENDIX A--CALCULATION OF SOIL LOSS BY THE POLLUTION GENERATOR

The pollution generator is given the rainfall code from the main model. It then determines the rainfall (R) factor in terms of erosion-index units. The R factors for rainfall below or above normal were found by linear interpolation (Appendix Table A1) with the normal R factor for the LSRB equal to 75 erosion-index units per year.[1]

APPENDIX TABLE A1. THE RAINFALL "R" FACTOR AND DEVIATION FROM NORMAL, BY RAINFALL CODE

Rainfall Code	Deviation From Normal	Rainfall Factor[a]
	inches	*erosion-index units*
1	-3	64
2	-2	68
3	-1	71
4	0	75
5	1	79
6	2	83
7	3	86

[a]Straight line interpolation of rainfall factors by total rainfall.

The soil erodibility (K) factor is dependent on soil type (Appendix Table A2). There are 46 major soil associations in the basin ranging from Valentine sand to Gardena-Glyndon loams to Fargo clay.

The erosion control practice (P) factor is given with the management data base. It is dependent on the slope and the type of erosion control practice used. When no erosion control practice is used, the P factor is 1.0 (having no effect on the equation). Contouring or strip cropping

[1]USDA-Soil Conservation Service, "Estimating Soil Loss Resulting from Water and Wind Erosion in North Dakota," Bismarck, North Dakota, March, 1975.

APPENDIX TABLE A2. DESCRIPTION OF SOILS, PRODUCTIVITY INDICES, AND ERODIBILITY FACTORS IN THE LOWER SHEYENNE RIVER BASIN

Soil Code	Soil Association	Slope Class	Crop Productivity Index	Pasture Rating	Erodibility Factor
Soils with thin surface layer (Regosol) and associated soils with thick black surface layer (Chernozem), and poorly drained soil (Humic Gley)					
Loams					
1	Buse	hilly and steep	25[a]	.67	.32
Sands and loamy sands with sandy substrata					
2	Valentine-Maddock-Hamar	strongly rolling	16[a]	.67	.17
Soils with thick black surface layer (Chernozem) and associated soils with thin surface layer (Regosol), very limy subsoil (Calcium Carbonate Solonchak), or pooly drained soils (Humic Gley)					
Loams and clay loams					
3	Aastad-Forman	nearly level	89	.80	.32
4	Aastad-Hamerly	nearly level	86	.80	.32
5	Barnes-Buse	rolling	59	.80	.32
6	Barnes-Hamerly	undulating	78	.80	.32
7	Barnes-Sioux	rolling	40	.67	.32
8	Barnes-Svea	undulating	80	.80	.32
9	Forman-Aastad	undulating	80	.80	.37
10	Forman-Hamerly	undulating	78	.80	.37
11	Gardena-Glyndon	nearly level	96	.80	.28

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APPENDIX TABLE A2. DESCRIPTION OF SOILS, PRODUCTIVITY INDICES, AND ERODIBILITY FACTORS IN THE LOWER SHEYENNE RIVER BASIN (CONTINUED)

Soil Code	Soil Association	Slope Class	Crop Productivity Index	Pasture Rating	Erodibility Factor
12	Gardena-Glyndon, clay substratum	nearly level	94	.80	.28
13	Gardena-Glyndon, till substratum	nearly level	90	.80	.28
14	Overly-Beardon	nearly level	96	.80	.32
15	Overly-Beardon, till substratum	nearly level	96	.80	.32
16	Svea-Barnes	nearly level	89	.80	.32
17	Svea-Hamerly	nearly level	86	.80	.32
Loams with sandy and gravelly substrata					
18	Brantford	nearly level	66	.53	.28
19	Renshaw	nearly level	53	.53	.24
20	Renshaw-Sioux	undulating	45	.53	.24
Sandy loams with sandy and gravelly substrata					
21	Renshaw	nearly level	44	.53	.24
22	Renshaw-Sioux	nearly level	43	.53	.24
Sandy loams with loams and sandy substrata					
23	Embden-Glyndon	nearly level	79	.80	.20
Sandy loams with sandy substrata					
24	Embden-Ulen, till substrata	nearly level	75	.80	.17
25	Hecla	nearly level	59[b]	.80	.17
26	Maddock-Hecla, till substratum	undulating	51	.80	.17

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APPENDIX TABLE A2. DESCRIPTION OF SOILS, PRODUCTIVITY INDICES, AND ERODIBILITY FACTORS IN THE LOWER SHEYENNE RIVER BASIN (CONTINUED)

Soil Code	Soil Association	Slope Class	Crop Productivity Index	Pasture Rating	Erodibility Factor
Loamy sands with sandy substrata					
27	Hecla	nearly level	46[b]	.80	.17
28	Maddock-Hecla-Hamar	rolling	22[a]	.80	.17
29	Maddock-Hecla-Hamar	undulating	25[a]	.80	.17
Soils with very limy subsoil (Calcium Carbonate Solonchak) and associated soils with thick black surface layer (Chernozem or Grumusol), or claypan subsoil (Solonetz)					
Clays					
30	Hegne-Fargo	nearly level	73	.80	.43
Loams and clay loams					
31	Beardon	nearly level	93	.80	.32
32	Glyndon-Borup	nearly level	73	.80	.32
33	Hamerly-Aastad	nearly level	80	.80	.32
34	Hamerly-Svea	nearly level	80	.80	.32
35	Hamerly-Vallers	nearly level	60	.80	.32
Sandy loams with sandy substrata					
37	Ulen-Embden	nearly level	73	.80	.20

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APPENDIX TABLE A2. DESCRIPTION OF SOILS, PRODUCTIVITY INDICES, AND ERODIBILITY FACTORS IN THE LOWER SHEYENNE RIVER BASIN (CONTINUED)

Soil Code	Soil Association	Slope Class	Crop Productivity Index	Pasture Rating	Erodibility Factor
Sandy loams and loamy sands with sandy substrata					
38	Ulen-Hecla	nearly level	54	.80	.20
39	Ulen-Stirum-Hecla	nearly level	45	.80	.20
Clayey soils with thick black surface layer (Grumusol)					
40	Fargo	nearly level	82	.80	.43
Poorly drained soils with very limy subsoil (Lime Solonchak)					
Loams with sandy and gravelly substrata					
36,41	Benoit-Divide	nearly level	43[a]	1.80	.17
Poorly drained soils (Humic Gley) and associated soils with very limy subsoil (Calcium Carbonate Solonchak)					
Loamy sands with sandy substrata					
43	Hamar-Ulen	nearly level	43	1.80	.20

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APPENDIX TABLE A2. DESCRIPTION OF SOILS, PRODUCTIVITY INDICES, AND ERODIBILITY FACTORS IN THE LOWER SHEYENNE RIVER BASIN (CONTINUED)

Soil Code	Soil Association	Slope Class	Crop Productivity Index	Pasture Rating	Erodibility Factor
Soils with claypan subsoil (Solonetz)					
42	Cavour-Cresbard	nearly level	38	.53	.43
44	Cresbard	nearly level	60	.80	.37
Soils on bottomlands (Grumusol and Alluvial)					
45	Fargo-LaPrairie	nearly level	58	.80	.43
46	LaPrairie	nearly level	40	.80	.32

[a]These soil associations are not generally used as cropland.
[b]These soil associations have different productivity indices for corn. Soil association number 25 = 90 and number 27 = 70 for corn.

SOURCES: Soil Associations: Patterson, D. D., *et al.*, *Soil Survey Report, County General Soil Maps, North Dakota*, Bulletin No. 473, Department of Soils, Agricultural Experiment Station, North Dakota State University, Fargo, July, 1968.

Crop productivity and pasture ratings: unpublished data, D. D. Patterson, Department of Soils, North Dakota State University.

Erodibility (K) factor: USDA-Soil Conservation Service, "Estimating Soil Loss Resulting from Water and Wind Erosion in North Dakota," Bismarck, North Dakota, March, 1975.

lowers the P factor to between .6 and .9, depending on the degree of slope. Combining contouring and strip cropping lowers the P factor by an additional 50 percent (Appendix Table A3).

APPENDIX TABLE A3. VALUE OF THE EROSION CONTROL (P) FACTOR

Degree of Slope	P Factor	
	Contour or Strip Cropping	Contour and Strip Cropping
1.1- 2.0	.6	.30
2.1- 7.0	.5	.25
7.1-12.0	.6	.30
12.1-18.0	.8	.40
18.1-24.0	.9	.45

SOURCES: USDA-Soil Conservation Service, "Estimating Soil Loss Resulting from Water and Wind Erosion in North Dakota," Bismarck, North Dakota, March, 1975.

USDA-Agricultural Research Service, A Universal Equation for Predicting Rainfall-Erosion Losses: An Aid to Conservation Farming in Humid Regions, ARS Report 22-66, Washington, D.C., 1961.

The LS factor, which shows the effects of the length and degree of slope, is derived from an equation developed by the Agricultural Research Service.[2]

$$LS = L(.0076 + .0053S + .00076S^2)$$

where L is the generalized length of slope, and

S is the generalized degree of slope.

Crop management (C) factors are dependent on the type of crop planted. Since more than one management activity may be used on any parcel, each field in the parcel has its own C factor. There are 15 cropping alternatives, along with a factor for woodland (Appendix Table A4).

The Universal Soil Loss Equation (A = R•K•LS•C•P) is used to calculate the soil loss from each management activity. Soil loss from individual fields is calculated separately since the C factors differ and the model

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[2]Wischmeier, W. H., and D. D. Smith, Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains, Agricultural Handbook No. 282, USDA-Agricultural Research Service, Washington, D.C., 1965, p. 9.

APPENDIX TABLE A4. CROP MANAGEMENT "C" FACTORS FOR MANAGEMENT ACTIVITIES

Management Activity	C Factor	Description
1	.013	Cattle on Pasture
2	.013	Dairy on Pasture
3	.013	Sheep on Pasture
4	.35	Wheat on Fallow
5	.35	Barley on Fallow
6	.19	Wheat
7	.19	Barley
8	.19	Oats
9	.19	Durum
10	.20	Flax
11	.37	Corn
12	.37	Sugarbeets
13	.40	Silage
14	.40	Sunflowers
15	.40	Soybeans
16	.10	Alfalfa
17	.10	Other Tame Hay
18	1.00	Summer Fallow
19	.02	Woodland

SOURCE: "Estimating Soil Loss Resulting from Water and Wind Erosion in North Dakota," USDA-Soil Conservation Service, Bismarck, North Dakota, March, 1975.

allows for more than one management activity in any parcel. Soil eroded from used and unused pasture is calculated along with the soil moved on any woodland in the parcel. The soil eroded from each activity is aggregated to the total for the parcel.

Soil losses from cropland and from all land are summed to watershed totals. The total land area and the number of crop acres is also summed to watershed totals. The sediment contributed from a watershed is calculated by multiplying the total soil moved within the watershed and the delivery rate for the particular watershed. Delivery rates depend upon the size of the watershed (Appendix Table A5). The amounts of sediment, total soil moved, and soil moved from cropland are calculated as totals and as per acre contributions for each watershed.

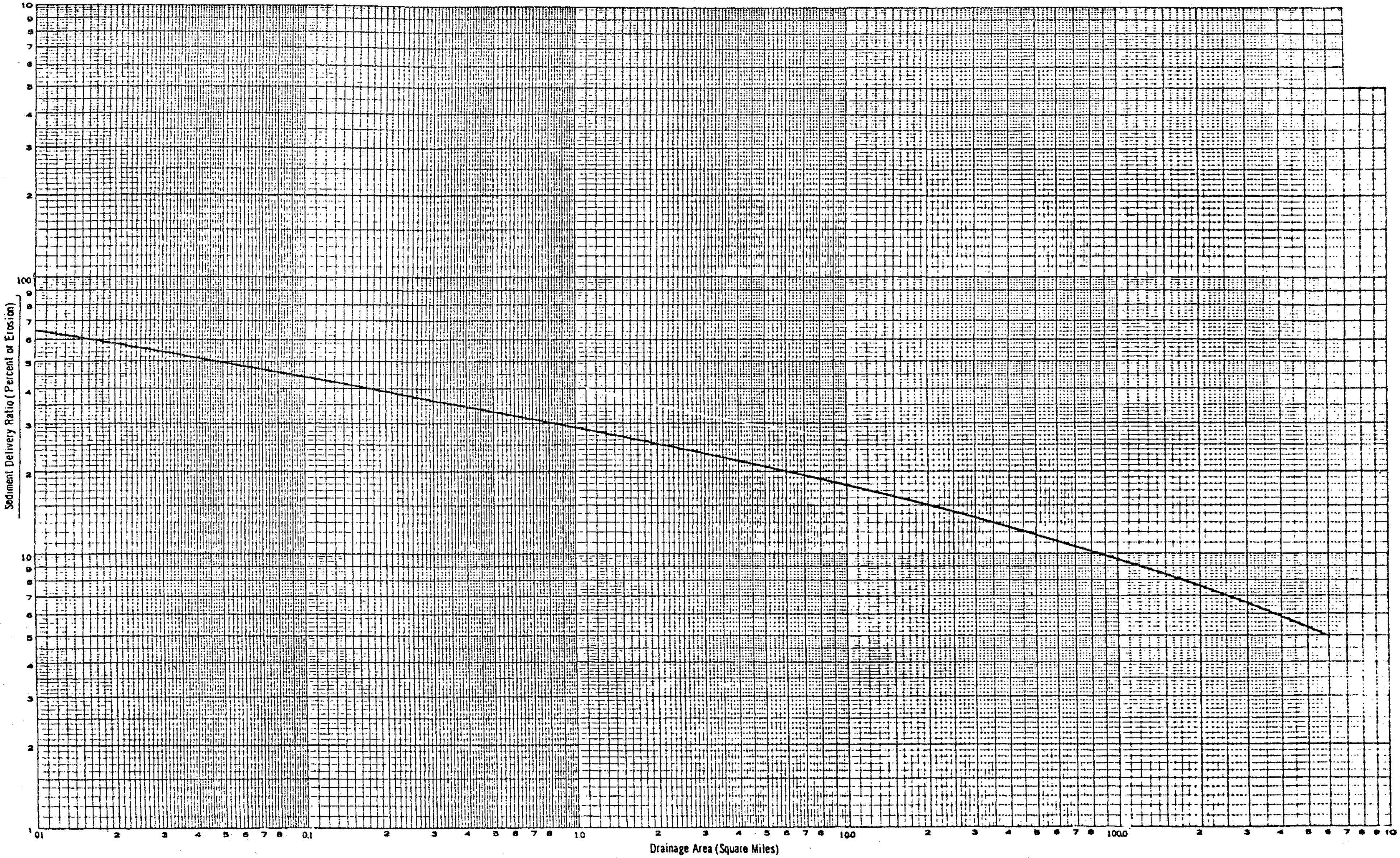
The delivery ratios used for this method were developed from research in reservoir sedimentation and by programs of sediment-load measurements. Soil Conservation Service estimates of the delivery ratios are derived from the function illustrated in Appendix Figure A1. However, these estimates

APPENDIX TABLE A5. SEDIMENT DELIVERY RATIOS BY WATERSHED SIZE

Size	Delivery Ratio
square miles	*percent*
1	29.0
2	25.0
3	23.2
4	22.0
5	21.0
10	18.0
15	16.2
20	15.0
25	14.1
30	13.5
35	13.0

are tempered by considerations of other influencing factors. These factors include texture, relief, type of erosion, the sediment-transport system, and areas of deposition within the drainage area.[3]

[3]Renfro, G. W., "Use of Erosion Equations and Sediment Yield," Present and Prospective Technology for Predicting Sediment Yield and Source, Proceedings of the Sediment Yield Workshop, USDA Sediment Laboratory, Oxford, Mississippi, November, 1972.



Appendix Figure A1. Sediment Delivery Ratio Vs. Size of Drainage Area

APPENDIX B

APPENDIX B--CALCULATION OF REVENUE AND COST ESTIMATES BY REVENUE GENERATOR

Data from State Agricultural Region 6 were used to compute cost and revenue figures when possible. State Agricultural Region 6 includes the eleven counties in southeast central North Dakota.

Total revenue from livestock is found by multiplying the revenue per head by the number of head. The total revenue per head for dairy production is $1,030.18 which assumes an average of $882.00 per head in revenue from milk production and $148.18 per head from the sale of calves and cull cows (Appendix Table B1).

APPENDIX TABLE B1. ANNUAL GROSS RECEIPTS FROM DAIRY PRODUCTION IN STATE AGRICULTURAL REGION 6, 1963-1972, ADJUSTED AVERAGE TO 1973 LEVELS

Receipts	Number	Weight	Price	Value
		pounds		
Milk		2,000	$ 7.35	$ 882.00
Cull Cows	.24	1,250	.29	87.00
Cull Heifers	.06	960	.34	19.58
Calves	.52		80.00	41.60
Total Receipts				$1,030.18

SOURCE: Vreugdenhil, Harvey, unpublished data, livestock budget summary, Department of Agricultural Economics, North Dakota State University, 1976.

Total receipts from beef cattle were estimated to be $232.61 per head. The sale of calves yielded $165.62, while the sale of cull cows and heifers added $66.99 per head (Appendix Table B2).

APPENDIX TABLE B2. ANNUAL GROSS RECEIPTS FROM BEEF CATTLE PRODUCTION IN STATE AGRICULTURAL REGION 6, 1963-1972, AVERAGE ADJUSTED TO 1973 LEVELS

Receipts	Quantity	Weight	Price	Value
		cwt		
Steer Calves	.45	4.50	$55.00	$111.38
Heifer Calves	.27	4.10	49.00	54.24
Cull Cows	.19	11.00	29.00	60.61
Cull Heifers	.02	7.15	44.50	6.38
Total Receipts				$232.61

SOURCE: Vreugdenhil, Harvey, unpublished data, livestock budget summary, Department of Agricultural Economics, North Dakota State University, 1976.

Total revenue from sheep was $70.27 per head. Wool production accounted for $5.76, sales of lambs and slaughter sheep contributed $62.06, and sales of culls added $2.45 (Appendix Table B3).

APPENDIX TABLE B3. ANNUAL GROSS RECEIPTS FROM SHEEP PRODUCTION IN STATE AGRICULTURAL REGION 6, 1963-1972, AVERAGE ADJUSTED TO 1973 LEVELS

Receipts	Quantity	Weight	Price	Value
		cwt		
Slaughter Sheep	1.40	1.10	$40.30	$62.06
Cull Ewes	.18	1.35	9.10	2.21
Cull Rams	.01	2.75	9.00	.24
Wool	8.00	.01	.72	5.76
Total Receipts				$70.27

SOURCE: Vreugdenhil, Harvey, unpublished data, livestock budget summary, Department of Agricultural Economics, North Dakota State University, 1976.

Total cost of livestock is found by multiplying the per unit (per head) cost by the number of head of livestock. Total cost includes supplies, equipment, costs for homegrown or purchased feed, pasture, labor, depreciation, and interest.

The cost of raising dairy cattle and their calves is $857.38 per head. Costs for raising beef cattle when selling the calves at weaning are $218.75 per head. The total cost of raising sheep is $78.07 per head (Appendix Table B4). Net revenue is found by subtracting total cost per head from gross revenue.

APPENDIX TABLE B4. ANNUAL COST AND REVENUE FROM LIVESTOCK PRODUCTION IN STATE AGRICULTURAL REGION 6, 1963-1972, AVERAGE ADJUSTED TO 1973 LEVELS

Animal	Total Revenue	Total Costs	Net Revenue
Dairy Cow	1,030.18	$857.38	$172.80
Beef Cow	232.61	218.75	13.86
Sheep	70.27	78.07	-7.80

SOURCE: Vreugdenhil, Harvey, unpublished data, livestock budget summary, Department of Agricultural Economics, North Dakota State University, 1976.

Total crop revenue for an individual commodity is found by multiplying its price (Appendix Table B5) times its yield per acre times the number of acres planted. The number of acres is given as an input from the main model.

APPENDIX TABLE B5. CROP PRODUCT PRICES, 1963-1972, AVERAGE ADJUSTED TO 1973 LEVELS

Crop	Price
	per bushel
Wheat	$ 3.50
Barley	2.25
Oats	1.25
Durum	3.50
Flax	6.00
Corn	2.50
Sugarbeets	25.00[a]
Corn Silage	22.00[a]
Sunflowers	.11[b]
Soybeans	5.90
Alfalfa	40.00[a]
Other Tame Hay	35.00[a]

[a]Price is in dollars per ton.
[b]Price is in dollars per pound.

SOURCE: Schaffner, LeRoy, unpublished data, crop budget summary, Department of Agricultural Economics, North Dakota State University, 1976.

In order to find the yield for a specific crop, average yield is adjusted to account for rainfall and differences in soil productivity. The average yield is the five-year average (1970-1974) for each of the five counties (Appendix Table B6).

Differences in rainfall are given in terms of deviations from normal rainfall during the critical growing season (April-July). The effects of rainfall deviation from normal yields (Appendix Table B7) are added or subtracted from the average yield. The effect of soil association on yield is estimated by using the soil productivity index (Appendix A, Appendix Table A2). The yield, adjusted for the effect of rainfall, is multiplied times the soil productivity index for the particular soil association and is divided by the soil productivity index for the county (Appendix Table B8). This estimates a unique crop yield for each soil association, county, and rainfall level.

APPENDIX TABLE B6. AVERAGE YIELD OF CROPS GROWN IN THE LSRB, BY COUNTY, 1970-1974

Crop	County				
	Barnes	Ransom	Sargent	Richland	Cass
			bu./acre		
Wheat on Fallow	28.4	29.9	31.0	31.3	31.5
Barley on Fallow	36.0	36.0	38.3	41.0	38.2
Wheat	24.1	24.5	26.0	29.8	30.2
Barley	36.2	38.1	39.9	42.8	41.8
Oats	43.8	48.8	48.5	55.3	51.6
Durum	24.0	24.4	24.1	27.2	29.3
Flax	10.6	10.0	10.8	10.5	11.3
Corn	43.6	51.2	48.6	63.2	52.8
Sugarbeets[a]	b	b	b	b	14.4
Corn Silage[a]	6.0	7.0	6.5	9.7	8.3
Sunflowers[c]	1,020.0	1,050.0	1,130.0	1,110.0	1,060.0
Soybeans	b	b	b	b	18.2
Alfalfa[a]	2.0	1.9	2.0	2.6	2.5
Other Tame Hay[a]	1.4	1.1	1.1	1.2	1.7

[a]Tons per acre.
[b]Not grown in this part of the basin.
[c]Pounds per acre.

SOURCE: Statistical Reporting Service, North Dakota Crop and Livestock Statistics, Annual Summaries, 1971-1975.

Crop costs are given on a per acre basis. The average cost of production (Appendix Table B9) is added to the county average cash rent adjusted by the productivity index to reflect the higher and lower valued soils. The average cash rent (Appendix Table B10) reflects return to land or opportunity cost for a parcel.

The total cost per acre is multiplied by the number of acres to find the total cost for a particular crop. All crop costs are summed to find the total crop cost for the parcel.

The number of pasture acres required to properly sustain livestock is found by multiplying the required number of AUM's and the AUM production from the pasture. Required animal unit months are found by multiplying the number of animals, the required AUM's per animal, and the number of months the animal is grazed. One AUM can support one cow and her calf (1.9 cattle) or eight sheep (three adults and five lambs). The animals are grazed for seven months of the year.

APPENDIX TABLE B7. EFFECTS OF DEVIATIONS FROM NORMAL RAINFALL ON CROP YIELD

Crop	Deviation						
	+3	+2	+1	Normal	-1	-2	-3
				bu./acre			
Wheat on Fallow	4.3	3.0	1.5	0	- 1.6	- 3.4	- 5.2
Barley on Fallow	10.6	7.3	3.8	0	- 4.1	- 8.5	- 13.1
Wheat	5.5	3.8	2.0	0	- 2.1	- 4.3	- 6.6
Barley	10.9	7.5	3.9	0	- 4.2	- 8.7	- 13.4
Oats	4.2	2.8	1.4	0	- 1.4	- 2.8	- 4.2
Durum	.5	.4	.2	0	- .2	- .4	- .5
Flax	4.5	3.1	1.6	0	- 1.7	- 3.5	- 5.4
Corn	1.7	1.1	.6	0	- .6	- 1.1	- 1.7
Sugarbeets[a]	2.9	2.0	1.1	0	- 1.1	- 2.3	- 3.6
Corn Silage[a]	1.0	.7	.4	0	- .4	- .8	- 1.2
Sunflowers[b]	360.0	240.0	120.0	0	-120.0	-276.0	-414.0
Soybeans	.8	.6	.3	0	- .4	- .8	- 1.2
Alfalfa[a]	.3	.2	.1	0	- .1	- .2	- .3
Other Tame Hay	.3	.2	.1	0	- .1	- .2	- .3

[a]Tons per acre.
[b]Pounds per acre.

SOURCE: The Effects of Added Rainfall During the Growing Season in North Dakota, Final Report, North Dakota Research Report No. 52, Interdisciplinary "ARE" Research Team, North Dakota Agricultural Experiment Station, August, 1974.

APPENDIX TABLE B8. COUNTY SOIL PRODUCTIVITY INDICES FOR COUNTIES IN LSRB

County	County Index
Barnes	73
Ransom	66
Sargent	80
Richland	71
Cass	75

SOURCE: Patterson, D. D., unpublished data, Department of Soils, North Dakota State University, 1976.

APPENDIX TABLE B9. ANNUAL COST OF CROP PRODUCTION IN STATE AGRICULTURAL REGION 6, 1973-1974 AVERAGE

Crop	Cost of Production
	per acre
Wheat on Fallow	$ 51.19
Barley on Fallow	52.19
Wheat	52.09
Barley	52.70
Oats	55.41
Durum	48.29
Flax	41.86
Corn	53.29
Sugarbeets	117.63
Corn Silage	54.19
Sunflowers	60.57
Soybeans	44.72
Alfalfa	20.94
Other Tame Hay	24.95
Summer Fallow	12.40

SOURCE: Schaffner, LeRoy, unpublished data, Crop Budget Summary, Department of Agricultural Economics, North Dakota State University, 1976.

The productive capacity of the pasture depends upon soil association and rainfall. The soil productivity index is applied to find AUM's per pasture acre for the particular soil association (Appendix A, Appendix Table A2). This figure is multiplied by a factor adjusting for annual rainfall (Appendix Table B11).

APPENDIX TABLE B10. ANNUAL AVERAGE CASH RENT BY COUNTY IN LSRB, 1973-1974

County	Cash Rent[a] Crop	Cash Rent[a] Pasture
	per acre	
Barnes	18.54	6.03
Ransom	18.54	6.03
Sargent	19.59	8.66
Richland	19.59	8.66
Cass	28.91	8.66

[a]Adapted to 1973-1974 levels.

SOURCE: Staroba, A. R., and J. E. Johnson, "North Dakota Farm Leasing in 1975," North Dakota Farm Research, Vol. 33, No. 5, May-June, 1976.

APPENDIX TABLE B11. PASTURE PRODUCTION ADJUSTMENTS FOR RAINFALL

Deviation in Rainfall	Production[a]
inches	*% of normal*
-3	.90
-2	.92
-1	.96
0	1.00
1	1.04
2	1.07
3	1.10

[a]Estimates based on the response of wild hay.

SOURCE: The Effects of Added Rainfall During the Growing Season in North Dakota, Final Report, North Dakota Research Report No. 52, Interdisciplinary "ARE" Research Team, North Dakota Experiment Station, North Dakota State University, August, 1974.

APPENDIX C

APPENDIX C--CROPPING PATTERNS FOR MANAGEMENT ALTERNATIVES

APPENDIX TABLE C1. DISTRIBUTION OF CROPLAND AND PASTURE IN THE LSRB FOR TYPICAL MANAGEMENT-ALTERNATIVE I[a]

	Barnes	Ransom	Sargent	Richland	Cass
			percent		
Planted Acres					
Wheat on Fallow	23.4	14.8	11.1	11.3	13.2
Barley on Fallow	5.0	4.3	3.4	2.2	1.3
Wheat	8.0	11.1	13.9	18.4	22.9
Barley	13.1	10.4	9.5	9.9	15.6
Oats	8.0	16.1	14.0	13.2	5.9
Durum	2.1	1.6	3.5	0.3	1.4
Flax	4.7	2.6	5.5	2.7	1.9
Corn	0.4	6.0	5.2	16.3	2.3
Sugarbeets	0.0	0.0	0.0	0.0	1.0
Silage	1.5	3.2	4.4	2.0	0.9
Sunflowers	5.1	3.0	1.2	7.0	10.0
Soybeans	0.0	0.0	0.0	0.0	10.7
Alfalfa	4.4	12.5	3.8	4.8	2.0
Other Tame Hay	1.1	3.6	6.1	1.7	0.9
Summer Fallow	23.2	10.8	13.4	10.2	10.0
TOTAL	100.0	100.0	100.0	100.0	100.0
Pasture					
Dairy	5.1	3.4	2.6	5.0	3.8
Beef	89.2	80.0	88.5	86.9	77.4
Sheep	5.7	16.6	8.9	8.1	1.8

[a]The distributions were found by summing the total acres estimated by the Statistical Reporting Service and finding the percentage of the total for each activity.

APPENDIX TABLE C2. DISTRIBUTION OF CROPLAND AND PASTURE ON CONTRIBUTING ACRES IN THE LSRB FOR TYPICAL MANAGEMENT, WITH RESTRICTIONS-ALTERNATIVE II[a]

	Barnes	Ransom	Sargent	Richland	Cass
			percent		
Planted Acres					
Wheat on Fallow	0.0	0.0	0.0	0.0	0.0
Barley on Fallow	0.0	0.0	0.0	0.0	0.0
Wheat	45.0	33.6	33.0	46.2	55.4
Barley	26.0	19.1	16.9	18.8	25.9
Oats	11.4	20.9	18.5	20.5	9.0
Durum	3.1	2.1	4.7	0.6	2.2
Flax	6.7	3.4	7.2	4.1	3.0
Corn	0.0	0.0	0.0	0.0	0.0
Sugarbeets	0.0	0.0	0.0	0.0	0.0
Silage	0.0	0.0	0.0	0.0	0.0
Sunflowers	0.0	0.0	0.0	0.0	0.0
Soybeans	0.0	0.0	0.0	0.0	0.0
Alfalfa	6.3	16.2	11.7	7.5	3.1
Other Tame Hay	1.5	4.7	8.0	2.3	1.4
Summer Fallow	0.0	0.0	0.0	0.0	0.0
TOTAL	100.0	100.0	100.0	100.0	100.0
Pasture					
Dairy	5.1	3.0	2.6	4.9	3.8
Beef	89.2	82.6	88.5	87.2	77.4
Sheep	5.7	14.4	8.9	7.9	1.8

[a]The distribution from Appendix Table C3 was used for noncontributing acres. The distribution for contributing acres was found by eliminating row crops summer fallow and prorating their acreage among the remaining activities.

APPENDIX TABLE C3. DISTRIBUTION OF CROPLAND AND PASTURE IN THE LSRB FOR PROFIT MAXIMIZATION-ALTERNATIVE III[a]

	Barnes	Ransom	Sargent	Richland	Cass
			percent		
Planted Acres					
Wheat on Fallow	0.0	0.0	0.0	0.0	0.0
Barley on Fallow	0.0	0.0	0.0	0.0	0.0
Wheat	51.9	51.9	51.9	51.9	75.2
Barley	16.4	16.4	16.4	16.4	0.0
Oats	1.0	1.0	1.0	1.0	0.0
Durum	3.8	3.8	3.8	3.8	0.0
Flax	0.0	0.0	0.0	0.0	0.0
Corn	0.0	0.0	0.0	16.0	0.0
Sugarbeets	0.0	0.0	0.0	0.0	12.7
Silage	0.0	0.0	0.0	3.3	0.0
Sunflowers	19.3	19.3	19.3	0.0	0.0
Soybeans	0.0	0.0	0.0	0.0	11.1
Alfalfa	3.9	3.9	3.9	3.9	1.0
Other Tame Hay	3.7	3.7	3.7	3.7	0.0
Summer Fallow	0.0	0.0	0.0	0.0	0.0
TOTAL	100.0	100.0	100.0	100.0	100.0
Pasture					
Dairy	0.0	0.0	0.0	0.0	0.0
Beef	100.0	100.0	100.0	100.0	100.0
Sheep	0.0	0.0	0.0	0.0	0.0

[a]The distributions were found by summing the total acres of recommended activities and finding the percentage for each activity.

APPENDIX TABLE C4. DISTRIBUTION OF CROPLAND AND PASTURE ON CONTRIBUTING ACRES IN THE LSRB FOR PROFIT MAXIMIZATION, WITH RESTRICTIONS-ALTERNATIVE IV[a]

	Barnes	Ransom	Sargent	Richland	Cass
			percent		
Planted Acres					
Wheat on Fallow	0.0	0.0	0.0	0.0	0.0
Barley on Fallow	0.0	0.0	0.0	0.0	0.0
Wheat	64.4	64.4	64.4	64.4	84.2
Barley	20.3	20.3	20.3	20.3	10.8
Oats	1.2	1.2	1.2	1.2	0.0
Durum	4.7	4.7	4.7	4.7	0.0
Flax	0.0	0.0	0.0	0.0	0.0
Corn	0.0	0.0	0.0	0.0	0.0
Sugarbeets	0.0	0.0	0.0	0.0	0.0
Silage	0.0	0.0	0.0	0.0	0.0
Sunflowers	0.0	0.0	0.0	0.0	0.0
Soybeans	0.0	0.0	0.0	0.0	0.0
Alfalfa	4.8	4.8	4.8	4.8	5.0
Other Tame Hay	4.6	4.6	4.6	4.6	0.0
Summer Fallow	0.0	0.0	0.0	0.0	0.0
TOTAL	100.0	100.0	100.0	100.0	100.0
Pasture					
Dairy	0.0	0.0	0.0	0.0	0.0
Beef	100.0	100.0	100.0	100.0	100.0
Sheep	0.0	0.0	0.0	0.0	0.0

[a]The distribution from Appendix Table C3 was used for the noncontributing acres. The distribution for contributing acres was found by eliminating row crops and prorating their acreage among the remaining activities.

APPENDIX D

APPENDIX D--REVENUE, COSTS, AND BUSINESS VOLUME ESTIMATES OF MANAGEMENT ALTERNATIVES

APPENDIX TABLE D1. REVENUE AND COSTS IN THE LOWER SHEYENNE RIVER BASIN, FOR MANAGEMENT ALTERNATIVE I, BY COUNTY

County	Total Revenue	Total Costs	Net Revenue	Per Acre Total Revenue	Per Acre Total Costs	Per Acre Net Revenue
		dollars			*dollars*	
Crops						
1	13,377,558.00	8,544,319.00	4,833,051.00	64.58	41.25	23.33
2	13,088,241.00	7,514,302.00	5,573,798.00	76.27	43.79	32.48
3	3,183,033.00	2,263,675.00	919,362.25	63.11	44.88	18.23
4	5,764,056.00	2,721,156.00	3,042,874.00	101.53	47.93	53.60
Basin	35,412,864.00	21,043,440.00	14,369,085.00	72.87	43.30	29.57
Livestock						
1	5,514,062.00	5,080,945.00	433,121.25	95.29	87.80	7.48
2	3,394,014.00	3,170,613.00	223,412.06	100.69	94.06	6.63
3	4,795,583.00	4,436,717.00	358,869.38	83.97	77.68	6.28
4	36,052.03	34,143.63	1,908.40	131.00	124.07	6.93
Basin	13,739,711.00	12,722,418.00	1,017,311.06	92.23	85.41	6.83
Crop and Livestock						
1	18,891,424.00	13,625,389.00	5,266,181.00	71.29	51.42	19.87
2	16,482,368.00	10,685,016.00	5,797,207.00	80.28	52.04	28.24
3	7,978,655.00	6,700,413.00	1,278,222.00	74.19	62.30	11.89
4	5,800,108.00	2,755,299.00	3,044,783.00	101.67	48.30	53.37
Basin	49,152,528.00	33,766,096.00	15,386,393.00	77.42	53.18	24.23

APPENDIX TABLE D2. ESTIMATED GROSS BUSINESS VOLUME GENERATED IN SELECTED SECTORS UNDER MANAGEMENT ALTERNATIVE I

Selling Sector	Purchasing Sector: Livestock	Purchasing Sector: Crop	Total
		1,000 dollars	
Livestock	16,599	2,751	19,350
Crop	5,458	38,708	44,166
Retail	9,751	28,804	38,555
Household	14,412	34,158	48,570
TOTAL	62,009	130,620	192,629

APPENDIX TABLE D3. REVENUE AND COSTS IN THE LOWER SHEYENNE RIVER BASIN, FOR MANAGEMENT ALTERNATIVE II, BY COUNTY

County	Total Revenue	Total Costs	Net Revenue	Per Acre Total Revenue	Per Acre Total Costs	Per Acre Net Revenue
	dollars			*dollars*		
Crops						
1	14,167,845.00	9,140,532.00	5,027,145.00	68.40	44.13	24.27
2	12,837,534.00	7,764,640.00	5,072,769.00	74.80	45.24	29.56
3	3,004,889.00	2,291,940.00	712,959.88	59.58	45.44	14.14
4	5,812,894.00	2,837,363.00	2,975,509.00	102.39	49.98	52.41
Basin	35,823,136.00	22,034,464.00	13,788,382.00	73.71	45.34	28.37
Livestock						
1	5,514,062.00	5,080,945.00	433,121.25	95.29	87.80	7.48
2	3,218,812.00	3,029,827.00	188,978.06	95.49	89.88	5.61
3	4,968,656.00	4,575,597.00	393,049.63	87.00	80.11	6.88
4	34,524.20	32,467.09	2,057.11	125.45	117.98	7.47
Basin	13,736,054.00	12,718,836.00	1,017,206.00	92.21	85.38	6.83
Crop and Livestock						
1	19,681,600.00	14,221,599.00	5,460,268.00	74.27	53.67	20.60
2	16,056,457.00	10,794,576.00	5,261,741.00	78.21	52.58	25.63
3	7,973,575.00	6,867,550.00	1,106,007.00	74.14	63.86	10.28
4	5,847,418.00	2,869,829.00	2,977,566.00	102.50	50.30	52.19
Basin	49,559,024.00	34,753,520.00	14,805,582.00	78.06	54.74	23.32

APPENDIX TABLE D4. ESTIMATED GROSS BUSINESS VOLUME GENERATED IN SELECTED SECTORS UNDER MANAGEMENT ALTERNATIVE II

Selling Sector	Purchasing Sector Livestock	Purchasing Sector Crop	Total
		1,000 dollars	
Livestock	16,595	2,783	19,378
Crop	5,457	39,158	44,615
Retail	9,749	29,138	38,887
Household	14,409	34,554	48,963
TOTAL	61,995	132,136	194,131

APPENDIX TABLE D5. REVENUE AND COSTS IN THE LOWER SHEYENNE RIVER BASIN, FOR MANAGEMENT ALTERNATIVE III, BY COUNTY

County	Total Revenue	Total Costs	Net Revenue	Per Acre Total Revenue	Per Acre Total Costs	Per Acre Net Revenue
		dollars			*dollars*	
Crops						
1	17,904,576.00	10,670,913.00	7,233,760.00	86.43	51.51	34.92
2	16,918,048.00	8,916,448.00	8,001,488.00	98.58	51.96	46.62
3	3,678,457.00	2,484,372.00	1,192,087.00	72.89	49.26	23.63
4	8,563,765.00	3,363,251.00	5,200,486.00	150.84	59.24	91.60
Basin	47,062,832.00	25,434,976.00	21,627,808.00	96.84	52.34	44.50
Livestock						
1	4,340,384.00	4,081,757.00	258,621.56	75.01	70.54	4.47
2	2,687,622.00	2,527,494.00	160,143.38	79.73	74.98	4.75
3	3,826,011.00	3,598,035.00	227,971.69	66.99	63.00	3.99
4	34,524.20	32,467.09	2,057.11	125.45	117.98	7.47
Basin	10,888,541.00	10,239,753.00	648,793.69	73.10	68.74	4.36
Crop and Livestock						
1	22,244,592.00	14,752,777.00	7,492,390.00	83.94	55.67	28.27
2	19,605,408.00	11,444,057.00	8,161,633.00	95.49	55.74	39.75
3	7,502,494.00	6,082,429.00	1,420,045.00	69.76	56.56	13.20
4	8,598,288.00	3,395,718.00	5,205,542.00	150.72	59.52	91.19
Basin	57,950,768.00	35,674,960.00	22,276,592.00	91.27	56.19	35.09

APPENDIX TABLE D6. ESTIMATED GROSS BUSINESS VOLUME GENERATED IN SELECTED SECTORS UNDER MANAGEMENT ALTERNATIVE III

Selling Sector	Purchasing Sector Livestock	Crop	Total
		1,000 dollars	
Livestock	13,154	3,656	16,810
Crop	4,325	51,443	55,768
Retail	7,728	38,280	46,008
Household	11,421	45,396	56,812
TOTAL	49,141	173,592	222,733

APPENDIX TABLE D7. REVENUE AND COSTS IN THE LOWER SHEYENNE RIVER BASIN, FOR MANAGEMENT ALTERNATIVE IV, BY COUNTY

County	Total Revenue	Total Costs	Net Revenue	Per Acre Total Revenue	Per Acre Total Costs	Per Acre Net Revenue
		dollars			*dollars*	
Crops						
1	17,372,768.00	10,514,892.00	6,857,907.00	83.87	50.76	33.11
2	16,155,176.00	8,715,329.00	7,439,690.00	94.14	50.78	43.35
3	3,605,836.00	2,484,612.00	1,121,224.00	71.49	49.26	22.23
4	6,893,148.00	3,016,247.00	3,876,883.00	121.41	53.13	68.29
Basin	44,026,896.00	24,731,056.00	19,295,696.00	90.60	50.89	39.71
Livestock						
1	4,340,384.00	4,081,757.00	258,621.56	75.01	70.54	4.47
2	2,687,622.00	2,527,494.00	160,143.38	79.73	74.98	4.75
3	3,826,011.00	3,598,035.00	227,971.69	66.99	63.00	3.99
4	34,524.20	32,467.09	2,057.11	125.45	117.98	7.47
Basin	10,888,541.00	10,239,753.00	648,793.69	73.10	68.74	4.36
Crop and Livestock						
1	21,712,768.00	14,596,755.00	7,116,543.00	81.93	55.08	26.85
2	18,842,608.00	11,242,942.00	7,599,836.00	91.78	54.76	37.02
3	7,431,874.00	6,082,671.00	1,349,187.00	69.10	56.56	12.55
4	6,927,673.00	3,048,713.00	3,878,940.00	121.43	53.44	67.99
Basin	54,914,912.00	34,971,056.00	19,944,496.00	86.49	55.08	31.41

APPENDIX TABLE D8. ESTIMATED GROSS BUSINESS VOLUME GENERATED IN SELECTED SECTORS UNDER MANAGEMENT ALTERNATIVE IV

Selling Sector	Purchasing Sector: Livestock	Crop	Total
		1,000 dollars	
Livestock	13,154	3,420	16,574
Crop	4,325	48,124	52,449
Retail	7,728	35,810	43,538
Household	11,421	42,467	53,888
TOTAL	49,141	162,394	211,535

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