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**Assessing the Impacts of Changing
Agricultural Production and
Resource Use**

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Assessing the Impacts of Changing Agricultural Production and Resource Use¹

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In many countries, there is interest in examining the potential for shifting some of the resources (land, labor, and capital) now employed in agriculture to alternative enterprises within agriculture or to uses outside the industry. This interest leads to a need for the analytical capability to evaluate both the **direct** effects of alternative patterns of agricultural production and resource use (or the policies and programs that cause these changes) and the **secondary** or **indirect** effects on other sectors of local or regional economies. Policy makers are particularly concerned with evaluating these impacts because agriculture still plays a dominant role in the economies of many rural areas, and changes in patterns of agricultural production and resource use can have profound effects on other economic sectors, as well as on the population, public services, and social fabric of rural areas (Sommer et al. 1993, Leistritz and Ekstrom 1986). This paper reports on the development and application of a modeling system that addresses

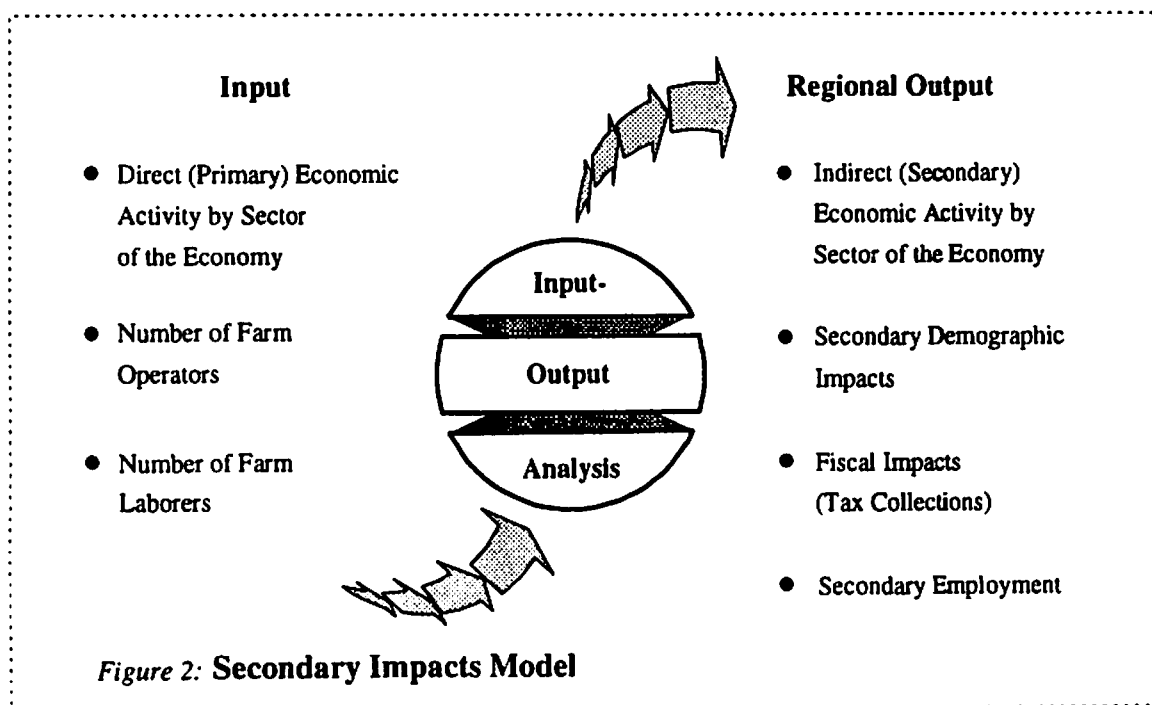
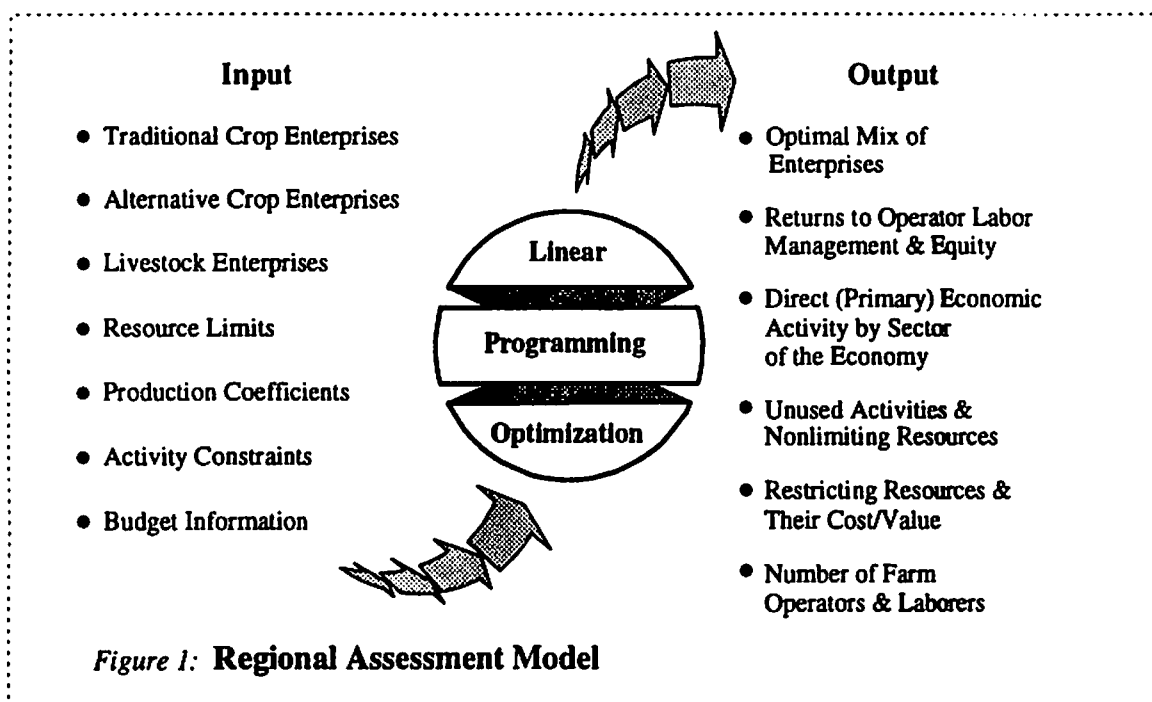
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the direct and secondary impacts of changes in resource use and production patterns within the agricultural sector.

The model was developed for use primarily by state policy makers who had become concerned that proactive measures were needed to increase economic development and diversification within the state economy and that the agricultural sector must play a key role in future growth. The purpose of the modeling system was to provide a stronger basis for state development planning for the agricultural sector, and particularly to enable a more comprehensive analysis of the potential for incorporating more intensive crop and livestock activities (commonly termed "value-added" enterprises) in the state's agricultural sector.

The modeling system has two major components: (1) a regional assessment model (RAM), which uses a linear programming algorithm to estimate the combination of crop and livestock production enterprises that will maximize the return to fixed resources, subject to various constraints (Figure 1), and (2) a secondary impacts model (SIM), which uses a regional input-output model together with demographic and fiscal estimation routines to provide estimates of changes in gross receipts by economic sector, secondary employment, population by age and sex, and revenue from major state taxes (Figure 2).



In the remaining sections of this paper, the structure and key inputs of the modeling system are briefly discussed. Then, an application of the model is presented, followed by conclusions and implications.

Model Structure

Linear programming (LP) was chosen as the central component of the Regional Assessment Model because LP models are well suited to evaluating different structural situations, such as changes in farm program requirements, consequences of new tax legislation, or mandated land use controls. Alternative modeling techniques, such as fixed-integer analysis and econometric modeling, present data and information obstacles and may be less reliable when applied in situations involving changes in economic structure (Hazell and Norton 1986). In addition, linear programming models are well suited to sensitivity analysis, which can be particularly useful in evaluating the feasibility of alternative enterprises.

The Regional Assessment Model (RAM) was designed to analyze, on a regional (aggregate) basis, changes in farm enterprise mixes, to identify potentially underused resources, and to trace changes in expenditures to various sectors of the North Dakota economy under alternative enterprise mixes and resource uses. The model was structured to reflect farm enterprises and resource situations

representative of eight regions within the State of North Dakota (Figure 3). The regional boundaries were chosen such that the regions were reasonably homogenous in terms of soil, climatic conditions, and typical agricultural enterprises and also closely approximated the trade areas of the state's major trade centers (Bangsund et al. 1991).

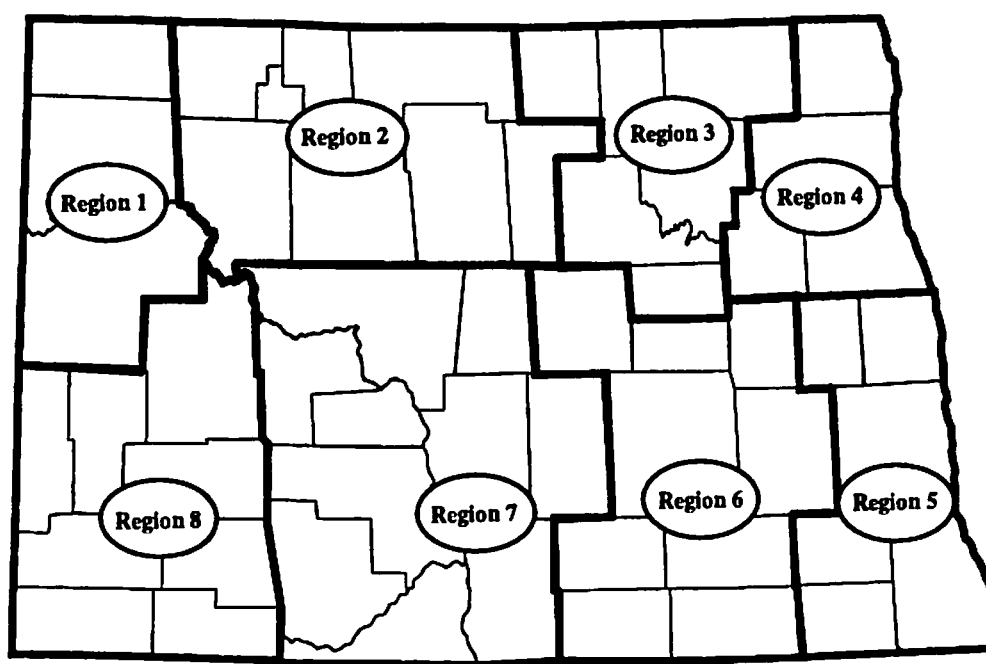


Figure 3: North Dakota Counties and Regional Assessment Model Regions

The RAM contains enterprises for all the *crops* currently grown in a given region, as well as selected nontraditional crops. For each crop enterprise, the LP matrix includes variable and fixed costs, yields, market prices, government farm program payments (deficiency payments) for selected crops, farm program restrictions, rotation constraints, and capital and labor requirements.

The RAM also contains the region's traditional *livestock* enterprises (beef, dairy, swine, and sheep), as well as selected nontraditional enterprises. Each livestock enterprise includes variable and fixed expenses, feed requirements, production coefficients (e.g., grazing requirements, breeding stock replacement rates), labor and risk capital requirements, products produced (e.g., feeder cattle, wool, milk), and market prices.

All RAM activities are constrained by resource limits, which include land, capital, farm program requirements, crop rotation restrictions, and policy measures designed to influence farm production and resource use. The RAM calculates the enterprise mix that maximizes returns to unpaid labor, management, and equity and allocates all expenses and returns to nine economic sectors of the SIM input-output model (see text box).

The Secondary Impact Model (SIM) is designed to estimate secondary economic impacts, demographic effects, and fiscal impacts of alternative agricultural scenarios. The SIM uses output from the RAM (particularly expenditures by sector, number of farm operators, and number of hired farm workers) as input. The SIM then estimates gross business volume (gross receipts), secondary employment, population change, number of school-age children, and state tax revenues.

| Economic Sectors | |
|-------------------------------------------|-------------------------------------------|
| <i>North Dakota Economy</i> | <i>Secondary Impact Model</i> |
| Agriculture: | |
| Livestock | Livestock |
| Crops | Crops |
| Nonmetal Mining | -- |
| Construction | -- |
| Transportation | -- |
| Communication and Public Utilities | Communications and Public Utilities |
| Ag Processing and Miscellaneous | -- |
| Manufacturing | |
| Retail Trade | Retail Trade |
| Finance, Insurance and Real Estate (FIRE) | Finance, Insurance and Real Estate (FIRE) |
| Business and Personal Services | Business and Personal Services |
| Professional and Social Services | Professional and Social Services |
| Households | Households |
| Government | Government |
| Coal Mining | -- |
| Thermal-Electric Generation | -- |
| Petroleum: | |
| Extraction/Exploration | -- |
| Refining | -- |

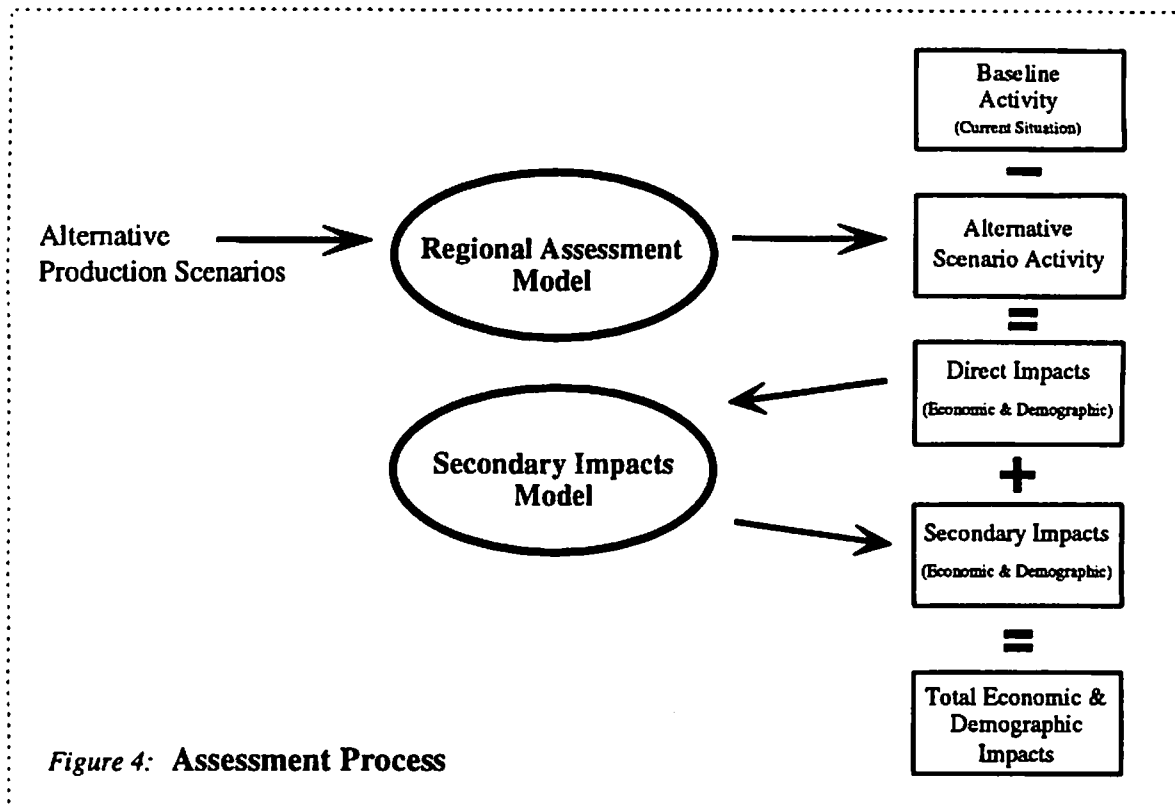
The SIM is based on an input-output (I-O) model. Input-output models are one of the most widely used methods for estimating the secondary economic impacts of a change in resource use or in the level of activity in a particular industry or economic sector (Leistritz and Murdock 1981). The input-output model requires, as input, estimates of

expenditures to each of nine economic sectors that result from a given scenario which are provided by the RAM model. The input-output model then provides estimates of gross business volume for each of the 17 major sectors of the North Dakota economy (see text box). The estimates of gross business volume by sector are used to estimate the secondary employment resulting from a given scenario. A set of coefficients, which describe the amount of gross business volume

required in each sector (e.g., retail trade) to support a full-time employee, is multiplied by the gross business volume created in each sector to develop the estimates of secondary employment. The estimates of gross business volume are also used to estimate the revenues from state sales and use tax, state personal income tax, and state corporate income tax associated with a given scenario.

The SIM also estimates the demographic impacts associated with the change from the baseline level of agricultural production in a region to an alternative scenario. The model develops estimates of the population changes associated with three types of workers (farm operators, hired farm workers, and secondary workers). These population changes could be increases or decreases depending on the specifics of a given scenario. Each population group is divided into six age groups (less than 5, 5-18, 19-25, 26-35, 36-45, and over 45) by gender. The demographic profiles for farm operators, farm workers, and secondary workers came from recent surveys of these groups (Leistritz et al. 1989, Mortensen et al. 1989, Halstead and Leistritz 1984).

Application of the modeling system required defining baseline agricultural production scenarios for each of the eight regions. Each baseline represents a benchmark, or measure of the existing situation (i.e., current production of crops and livestock throughout the region), to which all alternative scenarios are compared (Figure 4). The difference between the baseline and an alternative



scenario (estimated by the Regional Assessment Model) constitutes the direct impacts associated with that scenario. Direct regional impacts include changes in enterprise mixes and production levels, labor requirements, utilization of land or other resources, and expenditures to various sectors of the regional economy. The changes in expenditures to various sectors, together with changes in labor requirements, are inputs to the secondary impacts model.

Certain limitations of the assessment system also must be acknowledged. The assessment models develop estimates of impacts for the state and substate regions. As such, impacts resulting from a given scenario that occur outside the state are ignored. For example, if a scenario involves retaining more cattle for feeding within the state, those animals will not be available for feeding elsewhere. Also, the possible effects of various scenarios on market prices for agricultural commodities and inputs are not included in the analysis. Finally, the environmental effects of the scenarios are not examined by the assessment system.

Model Applications

The potential applications of the modeling system are extensive and include (1) changes in existing enterprises, (2) adoption of new enterprises, (3) assessing the effects of policy changes, and (4) analyzing the effects of changes in resource use (Figure 5). To illustrate these potential applications, two examples are briefly summarized: (1) analyzing the effects of expanded feeder calf backgrounding and (2) assessing the impacts of expanded irrigation.

Expanded Backgrounding

Feeder cattle production is the most common form of livestock enterprise on North Dakota's farms and ranches (Leistritz and Sell 1993). In 1991, about

- | | |
|------------------------------------------|------------------------------------------|
| ● Changes in existing enterprises | ● Effects of policy changes |
| -) Expanded livestock production | -) Farm program provisions |
| -) Substitute row crops for small grains | -) Loan assistance programs |
| | -) International trade |
| ● Adoption of new enterprises | ● Changes in resource use |
| -) Alternative crop production | -) Marginal cropland vs pasture |
| -) Supplemental livestock activities | -) Irrigation vs dryland production |
| -) Speciality enterprises | -) Summerfallow vs continuous production |

Figure 5: Alternative Production Scenarios

669,000 feeder calves were produced in North Dakota and about 50 percent were sold outside the state at weaning. An alternative would be to retain them in the state in a "backgrounding" program, which typically involves feeding the calves to gain 150 to 300 pounds per animal, after which they are transferred to a feedlot outside the state for feeding to slaughter weight. If additional calves were retained in the state for backgrounding, North Dakota's local and state economies would be stimulated through expenditures for feeds, fuel, utilities, and other inputs, as well as additional income for producers.

The scenario analyzed by the model involves backgrounding 95,327 additional calves in Region 7 (these are one-half the calves in Region 7 now estimated to be sold out of state at weaning). The estimated impacts of the

expanded backgrounding are shown in Table 1. The additional direct expenditures to the state economy total \$9.6 million, or about \$100 per animal. The total economic impact (sum of increased gross receipts in all sectors) of the increased livestock feeding is \$30.2 million, including \$8.6 million in increased retail trade and \$8.0 million in increased personal income. Additional state tax collections include \$397,000 in sales and use taxes, \$105,000 in personal income taxes, and \$46,000 in corporate income taxes.

The additional feeding was estimated to require about 11,400 days of extra farm labor. About three-fourths of this was assumed to represent extra work by existing farm and ranch operators and one-fourth to represent additional hired workers. Hence, 41 new farm workers would be hired. Also, the supplemental economic activity associated with added backgrounding would create an estimated 364 new secondary jobs. The total demographic impact was estimated to be an increase in population of 1,038 persons.

Expanded Irrigated Crop Production

Another alternative for increasing the intensity of agricultural production in North Dakota is expanding irrigated crop production (Leitch et al. 1991). To illustrate application of the model in assessing impacts of expanded irrigation, a scenario was specified that involved conversion of 10,000 acres of nonirrigated

**Table 1: Estimated Impacts of Expanded Feeder Calf
Backgrounding in North Dakota, Region 7, 1993**

| EXPENDITURES: | | BASELINE | SCENARIO | DIFFERENCE | |
|-----------------|---------|----------|----------|------------|-------|
| Ag Livestock | (\$000) | 57,845 | 57,845 | 0 | |
| Ag Crops | (\$000) | 55,396 | 60,648 | 5,252 | |
| Comm & Pub Util | (\$000) | 4,083 | 4,317 | 234 | |
| Retail Trade | (\$000) | 162,259 | 164,810 | 2,551 | |
| FIRE | (\$000) | 80,671 | 81,091 | 420 | |
| Bus & Pers Serv | (\$000) | 8,077 | 8,533 | 456 | |
| Prof & Soc Serv | (\$000) | 2,950 | 3,159 | 209 | |
| Households | (\$000) | 163,164 | 163,611 | 447 | |
| Government | (\$000) | 28,083 | 28,083 | 0 | |
| TOTAL | | (\$000) | 562,528 | 572,097 | 9,569 |

| ECONOMIC IMPACT: | | BASELINE | SCENARIO | DIFFERENCE |
|----------------------|---------|-----------|-----------|------------|
| Retail Trade | (\$000) | 476,018 | 484,600 | 8,582 |
| Personal Income | (\$000) | 541,717 | 549,740 | 8,023 |
| All Bus Sectors | (\$000) | 857,230 | 872,049 | 14,819 |
| Total Bus Volume | (\$000) | 1,645,038 | 1,675,241 | 30,203 |
| | | | | |
| Sales & Use Tax | (\$000) | 22,040 | 22,437 | 397 |
| Pers Income Tax | (\$000) | 7,042 | 7,147 | 105 |
| Corp Income Tax | (\$000) | 2,657 | 2,703 | 46 |
| | | | | |
| Secondary Employment | | 17,483 | 17,847 | 364 |

| DEMOGRAPHIC | | | | | | | |
|-------------|------------|--------|------------|--------|-----------|--------|-------|
| IMPACTS: | FARM UNITS | | FARM LABOR | | SECONDARY | | TOTAL |
| Age Cohort | Male | Female | Male | Female | Male | Female | |
| < 5 | 0 | 0 | 14 | 13 | 54 | 51 | 132 |
| 5-18 | 0 | 0 | 11 | 10 | 111 | 104 | 236 |
| 19-25 | 0 | 0 | 14 | 10 | 114 | 114 | 252 |
| 26-35 | 0 | 0 | 23 | 16 | 97 | 97 | 233 |
| 36-45 | 0 | 0 | 4 | 2 | 49 | 49 | 104 |
| 46 + | 0 | 0 | 2 | 1 | 39 | 39 | 81 |
| ----- | | | | | | | |
| Subtotal | 0 | 0 | 68 | 52 | 464 | 454 | |
| | | | | | | | |
| Total | 0 | | 120 | | 918 | | 1,038 |

cropland in Region 6 to irrigation. The newly irrigated acres, which were used to grow corn (8,333 acres) and potatoes (1,667 acres) based on RAM analysis, had previously been devoted to spring wheat production. The estimated impacts of this scenario are shown in Table 2.

One of the direct impacts of the conversion of dryland to irrigated cropland was an increase in expenditures, including net farm income, of about \$398 per acre. These direct expenditures result in a total impact of \$10.8 million, including \$3.6 million in additional retail trade and \$4.0 million in increased personal income. Additional labor requirements were estimated to be about 7.5 hours per acre. One-half of the additional labor requirement was assumed to represent additional hours for existing operators while one-half would be met by hired workers. Thus, 19 additional workers would be hired by irrigated farm operators. In addition, 79 secondary jobs would be created. The total population impact was estimated to be an increase of 249 persons.

Conclusions and Implications

This paper presents a model for assessing the economic, demographic, and fiscal impacts of changes in agricultural production and resource use. The model has two major components -- a regional linear programming model and an input-output model. The modeling system appears applicable for analyzing the impacts of a wide variety of changes in agricultural production and resource use.

**Table 2: Estimated Impacts of Expanded
Irrigation in North Dakota, Region 6, 1993**

| EXPENDITURES: | | BASELINE | SCENARIO | DIFFERENCE | |
|-----------------|---------|----------|----------|------------|-------|
| Ag Livestock | (\$000) | 40,613 | 40,613 | 0 | |
| Ag Crops | (\$000) | 38,019 | 38,019 | 0 | |
| Comm & Pub Util | (\$000) | 2,945 | 3,215 | 270 | |
| Retail Trade | (\$000) | 234,203 | 235,676 | 1,473 | |
| FIRE | (\$000) | 98,668 | 98,984 | 316 | |
| Bus & Pers Serv | (\$000) | 11,535 | 11,787 | 252 | |
| Prof & Soc Serv | (\$000) | 1,884 | 1,884 | 0 | |
| Households | (\$000) | 281,453 | 283,120 | 1,667 | |
| Government | (\$000) | 20,897 | 20,897 | 0 | |
| TOTAL | | (\$000) | 730,217 | 734,195 | 3,978 |

| ECONOMIC IMPACT: | | BASELINE | SCENARIO | DIFFERENCE |
|----------------------|---------|-----------|-----------|------------|
| Retail Trade | (\$000) | 641,945 | 645,507 | 3,562 |
| Personal Income | (\$000) | 741,682 | 745,639 | 3,957 |
| All Bus Sectors | (\$000) | 1,110,912 | 1,117,048 | 6,136 |
| Total Bus Volume | (\$000) | 2,086,616 | 2,097,420 | 10,804 |
| | | | | |
| Sales & Use Tax | (\$000) | 29,722 | 29,887 | 165 |
| Pers Income Tax | (\$000) | 9,642 | 9,693 | 51 |
| Corp Income Tax | (\$000) | 3,444 | 3,463 | 19 |
| | | | | |
| Secondary Employment | | 14,343 | 14,422 | 79 |

| DEMOGRAPHIC | | | | | | | |
|-------------|------------|--------|------------|--------|-----------|--------|-------|
| IMPACTS: | FARM UNITS | | FARM LABOR | | SECONDARY | | TOTAL |
| Age Cohort | Male | Female | Male | Female | Male | Female | |
| < 5 | 0 | 0 | 6 | 6 | 11 | 11 | 34 |
| 5-18 | 0 | 0 | 5 | 5 | 23 | 22 | 55 |
| 19-25 | 0 | 0 | 7 | 5 | 24 | 24 | 60 |
| 26-35 | 0 | 0 | 11 | 7 | 21 | 20 | 59 |
| 36-45 | 0 | 0 | 2 | 1 | 10 | 10 | 23 |
| 46 + | 0 | 0 | 1 | 1 | 8 | 8 | 18 |
| Subtotal | 0 | 0 | 32 | 25 | 97 | 95 | |
| Total | 0 | | 57 | | 192 | | 249 |

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