NORTH DAKOTA POTATO INDUSTRY

Report Submitted To:

North Dakota Department of Transportation
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ABSTRACT

In an attempt to increase net returns from farming efforts and stabilize agricultural commodities, rural communities are viewing value-added processing as a possible solution. Many attempts have been made at the value-added concept, and recently adding potato production under irrigation has changed farming for some North Dakota producers.

The potato industry is meeting consumer demands for more efficient and less time consuming methods of cooking by offering a wider variety of convenient processed potato items. The different uses of potatoes determines processor locations and movement of the raw product. However, the location of processing plants and warehouses impact highway demand and truck use.

A network flow model was developed to estimate the truck traffic generated by the potato industry. The model uses some of the steps implemented by Denver Tolliver of UGPTI in developing a *Prototype Corn Highway Network Model for Southeastern North Dakota*. A network model is a representation of supply and destination nodes and the transportation links.

The most important findings is the reduction in production in northeastern North Dakota, the traditional location of potato production and the introduction of irrigated acreage in the central and south central part of the state. The processors demand a uniform quality product which can best be controlled under irrigation.

Continued irrigation development will increase tonnage product from the land. This production may not be potatoes, but whatever the crop, the additional tonnage will have greater impacts on the North Dakota highway system. Development of flow models to coincide with NASS production data will provide valuable insight for North Dakota highway planners.

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INTRODUCTION

Value-added processing has become an economic development goal in agricultural regions. The instability of agricultural commodity prices encourages producers and rural communities to attempt to increase net return from their farming efforts. The value-added effort includes small changes in production methods, adding irrigation, changing crops, and building processing facilities. Many attempts have been made at the value-added concept, and recently adding irrigated potato production has changed farming for some North Dakota producers.

The location of potato processing plants near sources of production generates economic benefits for rural areas. However, the location of processing plants and warehouses impact highway demand and truck use. Shifts in production from dryland to irrigation and from grains to potatoes can significantly increase the tons produced per acre escalating heavy truck traffic. Adding irrigation to an acre of wheat may double the yield per acre, but changing from dry land wheat to irrigated potatoes increases weight harvested per acre an estimated 15 times.

The objective of the study is to provide information to aid transportation decision makers in planning and programming for future commodity transportation needs. Specific objectives of the study are to:

1. Describe recent trends in potato production and processing within the state.
2. Examine the logistics of potato transportation, storage, and processing.
3. Identify the potato industry's transportation needs in relationship to type and time of product movement.
4. Create a GIS database of potato production in North Dakota.

5. Forecast shifts in production and its implication on truck and highway use and maintenance.
6. Create a set of trip generation and truck type factors that can be used by highway planners.

A literature review was conducted to determine the characteristics of the potato industry. This review briefly covers potato types, growing conditions, diseases, uses, storage and transportation. NASS (National Agricultural Statistics Service) data was used to develop a network flow model to estimate potato movements and their impact on North Dakota's state and federal highway system. NASS data was used to show geographical changes in potato production within the state.

The first part of the study is a review of literature related to potato types and production and transportation. The next section presents the specific challenges of potato logistics in North Dakota. A Geographic Information System (GIS) database modeling potato production and movement was developed and explained. Finally, a summary and conclusions are presented.

POTATO TYPES AND PROCESSING

This section discusses current production practices and an overview of the potato processing industry. It also covers potato transportation, marketing issues and focuses on the dynamic changes occurring in the potato industry.

Since the sixteenth century the potato has served as a staple in the diets of most Europeans and later Americans due to its cost, nutritional characteristics, and storage qualities. Technological advances in production machinery and increased efficiency in processing spurred by changes in consumer demand have altered the potato industry since the end of World War II.

Potatoes are produced in every state in the nation. However, Idaho, Oregon, Washington, North Dakota, Minnesota, Colorado, Maine, Wisconsin, and Michigan produced about 80 percent of domestic production in 1995. These areas produce fall varieties of potatoes, and all except for the Red River Valley of North Dakota and Minnesota, rely heavily on irrigation to increase yields (USDA, 1996). Consumer demand determines potato production and processing. Potatoes are used for table stock, processed into fries or flakes, and the snack food industry. The different uses of the potato determines processor location and movement of the raw product.

Consumers are demanding more efficient and less time consuming methods of cooking. Consumers desire a great tasting meal while spending little time in the kitchen. Increased demand for convenient preparation has pressured food industries to search for ways to better fulfill consumers' needs. The potato industry is meeting these needs by offering a wider variety of convenient processed potato items.

A 1994 North Dakota State University study reported on the numerous uses of potatoes and potato byproducts. Processed potato items such as french-fries, tator-tots, hash browns, twice-baked potatoes, mashed potato products, potato flakes, and potato granules are some of the processed potato items. The primary byproduct of potato processing is a high protein waste often used as animal feed (Stearns, Petry, & Krause, 1994). Chemical residues remaining after processing can be used as cleaners or in other industrial processes (Natu, Mazze, & Jadhav, 1991).

North Dakota's potato crop is divided into four different product uses. Chipping potatoes account for 10-15 percent of production; another 50-55 percent are processed into french fries and potato flakes; about 10-15 percent for the fresh market; leaving 10-20 percent for seed. Demand has increased for processed potato items and decreased for table potatoes, however fresh market potatoes are still in high demand in the restaurant industry. Seed production in the Red River Valley is a part of North Dakota's potato industry (Johansen, 1993). North Dakota's potato crop is harvested in the fall of the year and the movement of the crop is dependent on its use: seed, tablestock, chipping, or processing.

Tablestock are fresh potatoes and preparation before sale is washing and sorting done at washplants close to the production area. There are presently 17 washplants located in North Dakota and Northwestern Minnesota.

Potato chips are processed at the source of final demand because chips are bulky and fragile. Potatoes used for chipping and other snacks are transported to urban centers before being processed. Red River Valley potatoes used for chipping usually move toward large eastern markets (Dunn, Brewer, Powell, Carson, & Cole, 1989). Currently production of chipping potatoes for Frito-Lay is on the decline with less than 3,000 acres grown for chipping (Rudy Radke, interview, July, 2000).

North Dakota seed production has declined in recent years. Seed production accounts for some 10 to 20 percent of all North Dakota potato production and less than 20 percent of the product raised for seed is shipped out of the state. These shipments are split among southern states from October to February and the remainder is used by North Dakota producers. Frozen, dehydrated, and flaked potato products are produced more efficiently closer to the production. North Dakota is home to three potato processing facilities J. R. Simplot, RDO, Aviko, and Western Polymer Corporation, a starch extraction company.

The J.R. Simplot Company is the largest potato processing facility in North Dakota and is a privately held agribusiness corporation. Simplot's food processing division operates a french fry processing plant at Grand Forks, North Dakota. Potatoes for processing are stored at Simplot's facility in Grand Forks and also at producers' warehouses. Simplot operates year round and the majority of their raw potatoes are grown in North Dakota with most of the production being sold out of state. The byproducts are used as livestock feed in various forms throughout North Dakota (Carmen Graving, interview, June, 2000).

RDO is a dehydration plant also located in Grand Forks. Because of the extreme competition in the flaking industry raw materials must be purchased at the lowest possible price. RDO attempts to buy excess North Dakota and Minnesota potato supply at reduced prices. RDO will only forward contracts with potato producers in years of anticipated strong demand or low supply (Jamestown Industry Meeting, June 22, 2000). The finished product is sold out of state and the potato by-products are used for cattle feed in North Dakota and Minnesota (RDO representative June, 2000).

In 1995 an unsuccessful attempt to develop a grower owned and operated potato processing plant led to the construction of the privately owned Aviko potato processing plant in Jamestown, North Dakota. Aviko is a Netherlands company and the plant in Jamestown processes potatoes into french fries (Leistriz, & Sell, 2000). Most of Aviko's contracted potato production is grown within a 100 mile radius of Jamestown, but Aviko also has contracts with producers as far away as Williston and Minot (Jamestown meeting, June 22, 2000). Potatoes produced in northwestern North Dakota are grown under irrigation and the production is considered experimental. Aviko strives to contract enough potatoes to operate the plant year round. Harvested potatoes are stored both with producers and at the processing plant with the finished product being transported out of state.

Western Polymer Corporation operates a starch extracting plant in Park River, North Dakota. The process uses potato water taken from potato processors in Grand Forks, North Dakota and Perham, Minnesota. The water is transported in tanker trucks to the Park River plant. Starch is extracted from the water and shipped to Moose Lake, Washington by rail car for further processing (Western Polymer representative, July, 2000).

Recent trends indicate that the irrigation potential and soil types in North Dakota fit well with potato production. Potato production long distances from a processor increases costs and risk. Higher transportation costs associated with producing farther from processor adds to cost of raw materials. Processors attempt minimize transportation costs of raw product, transportation of by products, and transportation costs of the processed product to the demand areas. If a weather or other event prevents product movement when a problem occurs with the stored product, there is risk of losing the stored potatoes (Jamestown meeting, June 22, 2000). This risk is perceived to be greater with increased distance.

POTATO CHARACTERISTICS

Farmers search for high value crops to use irrigation effectively which has led to increased potato production in North Dakota. Potatoes under irrigation also did well for processors by spreading the production over larger geographical areas reducing risk of production problems (Jamestown meeting, June 22, 2000).

Processors desire different varieties of potatoes to fit characteristics of their product. Advances in potato genetics has allowed for new varieties to be developed and old varieties improved. Several varieties of potatoes are grown in North Dakota and the most prevalent varieties included; Russet Burbank, Shepody, Frito-Lay, and Norland (Sheyna Richard, interview, March, 2000). The growing season in North Dakota allows only for fall potato varieties to be grown.

Russet Burbank is one of the most popular potato varieties grown in North America. In 1998, Russet Burbank accounted for 37.5 percent of North Dakota's potato acreage. The Russet Burbank stores well, and is desirable for cooking and processing (Sheyna Richard, interview, March, 2000).

The Shepody, favored for its high yields, ranked second in percent of North Dakota potato acreage at 13 percent in 1998 (Sheyna Richard, interview, March, 2000). Shepody is first in U.S. total potato acreage planted and is generally grown for early season fall french fry processing (Potato Association, 1993 B).

The Frito-Lay potato is used primarily for chipping and holds about 12.8 percent of the North Dakota potato acreage as of 1998 (Sheyna Richard, interview, March, 2000). The Frito-

Lay potato was developed by the Frito-Lay Company for its excellent chipping qualities (Duane Preston, interview, April 2000).

Norland (Red and Pontiac) accounted for 12.3 percent of North Dakota's potato acreage in 1998 (Sheyna Richard, interview, March, 2000). The Norland is grown primarily for its excellent fresh market tablestock qualities (Potato Association, 1993 B).

Potatoes are classified into four groups based on the season in which they are harvested: spring, summer, winter, and fall. Fall varieties are the most common, with spring, summer, and winter varieties used to satisfy consumer demands as stored fall varieties dwindle. Fall varieties are generally produced in northern states which have cooler climates that are more favorable to long-term storage. Winter, spring, and summer potatoes are generally merchandised through either the tablestock or chipping markets. The non-fall producing states are in warmer climates which are not favorable to long-term storage (Helgeson & Delmer, 1988).

Soil and water factors influencing tuber growth include; structure, water-holding capacity, aeration, temperature, drainage, and the nutrient-supplying capacity of the soil (Potato Association, 1993 A). Potatoes require at least 16 different nutrients for proper growth. Depending on crop rotations and other factors small nutrient deficiencies may occur in eastern North Dakota soils. On average a 300 hundred weight crop will commonly use 200 pounds of nitrogen, 60 pounds of phosphorus, and 300 pounds of potassium (Dahnke & Nelson, 1993). Dryland conditions using proper crop rotation with adequate precipitation can replace soil deficiencies (NDSU Extension Service, 1999).

Irrigation provides for control of water quantity and easy nutrient applications on the potato crop (Jamestown meeting, June 22, 2000). Soil testing measures nutrients and producers may apply those nutrients found inadequate. However, nutrient variations within a field provide for application challenges (Rosen, 1993).

Increased irrigation acres in North Dakota provide opportunity to produce alternative and higher value crops. New areas of potato production are encouraged by processors to minimize the effects and need for treatment of disease. In 1999 North Dakota's potato production was estimated at 29 million hundred weight with 65 percent produced on irrigated soil and 35 percent produced on dryland (Sheyna Richard, interview, June, 2000).

Irrigation commonly occurs on course textured soils such as sandy loams. These soils are usually low in organic matter, natural fertility, and quite acidic. Cost of production under irrigation is higher than dryland production because more inputs are required (Rosen, 1993). Benefits of irrigated potato production in North Dakota include higher yields, earlier production, drought protection, and most importantly to processors is the uniform size and quality of the potato.

Costs of production for dryland potatoes versus irrigated potatoes includes different expenses for seed varieties, chemicals, fertilizer, transportation, and equipment. From planting to harvest the dryland cost per acre ranges from $750-$900 and the irrigated cost per acre ranges from $1350-$1500 (Duane Preston, interview, May 2000). Higher costs are associated with irrigated production because of more input requirements and cost of irrigation equipment but irrigation also increases yield. A ten-year average for dryland production is 168 hundred weight per acre while irrigated averaged 243 hundred weight per acre. Because of the high cost of production it is crucial for a producer to determine market price through contract on the majority of the crop before planting. Consumers demand a uniform processed potato product therefore processors need uniform potatoes to meet this demand. The most uniform potatoes are grown on irrigated acres with sandy soil (Jamestown meeting, June 22, 2000).

Production or yield response to irrigation depends on season length and varieties produced. In general, full season varieties show the greatest response to irrigation. Many varieties perform well under dryland conditions and also perform well under irrigation (NDSU Extension Service, 1999).

Generally water supplied for North Dakota irrigation comes from glacial drift aquifers that developed during the ice age (Bluemle, 1991). Lakes are also being used as an irrigation source with the largest influence being Lake Sakakawea. If progress is made on Garrison diversion, good quality water will become available and many irrigation projects will materialize. Other irrigation experiments include surface water storage in ponds (Rudy Radke, interview, July, 2000).

Potato production under irrigation is as far west as Williams County. There is a new interest in alternative crops in all areas of the state. Farmers search for alternatives because many traditional crops suffer from low prices. In the summer of 2000 a potato warehouse was built north of Williston. With the closest processor at either Jamestown or Grand Forks, 300 miles away, these producers are trying to lure a processor to the area.

In the summer of 2000 a publication by the Williston Area Development Foundation identified areas now under irrigation and potential irrigation within 150 miles of Williston. Acres total 171,045 now under irrigation with 36,045 under pivot and 135,000 under flood, (much of which is the Yellowstone River Valley from Intake, MT to Buford, ND). The publication estimates that there is another 278,650 acres that are potentially irrigable and of that

194,290 acres are suitable for potatoes. This represents a possible shift in production that would have a direct effect on roads and highways in North Dakota.

If 194,290 acres shift from dryland small grain production to irrigated potato production there would be an additional 20,000 to 30,000 pounds per acre produced. The shift would result in an estimated increased 120,000 semi truckloads of potatoes moving from the land.

Potatoes can not be grown in consecutive years on the same acres because of risk of disease and insect problems. If the land is under irrigation alternative crops have to be used for rotation. This may reduce the total impact, but adding irrigation to small grains more than doubles production. Most crops should be grown in a crop rotation that enhances soil fertility, reduce weeds, and conserve soil moisture. Potato growers must develop a rotation best suited to environment conditions, crop alternatives, and market prospects (Potato Association, 1993 A).

Dryland potato production rotation is best suited with small grains or fallow. Small grains deplete soil moisture less than row crops and grains have few diseases in common with potatoes. It is important that potatoes and sugar beets are not planted in succession because of water preservation and disease problems. Table 3.1 shows a possible rotation for a potato producer.

Table 3.1 Recommended Crop Rotation for Potato Production

Year 1	Year 2	Year 3	Year 4
Potatoes	Small Grain	Small Grain	Potatoes

(Nelson & Preston, 1993)

The right potato seed can help prevent disease in potato production (Gudmestad, Nelson, Preston, & Secor, 1993). While disease is present at all times in the life span of the potato, early irrigation and planting practices lead to increased disease problems (Bissonnette, 1993). Some diseases most common in North Dakota potato production include a variety of seed diseases, leaf and stem blights, wilt diseases, and storage rots (Crop Diseases, 2000).

Common seed diseases present in North Dakota include bacterial soft rot, blackleg, and rhizoctonia canker/black scurf. These diseases develop in the seed through fungus, bacteria, and other pathogens. Bacterial soft rot is an infectious decay of the potato that leads to wet, odiferous smelling water-soaked abrasions that consume most of the potato.

Blackleg begins with a decaying seed piece, then continues with lower stem blackening, yellowed foliage, and finally death of the emerged plants (Lamey, Gudmestad, & Secor, 1993). Rhizoctonia canker or more commonly called black scurf is caused by a fungus that is found in the soil and tubers wherever potatoes are grown. Growers using three-year rotation should only have concern with the fungus if it enters the field attached to the seed (Anderson, 1993).

Potato growers in North Dakota also have concerns with leaf and stem blights in the potato field. The most common type of leaf and stem blight includes late and early blight. When conditions are favorable in North Dakota for the late blight fungus, it is distinguishable by its irregularly shaped, depressed areas of brown to purplish color of variable size on the potato skin (Crop Diseases, 2000). Early Blight appears in warm weather, with symptoms developing in July or August on the lower foliage. Crop rotation and effective fungicides aid in control of the early blight fungus (Lamey, 1993).

Common wilt diseases present in North Dakota include fusarium wilt, verticillium wilt, black dot, and bacterial ring rot. Fusarium and verticillium wilts are difficult to distinguish from on another. Verticillium wilt results in reduced tuber quality and yield. The fusarium wilt fungus has not infested potato fields to the same degree as the verticillium wilt fungus (Anderson & Bissonnette, 1993). Bacterial ring rot is potentially on of the most serious potato diseases. While wounds are necessary for the infection to spread it moves easily and rapidly during a growing season (Lamey, Gudmestad, & Secor, 1993).

Storage rot is a common potato disease found in North Dakota. Types of storage rot include: leak, pink rot, late blight, and dry rot. Pink rot and leak are classified as minor diseases. Both diseases are dependent on weather and favor wet conditions late in the planting season. However, for leak to occur a wound is mandatory for infection to happen. Pink rot disease can occur in the field before harvest (Secor, 1993). Dry growing conditions favor dry rot because of increased bruising due to higher specific gravity, more clods at harvest, and a tendency for a later harvest when the potatoes are colder and more susceptible to bruising (Gudmestad, Preston, & Secor, 1993).

In addition to diseases present in the life span of a potato there are also a variety of insect species that threaten the potato. Few insects have significant economic impact and even fewer are consistently present in the North Dakota potato-growing region. However, the Colorado potato beetle is very much present in the potato fields and is the most common leaf feeding insect known to attack potatoes. The potato beetle has developed a resistance to some insecticides and rotation of different classes of insecticides may aid in reducing the potato beetle population in the field. Other insects and worms present in North Dakota potato fields do not compare to the damage done by the Colorado potato beetle (Radcliffe & Ragsdale, 1993).

Processors determine if the potato is stored or processed immediately (Jamestown meeting, June 22, 2000). Storing potatoes provides a constant flow of raw materials to processors and table potatoes for consumers. During storage losses in sugar, protein, starch, and vitamin content may occur. Although optimum storage conditions vary by cultivar, length of storage, tuber maturity, and other factors including proper handling and storage practices can reduce or eliminate certain losses. While in storage, the potato is still a living organism so it continues to need oxygen, generate heat, and carbon dioxide (Preston, 1993).

The most common storage losses to potatoes are due to: internal black spot, tissue damage caused by nutrient deficiency or physical contact; blackheart, a discoloration of the tuber due to oxygen shortage during storage; chilling injury, damage to potatoes from low temperatures, (near freezing); greening, the production of chlorophyll by a stored potato; and post-harvest disease. A number of methods to reduce post-harvest losses exist to help producers preserve the value of their potato crop.

Storing potatoes at the proper humidity, temperature, and aerating prevents most types of damage. Reducing humidity of a potato, through curing is the most effective way to protect tubers. A controlled, ventilated, low temperature (below 15 degrees centigrade) facility reduces biological activity of the plant in storage (Preston, 1993). Recently, irradiation and chemical spraying of the harvested crop have become common methods of preserving potatoes in storage. If problems occur within a storage facility it is imperative that the potatoes are removed and processed immediately otherwise they become useless for processing (Jamestown meeting, June 22, 2000).

MARKETING AND TRANSPORTATION

A variety of marketing techniques reduce the risk of potato production. Contracting is the most common method of attempting to reduce market risk.

Major markets for potatoes include processed, fresh, and seed market. Seed production demands strict disease free standards for certification. Large portions of the potatoes produced in North Dakota are used for processing and are grown under contract. Contracts reduce risks to downside price, but limit the upside price potential (NDSU Extension Service, 1999).

From 1992 to 1997 prices paid to producers fluctuated from a low of $2.30 per hundred weight in June of 1992 to a high of $7.75 per hundred weight in April and May of 1994. Price fluctuations stress the need for managing price risk through forward contracts or hedging before incurring the capital investment required for production. In 1998 the growers price for seed potatoes was $8.00-$16.00 per hundred weight, processing potatoes were $4.35-$5.65 per hundred weight, chipping potatoes were $4.50-$6.65 per hundred weight, and $5.00-$12.00 for tablestock (Sheyna Richard, interview, June 2000).

Food industries are dependent on their ability to transport raw product to market. Within the United States, rail and trucking are the two most common methods of moving potatoes. USDA estimated in 1996 that 15 percent of North Dakota's raw potatoes left the state by rail and the remainder moved by truck. Flexibility and backhaul opportunities for trucks make them the preferred option for brokers representing local producers and out-of-state processors. Because of service problems with rail a number of chippers changed from rail to truck transportation (Dunn, 1989).

Transporting from the field to storage, farmers use either a tandem or tridem farm truck, but to wash plants or processors the move is almost exclusively with five axle-semi trucks. Trailer types are either live bottom or hopper bottom transporting potatoes from the field to storage. Depending on weather conditions, transporting to washplants or processors may require a semitrailer with some type of heat or refrigeration. From the washplant or processor the finished potato product is transported to a variety of outlet stores and warehouses.

Overloaded and heavy vehicles on roadways cause damage and reduce pavement life. Restrictions can be costly to potato producers where the only route to processing facilities is on roadways with load restrictions or where alternative routes add extra miles (Jamestown meeting, July 22, 2000). Legal weight limitations can be exceeded on North Dakota highways using permits allowing up to 10 percent over the allowable gross weight. This 10 percent overload rule does not apply to some bridges and federal and county roadways (North Dakota Highway Patrol, 2000).

Spring load restrictions create problems for growers that do not produce or store commodities next to unrestricted roads. If a problem occurs at a storage unit, trucks are immediately sent to the storage facility to collect the potatoes which are processed immediately to avoid loses. Transporting potatoes to processing plants when load restrictions are in force can be inconvenient and costly for processors and producers. Transportation restrictions limit the payload and may also determine the route taken when transporting potatoes and potato products. These restrictions cause increased transportation costs for producers and processors.

Bottlenecking often occurs when hauling potatoes from storage to processing facilities. This forces truckers to find a more time consuming and less economical route. Major problems exist at the Aviko processing plant where state highways leading to the plant all have gross weights up to 88,000 pounds for a five axle semi until U.S. Highway 281 where bridge formulas reduce the allowable gross weight to 84,000 pounds (Jamestown meeting, July 22, 2000).

Bridge formulas are created to determine the maximum gross weight allowable on the structure and still meet strict safety requirements. North Dakota highways and interstates use Bridge Formula B to determine the allowable gross weight on bridges. State highways and Interstates use the same bridge formula. The State Highways enforce only exterior bridge measurements while the Interstate systems includes the interior and exterior bridge measurements to determine the gross weight allowable for a vehicle. Current bridge formulas allow extra weight for longer vehicles and for vehicles with more axles. Longer vehicles reduce bridge stress and more axles on a vehicle reduces its impact on pavement (LeAnn Emmer, interview, July, 2000).

POTATO PRODUCTION

Location of potato production in North Dakota has changed over time. Areas of traditional production, northeastern North Dakota, have seen a significant decline in both the number of acres and production of potatoes from the 1990 to 1999 crop year. At the same time, counties in central and southern North Dakota have seen an increase in total acres of potato production. Irrigation makes many new areas available to potato production, where soil conditions meet production requirements.

Table 5.1 provides the potato production by county and region for the 1999 crop year. This information was provided by the North Dakota National Agriculture Statistics Service. It provides a snapshot of the production in 1999.

Table 5.1. Potato Production by Area and County.

	Potato County Estimates, North Dakota, 1999 *			
	Planted (acres)	Harvested (acres)	Yield (cwt.)	Production (cwt.)
Benson	1,100	1,100	286	315,000
McHenry	3,200	2,800	367	1,028,000
North Central	**4,900**	**4,500**	**352**	**1,585,000**
Grand Forks	18,000	11,700	294	3,439,000
Pembina	31,500	30,400	198	6,010,000
Towner	1,700	1,500	261	392,000
Walsh	39,700	38,600	178	687,600
North East	**91,900**	**83,200**	**204**	**17,011,000**
Foster	1,200	1,100	289	318,000
Kidder	7,000	6,800	394	2,682,000
Central	**9,200**	**8,900**	**375**	**3,338,000**
Traill	2,800	1,600	208	333,000
East Central	**4,100**	**2,900**	**256**	**743,000**
Emmons	1,600	1,500	362	543,000
South Central	**2,100**	**2,000**	**350**	**699,000**
Dickey	1,900	1,800	391	704,000
LaMoure	1,000	1,000	342	342,000
Ransom	2,800	2,700	363	980,000
Sargent	1,800	1,700	351	597,000
South East	**7,800**	**7,500**	**357**	**2,677,000**
Other	1,000	1,000	347	347,000
STATE	**126,000**	**122,000**		**26,400,000**

In an attempt to analyze the changes in potato production over the years, a number of simple regression models were built to determine factors that affect the location and quantity of potatoes produced. Information from NASS (National Agriculture Statistics Service), the primary source of national production data proved inadequate for such analysis as counties need a minimum of 1000 acres of a crop to be counted. Outside of the northeastern portion of the North Dakota production has been inconsistent. As a result, reliable production models for most of the state were not possible.

Next, counties were classified according to NASS Districts allowing for seemingly unrelated regression (SUR) models to be built. The SUR technique is used when similarities between data sets are likely to exist, but exact parameters are unknown. In the case of potato production, it can be assumed that producers in adjoining counties used similar inputs to make decisions, similar methods to produce their crops, and experienced similar climatic circumstances. The use of NASS reporting districts, grouped by the USDA (due to similar climate, soil types, and field crops) work well with SUR analysis.

Six statistical models were built, one for each reporting district with significant potato production in North Dakota over the 1990 to 1999 growing seasons. This technique, though having better results than the simple regression model suffered from lack of observations.

While the statistical analysis did not provide the desired results for determining factors that influence potato production. Visual analysis using graphs demonstrate changes that have occurred within the industry. Line graphs were developed displaying changes in two areas, northeastern North Dakota and the remainder of the state, and for irrigated and non-irrigated acres. Northeastern North Dakota has traditionally produced the majority of the states potatoes on non-irrigated land. Other areas of the state have seen rather isolated pockets of production, primarily on irrigated acres.

Northeastern North Dakota includes the counties of Grand Forks, Pembina, Towner, and Walsh. The chart below shows the level of production in this area on non-irrigated acres. From 1994 to the 1999 growing season planted acres fell from 103,400 to 72,100 a 30.2 percent decline (Figure 5.1). Over the same period, production, measured in hundredweight (cwt.), declined at a similar rate. Potato production in 1999 was 12,982,000 cwt. a 34.5 percent decline over its 1994 level.

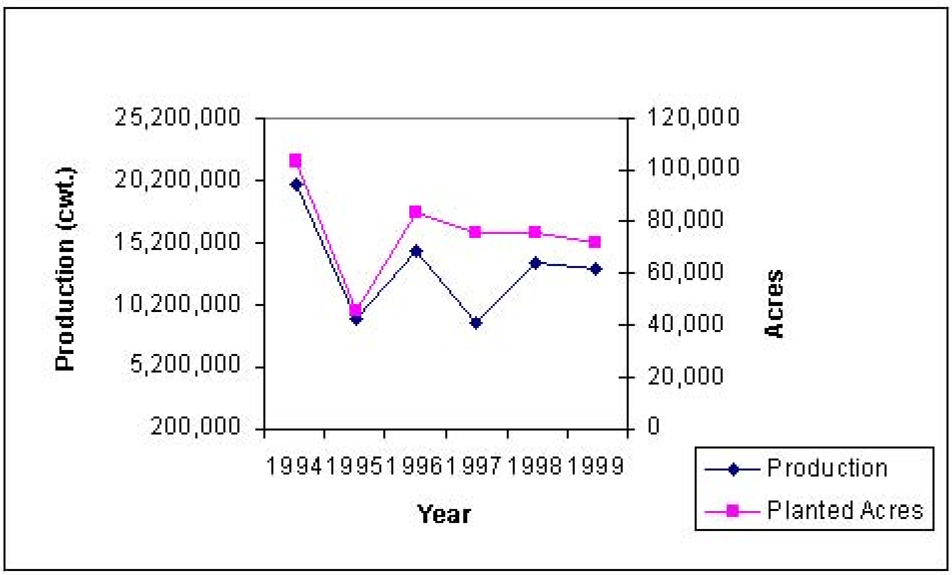

Figure 5.1 Northeast North Dakota Non-Irrigated Potato Production

While northeastern North Dakota is predominantly defined as a non-irrigation region of potato production, irrigated production does occur. Figure 5.2 displays the changes in irrigated potato production in northeastern North Dakota from the 1994 to 1999 growing seasons. During this time both planted acres and total production declined. Irrigated acreage saw a high of 5,900 acres in 1994, which dropped to a relative low of 800 acres two years later in 1996. It has since risen to 1,800 planted acres.

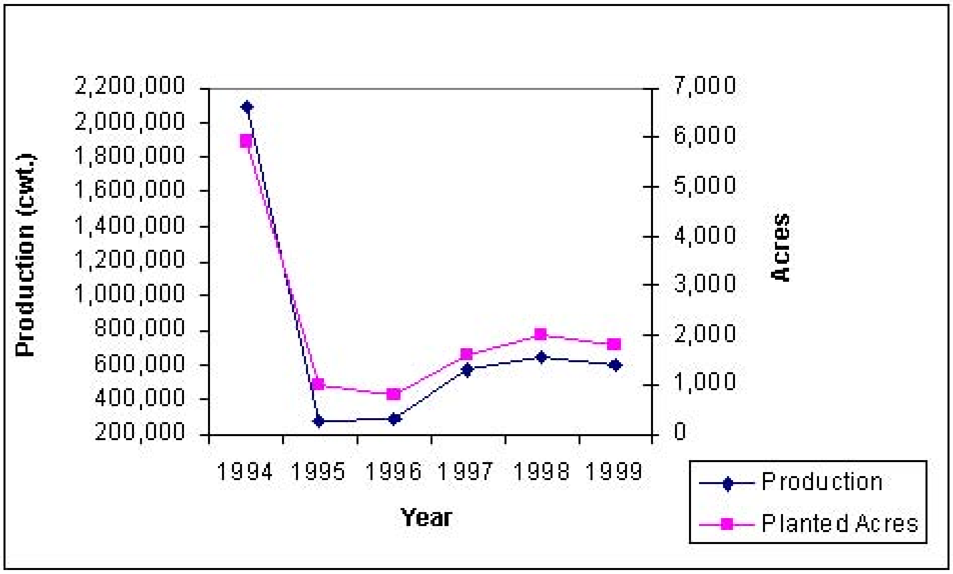

Figure 5.2 Northeast District Irrigated Potato Production

Production mirrored the changes in planted acres, as yields over the period has remained relatively constant. Irrigated production fell from 2,098,000 cwt. in 1994, to 276,000 the next year, a decline of over 85 percent. Following 1996, irrigated potato production has risen, reaching a level of 570,000 cwt. in 1999, 27 percent of the1994 level. Since that time production has stabilized to about 600,000 cwt, during both the 1998 and 1999 growing seasons.

Between 1994 and 1999, total North Dakota non-irrigated planting has steadily declined, while the opposite is true of irrigated acres. It is important to note the difference of magnitude between the two groups, with non-irrigated acreage accounting for nearly ten times the number of irrigated acres.

North Dakota potato production traditionally associated with northeastern North Dakota has expanded into central and southern parts of the state. Figure 5.3 shows non-irrigated production in areas outside of northeastern North Dakota. From 1994 to 1999, non-irrigated production has been relatively constant except for the 1995. In 1995 an increase in both acreage and production occurred.

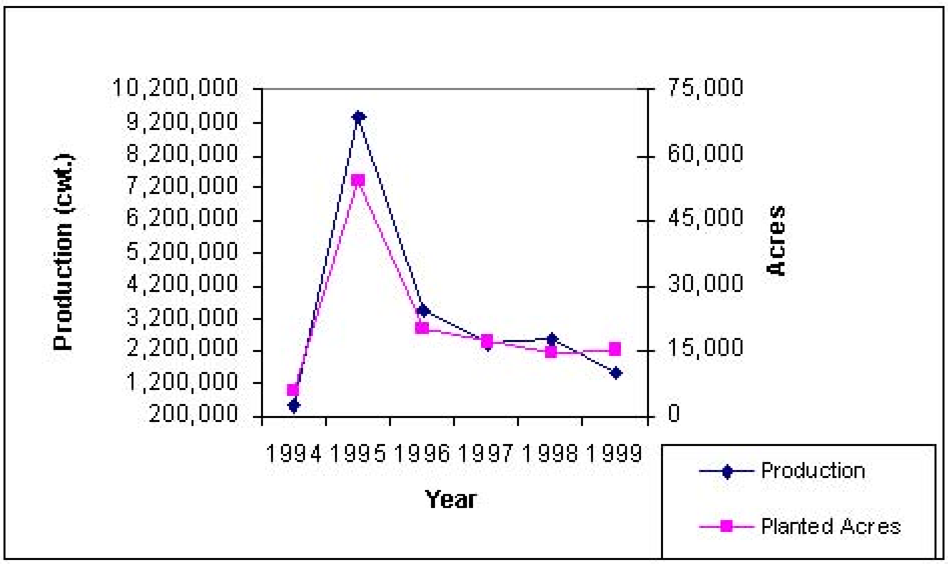

Figure 5.3 Other North Dakota Non-Irrigated Production

Most attention in the industry has been focused on the opportunities for irrigated potato production outside of the Red River Valley. The following chart shows irrigated potato acreage and production outside of northeast North Dakota. This area has seen a steady increase in both acreage and production from 1994 to 1999. In 1994, 18,100 acres were planted and increased to 31,700 acres in 1999. Increasing acreage led to increased production, as yields on irrigated land are less dependent on weather. Production peaked in 1998 at 12,026,000 cwt. then falling slightly to 11,287,000 cwt. in 1999 (Figure 5.4).

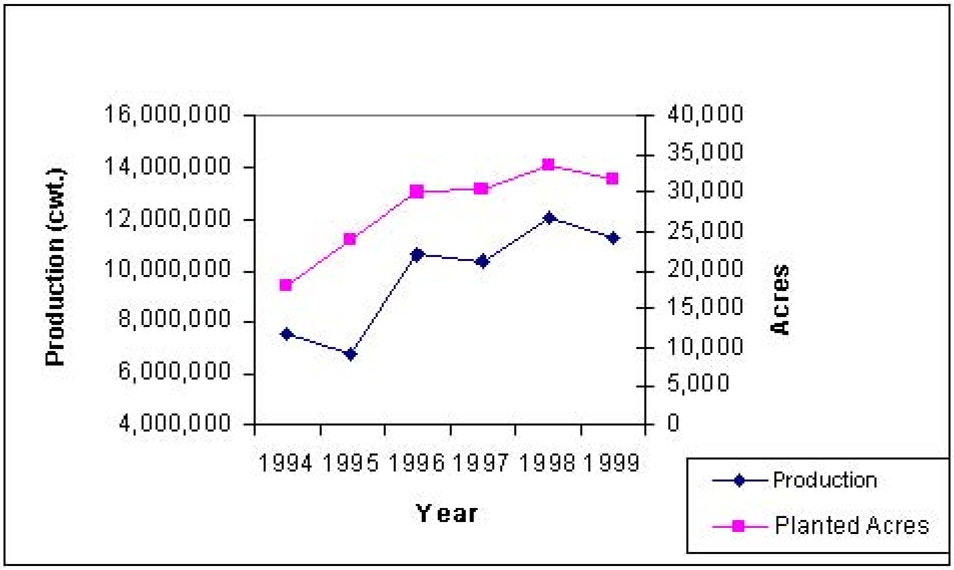

Figure 5.4 Other North Dakota Irrigated Production

Figure 5.5 displays the trend of potato acreage in areas outside of the northeast from 1994 to 1999. The left axis describes non-irrigated acres, while the right axis measures irrigated acres. Within this area, irrigated acreage has increased from 16,000 in 1994 to 26,000 in 1999. Over the same time period non-irrigated acres declined from 1995.

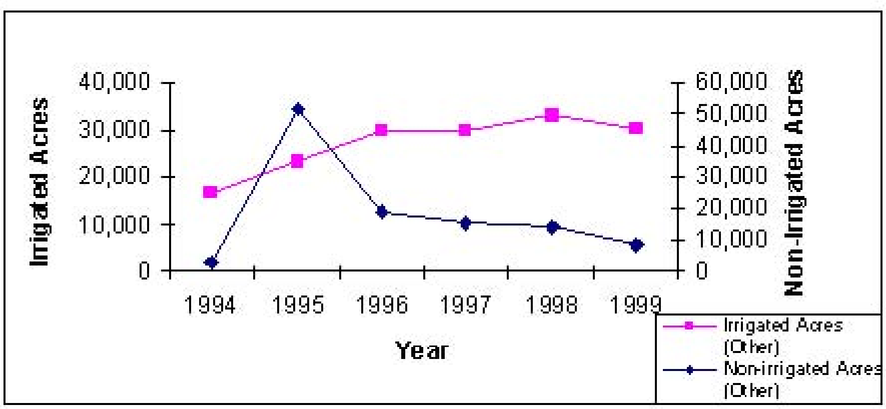

Figure 5.5 Other North Dakota Acreage (other than northeast)

Figure 5.6 shows the number of irrigated acres planted in the State of North Dakota from 1994 to 1999. Potato production again is divided into two areas: the Northeast District, and other areas. An increase in irrigated acres occurred outside northeastern North Dakota during the six-year period. Irrigated acres decreased from 1994 to 1996 in the northeast and since have stabilized.

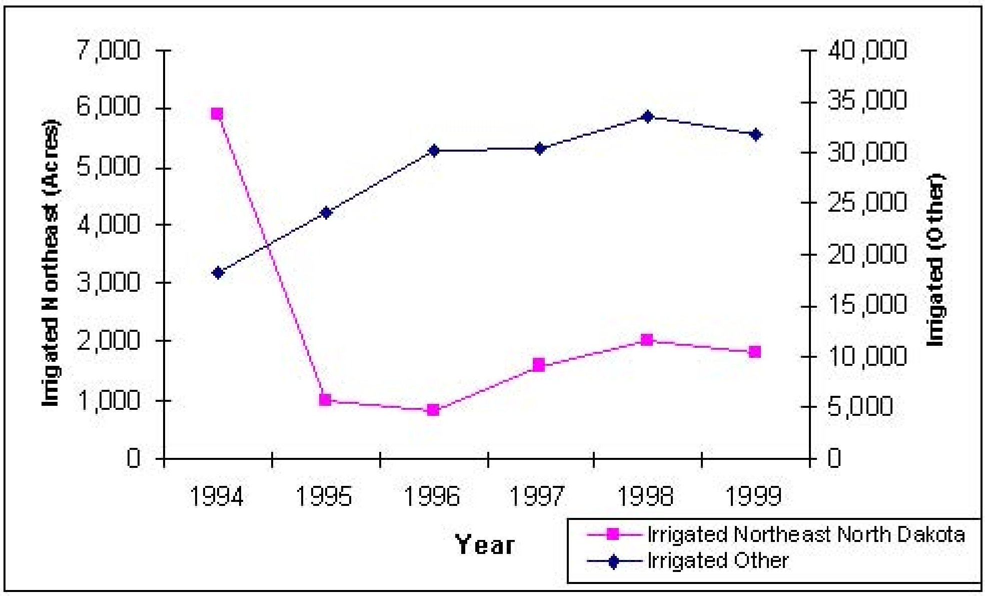

Figure 5.6 Irrigated Potato Acres in North Dakota

Figure 5.7 shows the decline in non-irrigated acreage over a six-year period beginning in 1994 for the northeast North Dakota and the remainder of the state. The axis on the left measures changes in harvested acres in the northeast, while the axis on the right measures changes for the rest of North Dakota. Both areas show decline during the interval. The northeast shows a much larger decrease, especially between the 1995 and 1996 growing seasons, when acreage dropped by approximately one-third. Reductions in other non-irrigated parts of the state have been steady over time.

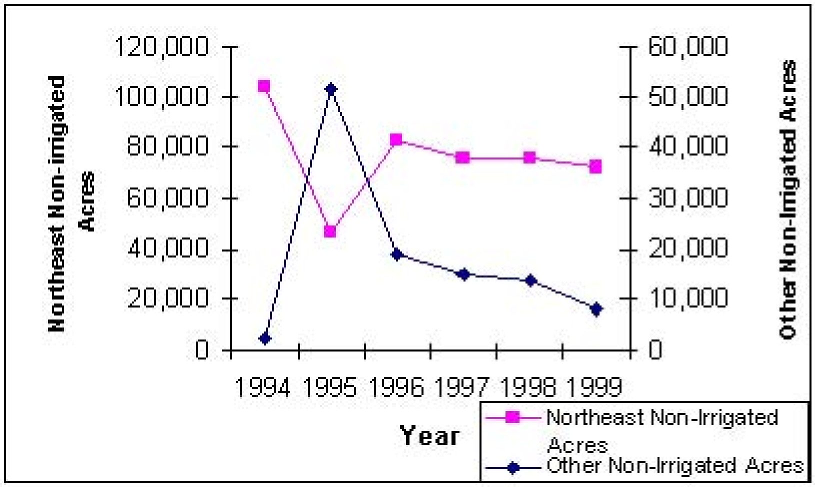

Figure 5.7 Non-Irrigated North Dakota Potato Acreage

Figure 5.8 shows potato production in the northeast North Dakota from 1994 to 1999. The left axis shows production on non-irrigated land, the right axis shows production in hundredweight (cwt.) on irrigated land. Over the six year period production on non-irrigated

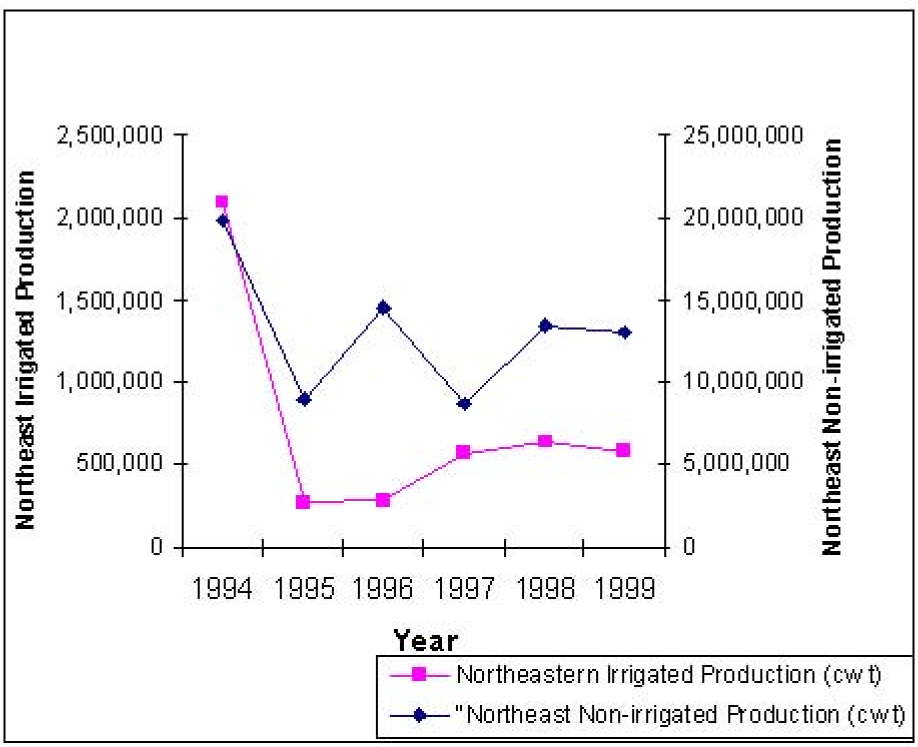

Figure 5.8 Northeast North Dakota Potato Production

land has decreased gradually from 19,812,000 cwt. to just over 14,000,000 cwt. in 1999. During this same period production on irrigated land has increased to 5,002,000 in 1999 (Figure 5.8).

Potato production in other areas of the state is shown in Figure 5.9. The left axis measures non-irrigated production, while the right axis measures production under irrigation. Non-irrigated, other than the northeast, production has been declining since 1995 when it peaked at over 9,000,000 cwt. Irrigated production has risen from 7,582,000 in 1994 to 11,287,000 in 1999.

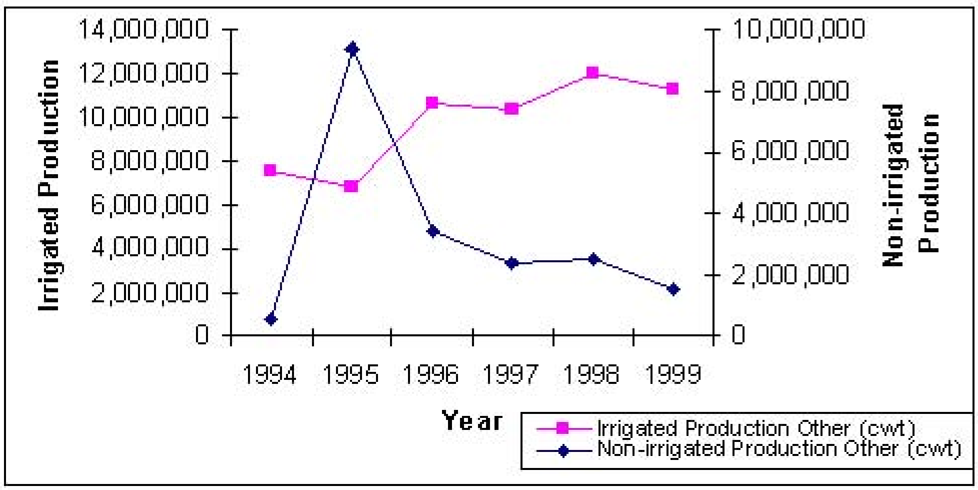

Figure 5.9 Other Areas North Dakota Potato Production (other than northeast)

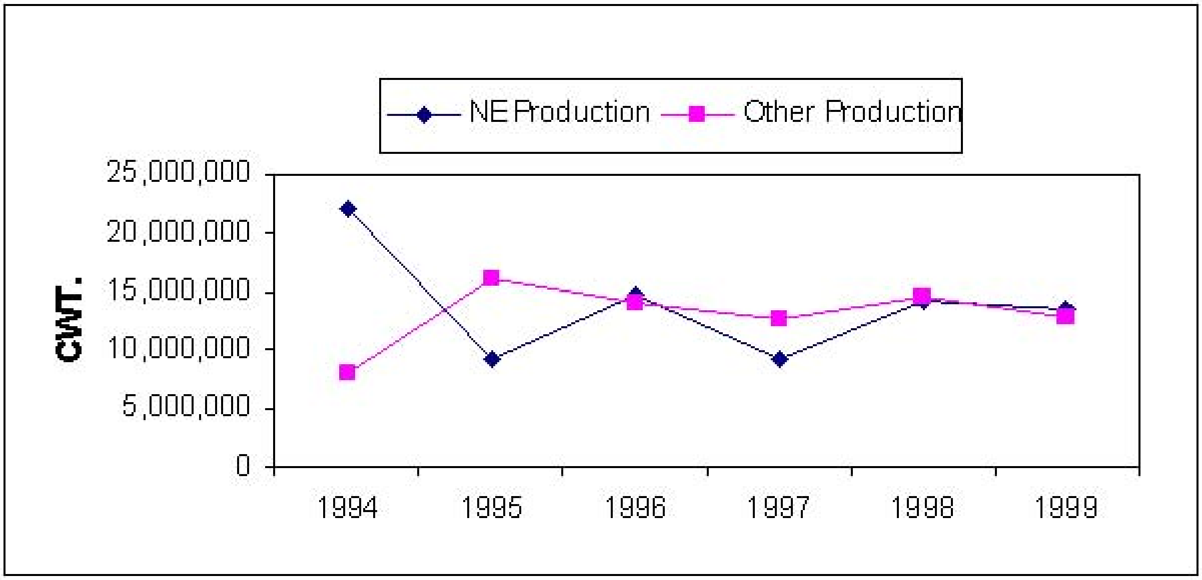

Figure 5.10 Total North Dakota Potato Production

The preceding charts illustrate changes that have occurred within North Dakota over the last seven years. Most important are the exit of acreage and production in northeastern North Dakota, the traditional location of potato production, and the introduction of irrigated acreage in the central part of the state. Statistical models designed to determine factors influencing potato production in the state of North Dakota were ineffective. Improvements in data collection methods by the National Agricultural Statistics Service, time and continued increased production in central and western North Dakota will provide reliable data for analysis.

NETWORK FLOW MODEL

A network flow model was developed to estimate the truck traffic generated by the potato industry. This model is a combination of several steps to determine the number of 5 axle semi-trucks moving potatoes to a given market. The model uses some of the steps implemented by Denver Tolliver of UGPTI in developing a *Prototype Corn Highway Network Model for Southeastern North Dakota*.

A network model is a representation of supply and destination nodes and the transportation links. The supply nodes are county wide data and the destination nodes are known processing facilities or wash plants in North Dakota.

The first step in determining the route of the potatoes was to determine the supply areas in the state. National Agricultural State Statistics (NASS) data were used to determine the production areas. NASS collects county crop data every year. A crop is counted if a minimum 1,000 acres are planted within the county. For most crops this is adequate, however it is somewhat deceptive from a transportation point of view. If 900 acres producing 30 bushels per acre of dryland wheat are not counted the transportation impact would be about 1,800 pounds per acre or 28 truck loads, but if a 900 acres of irrigated sugar beets or potatoes remain uncounted it would have a much larger transportation or pavement damage impact. For instance 900 acres of potatoes could equate to approximately 500 truckloads (this is 5 axle semi truckloads at a GVW of 80,000).

The demand points or nodes are eight processing and or wash plants in North Dakota. The capacity of these plants vary. The largest demand point in the state is Simplot in Grand

Forks and the second largest is Aviko in Jamestown. Cities are identified at the demand points in Table 6.1.

Table 6.1 Demand Nodes in Network Flow Model

Name	Address	Volume cwt
Folson Farms	Grand Forks	396200
A&L Potato	Grand Forks	396200
Potato Sales Inc	Park River	200000
Aaland Potato	Hoople	52500
Northern Valley Growers	Hoople	32000
OC Schulz & Sons	Crystal	250000
Associated Potato Growers	Grand Forks	800000
RDO	Grand Forks	3000000
Simplot	Grand Forks	7000000
Aviko	Jamestown	5000000
Bjorneby Potato Co	Minto	120000

Other demand points were identified, but the wash plants at these locations failed to share information because of proprietary concerns. These included NoKota Packers in Buxton, and J.G. Hall and Sons in Edinburg.

Excess supply of potatoes are produced in North Dakota. Some of this supply would be used by NoKota and J.G. Hall and Sons, but large volumes move to processors outside North Dakota. The excess supply remained at the origin, because the destination is unknown.

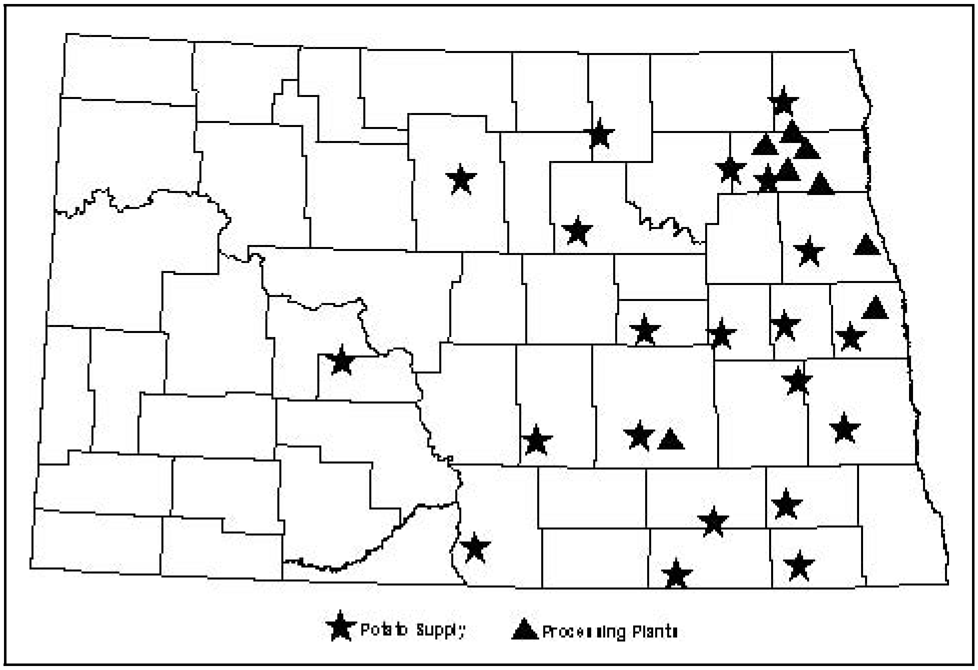

Figure 6.1 Counties with Production Nodes and Demand Nodes

The attraction of each demand node is transportation cost minimization. In many instances farmers or truckers have alternatives to the route they choose from the origin to the final destination. If more than one possible route exists, a farmer or trucker would choose the least cost route.

Routes were established from supply to demand areas. The North Dakota Department of Transportation Route and Mileage map was used in determining three common sense routes. Because potato production is not constant on a particular parcel of land, the onerous task of assigning production to particular parcels of land was omitted and estimated production points or a centroid were chosen in each county.

After the routes were established and entered into spreadsheet form, a low cost route was established by determining minimum distance. The low cost route was used on state and the U.S. Highway System. On the Interstate Highway System a strict weight regulation exists while on the state system a ten percent overload permit is available. It may be that the shortest distance is not always the least cost route. However, within the areas of North Dakota that potatoes are moved, it is difficult to avoid the U.S. Highway System. Therefore, it is reasonable to include the U.S. and Interstate Highway System in the model.

The prototype model is set to minimize trucking or distribution costs. In this scenario potatoes are moved from production zones to demand points to minimize transportation costs. This provides for road use or the number of five axle loads on a given section of highway. The production points are a particular centroid within the county. This posses a problem because potatoes move first from the field either to market or to a warehouse and may move on county, collectors, and/or the state highway system. Again because the satellite imagery data that is field specific, is not possible to connect directly to the model, therefore a specific point or points were picked in each county. This process presents only an estimate of flows from the county to the processor on the state highways system through a transportation cost minimization function and may or may not replicate the actual movement of potatoes.

This section of the report identifies routes and truck loads of potatoes moving on North Dakota highways. The report estimates truckloads, on an annual basis, moving from supply points to final demand nodes (Table 6.1).

In estimating flows or routes, sections of highway were identified in the flow sequences. Table 6.2 estimates truckloads of potatoes being transported over the identified segments of state and U.S. Highway. Column 1 in Table 6.2 identifies the roadway and columns 2 and 3 determine where the impact occurs. Column 4 is the miles affected while column 5 is the number of hundred weight transported. Column 6 is the estimated number of 5 axle 80,000 GVW trucks moving across that particular segment of roadway annually as a result of potato production. The bold lines horizontally in the table are the breaks between different origins and the destinations of product flow.

Table 6.2 Highway Segments Impacted from Potato Movement

Highway	From	To	Miles	CWT	Truckloads
ND-5	Cavalier	ND-5&I-29	18.5	592,800	1,056
I-29	I-29&ND-81	US-2&I-29	62.2	592,800	1,056
US-2	I-29&US-2	Grand Forks	2.61	592,800	1,056
ND-17	ND-35&ND-17	US-81 (Grafton)	33.7	6,483,000	11,577
US-81	Grafton	I-29	27.6	6,483,000	11,577
I-29	US-81&I29	I-29&US-2	10.3	6,483,000	11,577
US-2	I-29&US-2	Grand Forks	2.61	6,483,000	11,577
ND-17	Park River	ND-17&I-29	26.9	367,600	656
I-29	ND-17&I-29	I-29&US-2	34.5	367,600	656
US-2	I-29&US-2	Grand Forks	2.6	367,600	656
ND-200	Finley	Portland	18.3	410,000	196
ND-18	Portland	ND-18&ND-15	14.9	410,000	196
ND-15	ND-18&ND-15	Thompson	19.2	410,000	196
I-29	Thompson	I-29&US-2	11.1	410,000	196
US-2	I-29&US-2	Grand Forks	2.6	410,000	196
ND-200	Mayville	ND-200&I29	11.1	300,000	534
I-29	ND-200&I29	I-29&US-2	31	300,000	534
US-2	I-29&US-2	Grand Forks	2.6	300,000	534
ND-18	Inkster	ND-18&US-2	15	3,439,000	6,141
US-2	ND-18&US-2	Grand Forks	27.5	3,439,000	6,141
ND-18	Cavalier	ND-18&ND-66	13.4	250,000	446
ND-66	ND-18&ND-66	Crystal	2.71	250,000	446
ND-18	Cavalier	Hoople	17.6	84,500	151
ND-17	Park River	Grafton	16.8	120,000	214
US-81	Grafton	Minto	9.7	120,000	214
ND-17	Park River	Park River	1.8	200,000	357
US-52&281	Carrington	Jamestown	43.5	656,000	1,168
3rd St SE	US-52&281	Aviko	3	656,000	1,168
ND-36	Robinson	Pingree	42	2,341,000	4,170
ND-52&281	Pingree	Jamestown	21	2,341,000	4,170
3rd St SE	US-52&281	Aviko	3	2,341,000	4,170
ND-3	ND-3&ND-36	ND-3&I-94	20	341,000	607
I-94	ND-3&I-94	County 22	76	341,000	607
ND-13	Lamoure	Edegely	19	342,000	609
US-281	Edegely	Jamestown&I-94	36	342,000	609
I-94	US-281&I-94	I-94&County 22	4	342,000	609
US-83	Linton	US-83&I-94	40	699,000	1,245
I-94	US-83&I-94	I-94&County 22	80	699,000	1,245
ND-32	Lisbon	ND-32&I-94	39.5	621,000	1,106
I-94	ND-32&I-94	I-94&County 22	40.6	621,000	1,106

The model fills demand at all locations but there is excess supply left at the origins in many counties. The destinations of this excess supply are out of North Dakota and demand nodes are unknown. Much of the production in central and south central North Dakota moves east into plants in Minnesota. Some Kidder county production is between ND-36 and I-94, therefore some traffic moves to I-94 via ND-3 or county roads. Table 6.3 estimates the 1999 production not processed in North Dakota. Within the table are the counties and the districts and the district totals. The sum of counties does not equal the district totals whereas production is reported in the district but does not equal 1,000 acres so it is not attributed to a specific county. It is estimated that almost 10 million cwt. are processed or used for tablestock outside of North Dakota (Table 6.3).

Table 6.3 Excess Production Left at Origins

County	CWT	Truckload
Benson	315,000	563
McHenry	1,270,000	2,268
North Central	**1,585,000**	**2,824**
Grand Forks	0	0
Pembina	4,349,700	7,750
Walsh	0	0
Towner	392,000	700
North East	**6,261,600**	**11,157**
Foster	0	0
Kidder	0	0
Central	**338,000**	**602**
Traill	0	0
East Central	**0**	**0**
Emmons	0	0
South Central	0	0
Dickey	704,000	1,257
LaMoure	0	0
Sargent	597,000	1,066
Ransom	363,000	643
South East	**1,714,000**	**3,054**
Other	347,000	440
Total	**9,898,600**	**17,637**

GEOGRAPHICAL INFORMATION SYSTEMS

The 1998/1999 NASS Land Cover Classification data could not be used to pinpoint potato production in North Dakota. Problems exist with the NASS data as this is a combination of reported data and satellite imagery. This process has yet to be perfected for minor crops or new areas of production.

The NASS map shows potato production, but because in some cases the data needs to be verified by ground observation, some areas of production are unidentified. For instance there is no observed production in western North Dakota but there was some production under irrigation. Therefore county data and imagery data do not correlate. Figure 7.1 is the NASS imagery map showing potato production in North Dakota. The map shows only the specific area of land used in potato production in1999 but does not reflect levels of production.

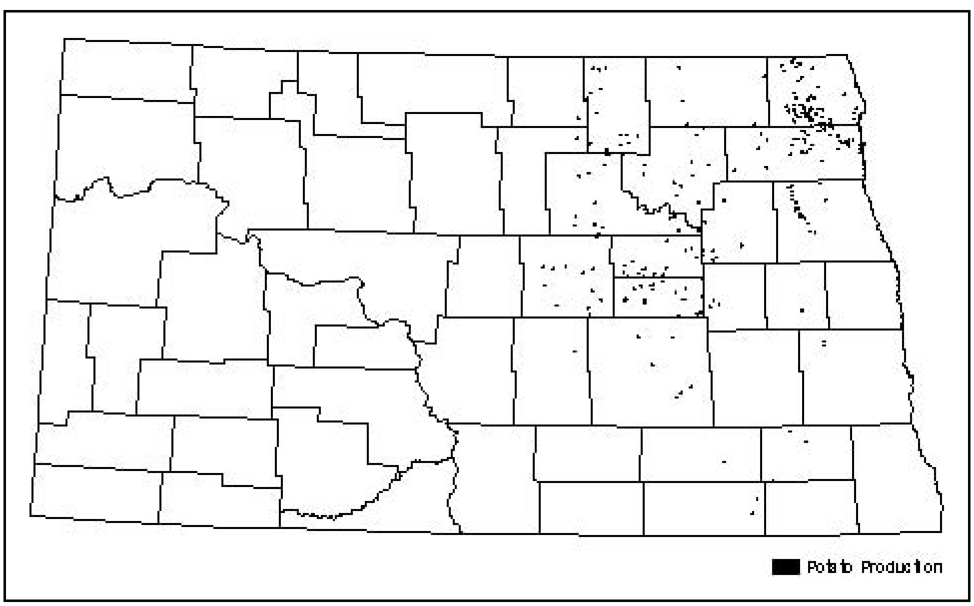

Figure 7.1 NASS Potato Production (Land Cover Classification 1999 and 1998

Because of the nature of potato production it may be better to show production using county boundaries and NASS reported data. This was done in Figure 7.2 showing the different production levels in the counties. Both maps show the counties with the most acres are in northeastern North Dakota. Figure 7.2 shows the density of production in the different counties.

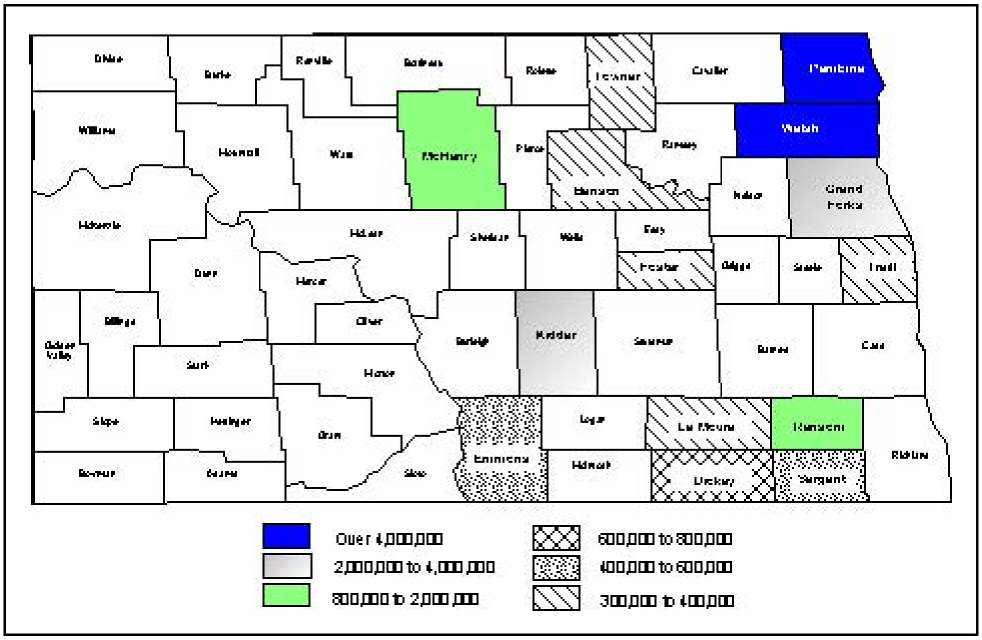

Figure 7.2 Total Potato Production by County

Figure 7.3 and Figure 7.4 compare 1990 with 1999 potato acres according to NASS data. As the maps show the production has moved from the northeast portion of the state to the central and south central counties of North Dakota. There is production in other counties, but NASS only counts counties with at least 1000 acres of production.

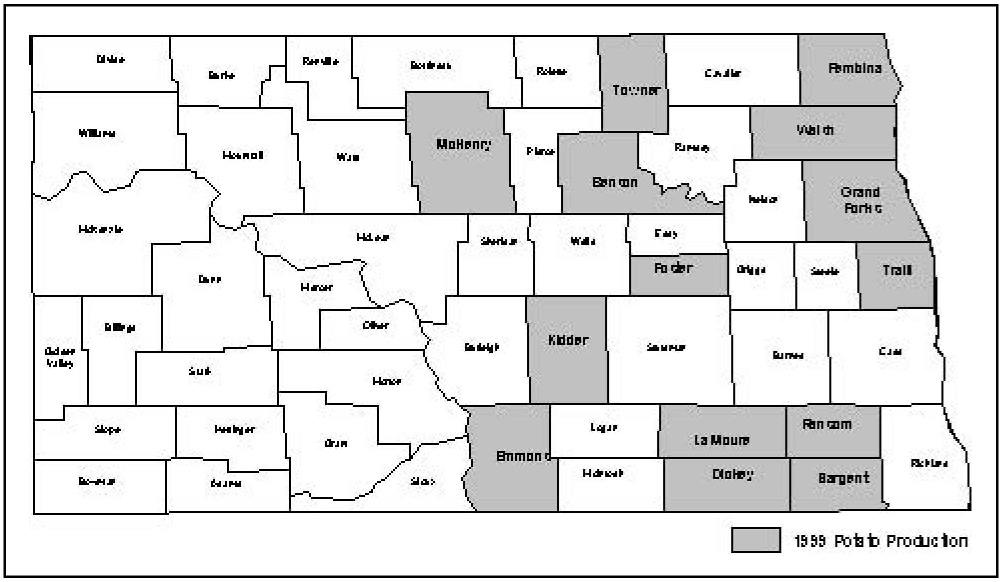

Figure 7.3 NASS Reported 1999 Potato Production

Figures 7.3 and 7.4 show reported potato production to NASS in 1990 and 1999. NASS continues to improve their satellite image data and in the future will become a valuable tool for other agencies in need of point source crop data.

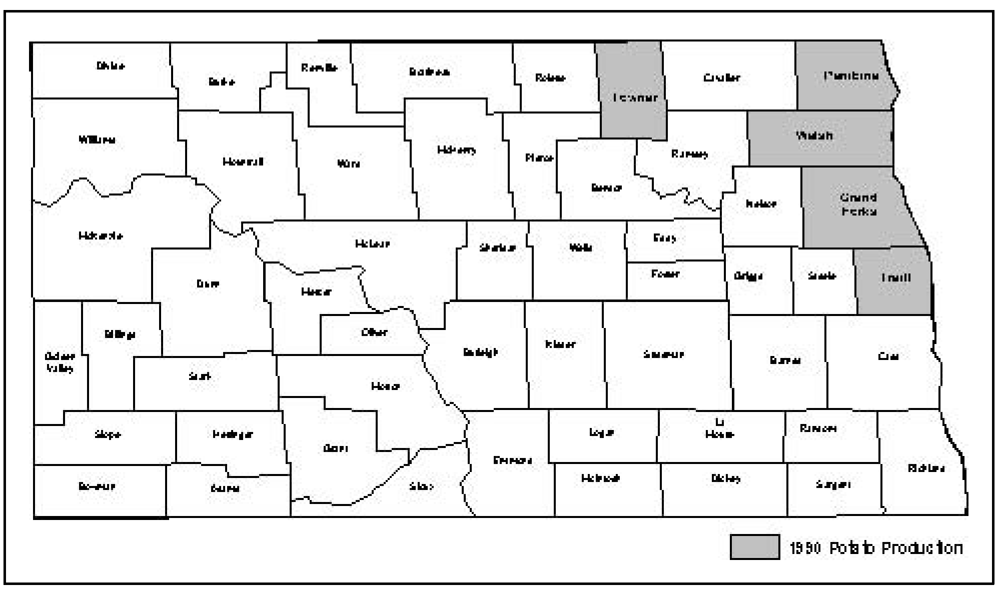

Figure 7.4 NASS Reported North Dakota Potato Acres

Figure 7.5 singles out the counties that are reporting potato acres in 1999 and not showing acres in 1990. This map reflects the shift in potato production to more western locations.

Figure 7.5 shows the counties reporting potato acres in 1999 but not reporting in 1990. This reflects that northeastern North Dakota leads North Dakota potato production, but production has declined in the Northeast. The largest reason for the shift in production is the demand for a more uniform potato product produced under irrigation for french fries and other frozen potato products. It is uncertain if demand will continue to increase, but if market conditions are positive, expansion of potato production under irrigation could continue in North Dakota.

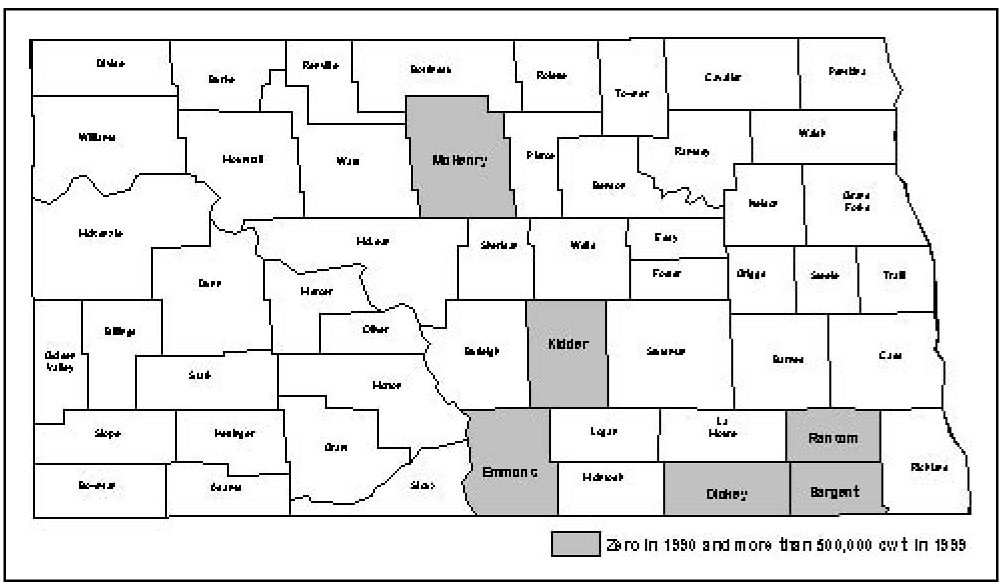

Figure 7.5 Counties Reporting Production in 1999, but not in 1990

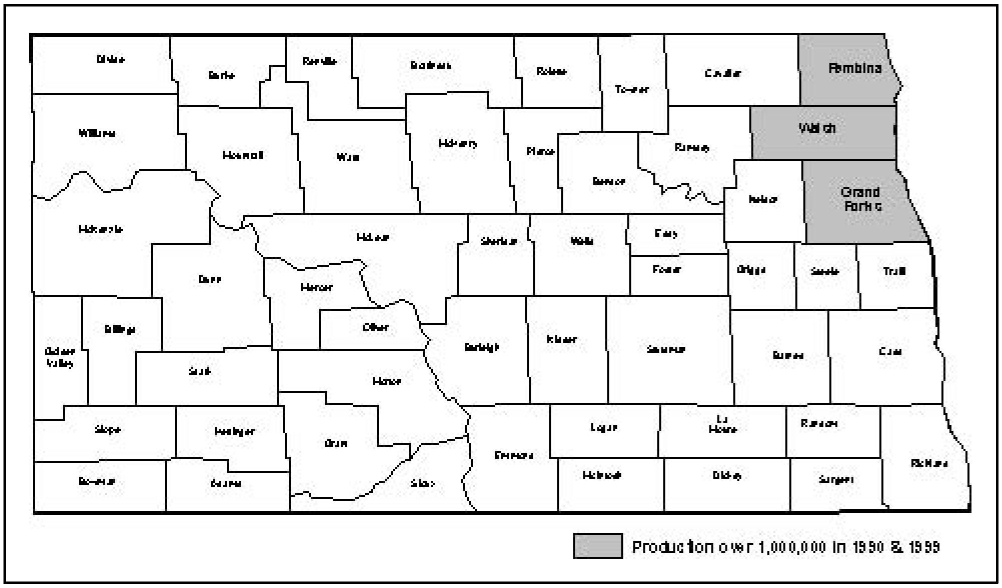

Figure 7.6 Countywide Potato Production with More Than a Million Hundredweight in both 1990 and 1999

CONCLUSION

The objective of this study was to provide information to aid transportation decision makers in planning and programming for future commodity transportation needs. The instability of agricultural commodity prices encourages producers and rural communities to attempt to increase net returns from their farming efforts. The value-added effort includes small changes in production methods, adding irrigation, changing crops, and building processing facilities. Many attempts have been made at the value-added concept, and recently adding potato production under irrigation has changed farming for some North Dakota producers.

Increased demand from consumers for conveniently prepared meals has pressured food industries to search for ways to better fulfill consumers' needs. This can explain the changing trend from fresh table potatoes to processed potato items. A gross portion of potatoes produced in North Dakota are used for processing, usually grown under contract.

Three potato processing facilities are located in eastern North Dakota. RDO, located in Grand Forks, is a dehydration plant making potato flakes. J.R. Simplot Company, also in Grand Forks, and the largest potato processing facility in North Dakota, makes primarily french fries. Aviko, located in Jamestown, potato processing plant also makes primarily french fries. Other states and some Canadian provinces use a percentage of North Dakota grown potatoes for processing.

Potato production is a complex procedure demanding large investments from producers. Risks associated with production include disease, insects, rainfall (excess or shortage), harvest risk, quality, quantity, and storage for harvested crop. Potato production has migrated from eastern North Dakota to other areas of the state partially to minimize some of the risks for the processors. Raising potatoes in different locations attempts to ensure the processor a supply of raw materials. Potato production also may provide farmers with an opportunity to increase returns from land being developed for irrigation.

Spreading production over larger geographical areas increases transportation needs associated with potato movements from field to the processor. From the field to storage farmers use either a tandem, tridem, and some 5-axle semi trucks, but movements to wash plants or processors are almost exclusively transported with five axle semi trucks. Trailer types are either live bottom or hopper bottom transporting potatoes from the field to storage. When transporting to washplants or processors a semitrailer with some type of refrigeration may be used depending on the temperature and the time of year. From the washplant or processor the finished potato product is transported to a variety of outlet stores and warehouses.

Overloaded and heavy vehicles on roadways damage roadways and reduce pavement life. The public pays for pavement-related costs but there is an added cost to industry for weight restrictions or seasonal load limits.

Load restrictions can be costly to potato producers where the only route to processing facilities is the roadway with load restrictions or where an alternative route adds extra miles (Jamestown meeting, July 22, 2000). In fall and winter the North Dakota Highway Patrol writes permits allowing up to 10 percent excess over the allowable gross weight. Therefore a 5-axle semi with a normal gross weight of 80,000 pounds can add 8,000 pounds of payload. This 10 percent overload rule does not apply to some bridges, the Interstate System, or county roadways (North Dakota Highway Patrol, 2000).

Seasonal load restrictions may create problems for growers that do not produce or store commodities next to unrestricted roads. Regardless of load restrictions, if a storage unit fails trucks are immediately sent to the storage sight to collect the potatoes which are processed immediately to avoid loses. Transportation restrictions limit the payload and increase transportation costs for producers and processors.

Continued irrigation development will increase tonnage produced from the land. Regardless of the type of crop the additional tonnage will have greater impacts on the North Dakota highway system. Development of flow models to coincide with NASS production data will provide valuable insight for North Dakota highway planners as to where this increased production is moving.

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APPENDIX 1

(Copied from the Soil Survey Digitizing Program's Website)
(www.state.nd.us/ndgs/Soils/soils.htm)

SOIL SURVEY DIGITIZING PROGRAM

Since 1997, the North Dakota Geological Survey (NDGS) and the Natural Resource Conservation Service (NRCS) have been participating in a cooperative project to compile and digitize the soil resources of North Dakota. Prior to 1997, the North Dakota Soil Conservation Committee was the state agency involved with this project. As of December, 2000, approximately 55 percent of the soil maps in the state have been compiled and digitized.

There is often a delay of at least several months between the time the Geological Survey completes a county and the NRCS certifies that county and makes it available to the general public. To help expedite the process the North Dakota Geological Survey has begun releasing digitized data to state and county agencies and consulting companies as soon as we complete them. In addition, due to the large size of these county files and the difficulties involved in downloading, searching, etc., the ND Geological Survey is exploring methods to download soils data for specific quadrangles to a computer disc for interested farmers either without charge or for a very nominal fee.

The NRCS determines the order in which counties will be compiled based on availability of material and available funding or interest expressed by a given county. When either the Geological Survey or NRCS is notified of a specific need or interest in a particular area, we attempt to prioritize that county. This cooperative program can be grouped into six main tasks: 1) compilation, 2) editing, 3) edge matching, 4)scanning, 5) digitization, and 6) certification.

Compilation

The drafting technicians spend approximately 70 % of their time compiling. Compilation consists of transferring soil lines, symbols, and labels from an old orthophotoquad (typically these sheets are right out of the old county soils reports) onto clear mylar using a recent orthophoto quad as the base map. The recent orthophoto base is overlain by the old half-toned orthophotos which, in turn, is overlain by a clear mylar sheet. Typically, there is a ten- to twenty-year difference between the photos and that can make it difficult to line up features. Compilation must be done by hand, rather than computer-aided, because the inherent distortion between the two photo sheets require that drafting technicians continuously shift the photos to keep them lined up–a difficult, time-consuming task.

Editing

Upon completion of the compilation phase, all sheets are thoroughly checked for line accuracy and correct label and symbol placement. An edit sheet of mylar is placed over the compiled sheet and all lines are physically retraced to insure that all polygons close correctly. The correct position of all symbols and labels is also verified. Approximately 20% of the drafting technician's job is spent editting others work.

Edge Matching

All four edges of a sheet are aligned with adjoining sheets ensure that all of the soil lines are properly aligned from one sheet to another. When needed, small adjustments are made so that lines connect from one sheet to another.

Digitizing

The digital scan is returned to either the Geological Survey office for completion or, occasionally, it is sent to an NRCS office in Montana to be digitized. Digitizing consists of entering all attributes (labels and symbols) into the proper place on the soil maps in the computer. The quad maps are geo-referenced to real-world coordinates at this time so they can be used in conjunction with various other layers. The Geological Survey uses ArcInfo to digitize these sheets.

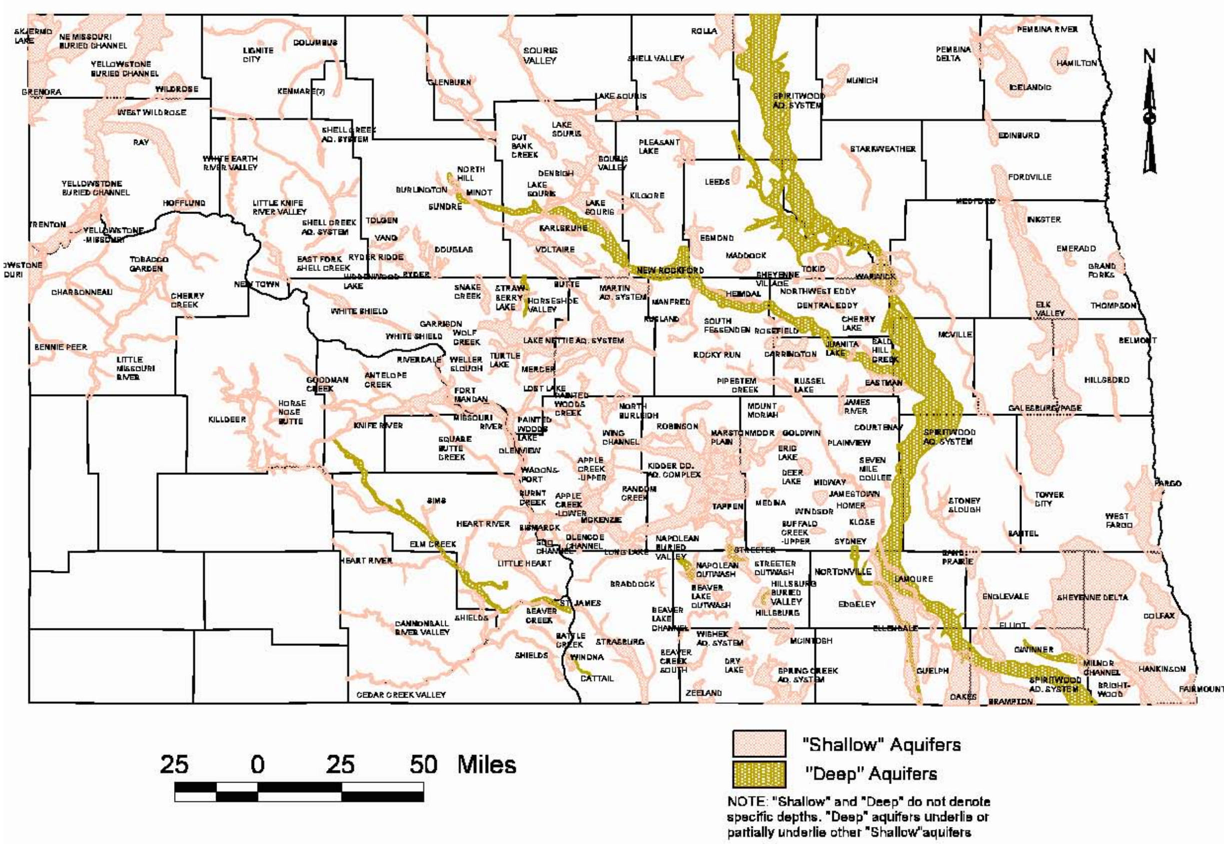
Certification

Once all the sheets in a county have been digitized they are sent to an NRCS office in Bozeman, Montana. Personnel in the Montana office edit the digital product with diagnostic software programs, make any necessary corrections, generate a county-wide soils map, and create related data tables. Once this task has been completed, the county is Soil Survey Geographic (SSURGO) certified and archived in a NRCS office in Fort Worth where it is available to the general public.

John Nowatzki, Water Quality Specialist, Extension Ag & Biosystems Department, NDSU, uses the digitized soils to develop computerized applications of assessment systems. To date, he has developed three systems: 1) potential groundwater contamination by pesticides, 2) potential surface water contamination by pesticides, and 3) potential groundwater contamination by nitrogen. John has made 26 presentations across the state to audiences totaling 950 people and has found widespread interest in this data. In 1999, he conducted nine workshops for farmers using this data. A number of individuals have expressed interest in digital soils data to John in relationship to irrigable crops, potential crop yields, potential septic drainage problems, and in one instance an agricultural lender asked yield potentials for specific crops in order to help a farmer develop a cash flow statement. Nineteen local companies and organizations have made use of the maps that Nowatski generated using digital soils data

APPENDIX 2

Figure C-1. Major Glacial Drift Aquifers in North Dakota



APPENDIX 3