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# MINNESOTA AGRICULTURAL GROWTH, 1880-1970

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# Minnesota Agricultural Growth, 1880-1970

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The growth of Minnesota's agricultural sector, 1880-1970, was quite considerable. It has not been studied in its entirety.[1/] More important than providing a history, this study provides the necessary background for examination of the agricultural research system of Minnesota. Here, the record will be detailed. The accounting for growth and productivity changes in the state's agricultural sector is reserved to a later chapter. This study examines, in turn, the record of: output and production; the factors of production; relative output and input prices changes; and the structural changes in the sector.

## 2.1 TRENDS IN AGRICULTURAL OUTPUT

Total agricultural output, used in this study to measure growth in Minnesota's agricultural sector, is defined as total agricultural production minus "agricultural intermediate products". Intermediate products are primarily crops used for seed or livestock feed, and milk used for feed. Total production is a simple aggregation of the values of cereals, other crops, livestock, and poultry and livestock and poultry products. It is valued in constant 1950 dollars. In deriving output, products sold from the farm and used elsewhere in the state for feed or seed purposes are, as

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Table 2-1: Value of Minnesota Agricultural Production, 1880-1970 (in millions of constant 1950 dollars)

| | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Small Grains[a/] | 92.2 | 130.3 | 210.9 | 233.1 | 219.2 | 231.8 | 239.8 | 223.0 | 201.0 | 283.7 |
| Wheat | 71.2 | 86.7 | 149.0 | 125.3 | 79.4 | 56.1 | 62.6 | 40.5 | 49.0 | 80.3 |
| Other[b/] | 22.6 | 28.9 | 43.0 | 103.1 | 181.9 | 213.8 | 302.0 | 417.8 | 533.7 | 742.9 |
| Corn | 22.6 | 28.9 | 43.0 | 88.0 | 169.3 | 188.4 | 245.1 | 316.1 | 392.0 | 537.2 |
| Potatoes | 7.4 | 15.1 | 19.3 | 36.0 | 45.8 | 41.5 | 26.5 | 20.3 | 29.0 | 33.5 |
| Hay[c/] | 29.5 | 52.4 | 73.5 | 80.2 | 100.5 | 91.4 | 116.9 | 106.6 | 130.2 | 140.7 |
| Veg & Fruit | -- | -- | -- | -- | 1.5 | 7.3 | 11.4 | 14.6 | 19.5 | 35.6 |
| Crops Total | 151.7 | 226.7 | 308.0 | 420.0 | 548.9 | 585.8 | 696.6 | 782.3 | 913.4 | 1236.4 |
| Livestock[d/] | 31.7 | 65.6 | 134.7 | 203.8 | 273.4 | 393.8 | 489.0 | 472.0 | 557.3 | 580.0 |
| Livestock Products[d/] | 1.0 | 13.7 | 26.4 | 14.6 | 178.4 | 188.5 | 213.9 | 210.5 | 276.1 | 267.8 |
| Poultry and Eggs[d/] | 3.1 | 6.8 | 13.1 | 15.9 | 31.7 | 47.9 | 71.5 | 127.5 | 187.0 | 164.0 |
| Other[d/] | 0.03 | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 0.7 | 3.5 | 2.5 |
| Non-crops Total[d/] | 35.8 | 86.2 | 174.3 | 234.4 | 483.7 | 630.6 | 775.0 | 810.7 | 1023.9 | 1014.3 |
| Total: Crops and Non-crops | 187.5 | 312.9 | 482.3 | 654.4 | 1032.6 | 1216.4 | 1471.6 | 1593.0 | 1937.3 | 2250.7 |

a/ Wheat, buckwheat, rye, oats, and barley

b/ Corn, Flax, and soybeans

c/ Adjusted using the per annual data for 1880 and 1920-30, i.e. 6 tons per horse and mule

d/ Identical to value of output (Table 2-2) because of the difficulty in estimating actual production levels.

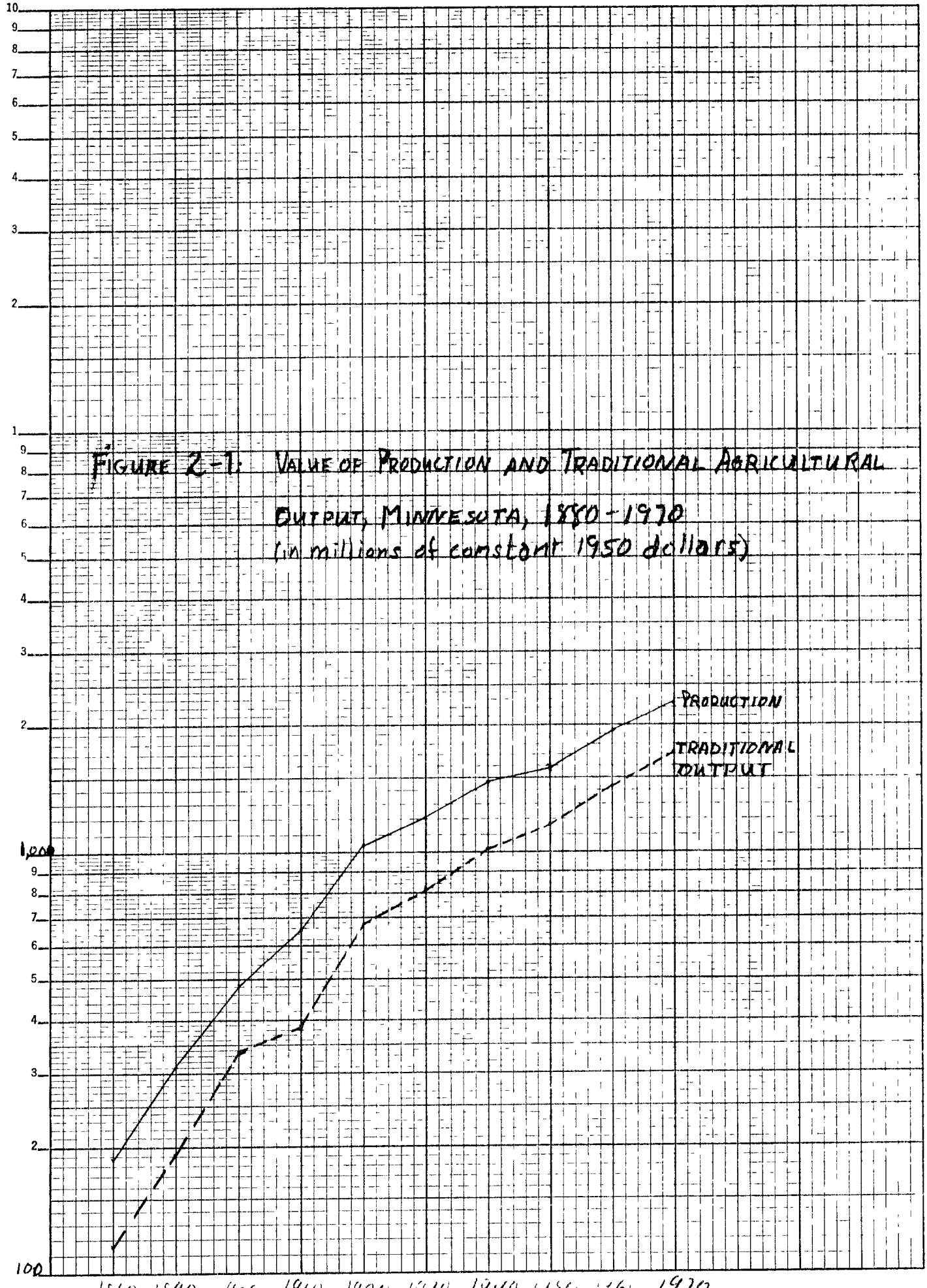



FIGURE 2-1: VALUE OF PRODUCTION AND TRADITIONAL AGRICULTURAL OUTPUT, MINNESOTA, 1850-1970
(in millions of constant 1950 dollars)

best as possible, excluded. Commercial and imported seeds and feeds are also excluded. Home consumption is included in output.[2/]

Total production and total output values are plotted in Figure 2-1, and the major components of production (Table 2-1) and output (Table 2-2) are listed. From these, certain lines of development stand out. The importance of hay is noteable. Potatoes also are of considerable importance. Shifts between cereal crops and other crops, and between crops and livestock-poultry and their products stand out.

Hay is particularly important as a source of fuel. Grown on-farm, the wild and tame (Aliske and Timothy) hays represent a valuable input. With mechanized equipment fueled by kerosene, tractor fuel, gasoline, or diesel oil, cash or credit purchase is necessary. This needed item, provided by the users represents an added saving relative to purchased fuels. As the numbers of draft animals on farms decreased, hay production also declined.[3/]

Until 1920, the value of potatoes, produced and sold or consumed on the farm, in constant dollars, increased. From the 1920's to the 1950's, values declined, rising since the mid 1950's. A major protein source, for humans especially, the decline in potatoe production coincides with a noticeable rise in the cultivation of "vegetables and fruits," primarily sugarbeets.

Traditionally, wheat is regarded as a major crop before the first World War, though of lesser importance after 1900. The production and output series confirm this view. Between 1900 and 1930, the value series for both production and output, show about a sixty percent drop. The post-1930 level is consistent in output value, but not in production, as more wheat is used for feed. The 1950 data illustrates the impact of the early 1950s rust infections upon the wheat crop, with about a thirty percent drop in production and output.

Table 2-2: Value of Minnesota Agricultural Output, 1880-1970 (in millions of constant 1950 dollars)

| | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Small Grains | 68.0 | 88.8 | 138.4 | 146.9 | 108.3 | 80.5 | 96.7 | 95.7 | 112.5 | 144.6 |
| Wheat | 60.5 | 73.1 | 126.6 | 104.8 | 62.4 | 41.4 | 49.3 | 33.3 | 49.4 | 48.6 |
| Other | 5.1 | 6.1 | 10.0 | 30.6 | 43.1 | 57.3 | 106.5 | 219.2 | 256.5 | 490.7 |
| Corn | 5.1 | 6.1 | 10.0 | 16.8 | 31.7 | 34.1 | 52.8 | 122.6 | 121.7 | 290.5 |
| Soybeans | -- | -- | -- | -- | -- | -- | 2.5 | 41.0 | 109.7 | 184.0 |
| Potatoes | 6.1 | 12.5 | 16.0 | 29.9 | 38.0 | 34.5 | 18.2 | 16.7 | 24.1 | 29.7 |
| Veg & Fruit | -- | -- | -- | -- | 1.3 | 7.6 | 11.7 | 14.8 | 19.6 | 35.2 |
| Crops - Total | 79.2 | 107.4 | 164.4 | 146.2 | 190.7 | 179.9 | 233.1 | 346.4 | 412.7 | 700.2 |
| Livestock | 31.7 | 65.6 | 134.7 | 203.8 | 273.4 | 393.8 | 489.0 | 472.0 | 557.3 | 580.0 |
| Milk | 0.3 | 12.7 | 25.0 | 12.8 | 176.8 | 185.2 | 209.5 | 208.2 | 273.0 | 265.2 |
| Wool | 0.7 | 1.0 | 1.4 | 1.8 | 1.6 | 3.3 | 4.4 | 2.3 | 3.1 | 2.6 |
| Poultry | 1.2 | 2.2 | 3.4 | 3.8 | 7.0 | 16.7 | 28.2 | 38.7 | 102.4 | 109.0 |
| Eggs | 1.9 | 4.6 | 9.7 | 12.1 | 24.7 | 31.2 | 43.3 | 88.8 | 84.6 | 55.0 |
| Other | 0.03 | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 0.7 | 3.5 | 2.5 |
| Non-crops Total | 35.8 | 86.2 | 174.3 | 234.4 | 483.7 | 630.6 | 775.0 | 810.7 | 1023.9 | 1014.3 |
| Traditional Output | 115.0 | 193.6 | 338.7 | 380.6 | 674.4 | 810.5 | 1008.1 | 1157.1 | 1436.6 | 1714.5 |
| Land | 98.8 | 78.1 | 147.1 | 24.2 | 37.1 | 126.1 | — | — | — | -- |
| Buildings | 3.2 | 1.8 | 2.6 | 0.1 | 1.6 | 0.5 | 0.8 | — | -- | -- |
| Overhead K E | 102.0 | 79.9 | 149.7 | 24.3 | 38.7 | 126.6 | 0.8 | -- | -- | -- |
| Total Output | 217.5 | 273.4 | 488.5 | 404.9 | 711.5 | 937.1 | 1008.9 | 1157.1 | 1436.6 | 1714.5 |

As wheat declined, other crops, especially corn, and soy beans after 1940, increased rapidly in value produced and sold. After 1900, livestock, poultry, and products have regularly exceeded crops in value of output. the increases are consistent, while the crop values have pluckcated downwards in come years. Minnesota was a wheat state to 1910, a dairy state after 1910, and a "meat" state from 1900, though diversified farming was common into the 1950s, and specialized farming is common in the 1960s.

One major line of agricultural productions and output, is the creation of "overhead capital". Land clearance, drainage, fencing, and the construction of houses, farms, and other buildings necessary for traditional agricultural production are in "output." Allied to this, and even harder to estimate, is the social overhead capital produced by farmers in lieu of taxes, e.g. road and bridge building. While "overhead capital" is an input it is also a product of farmers. For completeness, it should be counted.

In their excellent study of "Farm Gross Product and Gross Investment in the Nineteenth Century," Marvin W. Towne and Wayne D. Rasmussen[4/] developed the first method, using only free labor costs. They assumed the "average settler could clear and sow ten acres and erect a cabin" during one year on forest land. On prairie land, following Robinson, they assume that costs are one-third that of forest land. The labor time needed on forest land was 0.1 man-years, .032 man-years on prairies.

These reasonable figures are too low. Hiram M. Drache[5/] found that the average quarter-section settler in the Red River Valley could plow ten to twenty acres in the first year. They did not normally get a crop in the first year, and spent most of their time breaking and backsetting the land. A professional sod-breaker charged $2.50 per acre for breaking and $1.50 for backsetting, giving a market rate for such labor of $4.00 per acre.

Table 2-3: Decadal Increases in the Values of Land Clearing and Fencing, and Buildings

(in millions of constant 1950 dollars)

| | 1870-1880 [a] | 1880-1890 | 1890-1900 | 1900-1910 | 1910-1920 | 1920-1930 | 1930-1940 |
|---|---|---|---|---|---|---|---|
| Land Clearing and Fencing | 988.5 | 780.6 | 1471.1 | 24.2 | 37.1 | 126.1 | -- |
| Buildings | 32.0 | 17.1 | 26.4 | 1.0 | 16.2 | 4.7 | 8.5 |
| Total | 1020.5 | 797.7 | 1497.5 | 25.2 | 53.3 | 130.8 | 8.5 |

a/ Acreage more than doubled, and so did the numbers of new farms.

Fence on a quarter section ran another $8.00 per acre. These estimates indicate a total cost of $640 for a quarter section plowed and backset; and another $1,280 for fencing the land.

Assuming Drache's figures are accurate, and that forest land clearance was three times as expensive, the comparable costs are $1,920 for clearing, and $1,280 for fencing, a quarter section of forest land.

Building costs are less precise. Drache notes that lumber prices remained about constant over the 1870s, 1880s, and into the 1890s. Pricing the lumber cost of two invoices, in 1892-93 at $28.13, in 1969 terms at $363.10 indicates a net rise of 1190.8 percent in lumber costs. The average farm house cost was less than $400 in the 1880s. A log cabin cost $25 to $100 in the 1870s and 1880s, but was uncommon in the Red River valley. Some farm houses in Southern Minnesota cost about $300-$350 in the late nineteenth century.[6/]

Since $300 appears reasonable for housing costs, and about twenty-five percent is labor's share, the farm-supplied portion of housing construction is approximately $75 for South and Central Minnesota. In the Red River Valley and west-central regions, housing costs were higher, primarily for materials. The labor cost for a farm would, reasonably, be somewhat less because of the greater finishing and interior division work in house construction.

For south and central Minnesota, it appears likely that the average yearly cost of opening new land was about $12 per acre in the Valley and west central areas and about $36 per acre in the central and south. Assuming ten acres cleared and fenced per year, the yearly estimate is $120 and $360 respectively. Building costs would be about $100 - $150 per farm, and only 10 percent of the new farms are included, along with 10 percent of the improved acreage.

Overhead capital output becomes insignificant after 1930, as improved acreage declines. The numbers of farms increased, indicating that farms were being broken up as tenancy increased. The production of overhead capital forms as much as 23 percent of total output (in 1890), and fluctuates as entry into the state, and the opening of new farms change. This is, purposely, an underestimate.

In the early years of Minnesota agriculture, the production of overhead capital by farmers is the third largest component of farm output. It follows wheat and livestock sold or consumed on the farm. This non-traditional agricultural output represents a significant missing item in most historical accounts of output growth, and is missing from most studies of agricultural growth in other nations. Inclusion is justifiable because it represents the alternative to crop/livestock production, an opportunity cost to the farm sector. It is a necessary item for production of the traditional agricultural outputs.

Over the 1880-1970 period of study, several important shifts occurred in the composition of output. First, the decline in hay production and a rise in purchased fuels as farmers shifted from draft animals to machine power. Second, a shift from crop production to emphasis upon livestock and, following T. L. Haecker's encouragement of dairying and dairy co-operatives, dairy production. With this is a shift from wheat to corn, used for animal feed, and a movement of corn production northward based on and made possible by new hardier varieties produced by the Minnesota Agricultural Experiment Station. Third, the commercial production of fruits, notably apples. This was made possible first by the work of Gideon and the State Horticulture Society, and latter by the work of the horticulturalists at the MAES. Fourth, after 1935, the rise of soy bean production, primarily

for use as livestock feed. Fifth, the "factory-like" breeding of chickens and, especially, turkeys after 1950, again buttressed by MAES research work. Finally, accompanying increased farm size and market changes, was the change first to diversified farming in the 1890-190 period, and then a return to specialization in production in the mid-1950s and 1960s.

## 2.2 TRENDS IN INPUTS TO AGRICULTURE

The inputs, or factors of production , used in agriculture include the three traditional factors of land, labor, and capital. Intermediate agricultural products used for feed and seed. In addition, there are the non-traditional factors or purchased inputs, including fertilizers, various chemical pesticides and herbicides, fuels, and machinery. Here, the levels of usage, and trends in use will be examined. Many of these shifts in use or demand are responses to changes in technology and relative factor prices. Technological and price changes will be discussed later.

### Land

In the early decades, land expansion was a primary cause of increased agricultural production. Total land in farms expanded until 1950/54, then contracted rapidly. Acres per farm increased to 1910, dropped into the 1940s, then rapidly increased. Land in crops expanded until 1940, then began to decline. The percentage of total farm lands devoted to crop production increased between 1880 and 1900, dropped slightly in the 1900/10 decade, then rose again to 1960. In the 1960s, the share of land in crops dropped by eleven percentage points. The remaining land was used for pasturage, farmsteads and roads, woodlots and waste, fallow, and soil improvement.

Between 1880 and 1970, land in farmsteads, roads, and waste ranged from 6.5% to 9.2% of total farm land, reflecting opportunities perceived by farmers

for using the land more efficiently (farm layout, or crops or pasturage). (Data from the farm management reports tends to suggest this conclusion.[7]) Another source of adjustment to land in use is to shift between cropland pastured, fallowed, and in soil improvement lands (after 1933), and land planted to crops. Especially in the early years, when land clearance was necessary, land in crops, pasturage, and farmsteads formed a small portion of total land in farms. Land clearance was limited primarily by labor availability, though the perceived advantages or disadvantages of increasing land under cultivation, in terms of benefits relative to costs, was also important.

Table 2-4 Land in Farms, Minnesota, 1880-1970 [8]

| Year | Farms (thousands) | Total land in farms in millions of acres | "Improved" acreage in millions of acres | Acres per farm |
|---|---|---|---|---|
| 1880 | 92.4 | 13.4 | 7.2 | 145.1 |
| 1890 | 116.9 | 18.7 | 11.1 | 159.7 |
| 1900 | 154.7 | 26.2 | 11.8 | 169.7 |
| 1910 | 156.1 | 27.7 | 19.6 | 177.3 |
| 1920 | 178.5 | 30.2 | 21.5 | 169.3 |
| 1930 | 185.3 | 30.9 | 27.7 | 166.9 |
| 1940 | 197.4 | 32.6 | 21.9 | 168.2 |
| 1950 | 179.1 | 32.9 | 30.0 | 183.6 |
| 1960 | 145.7 | 30.8 | 22.1 | 211.4 |
| 1970 | 110.7 | 28.8 | 22.6 | 260.5 |

Several items are of interest in the farms and acreage data. First, during the 1920s and 1930s, 19,000 new farms were formed. Second, in these same years, two million new acres were added to farm lands, and 2.3 million "improved acres" were brought into use. Breaking the data down, crop acreage increased by about the amount pasturage decreased, one million acres. The new farms are not all truly new. Some are the result of breaking

Table 2-5: Labor in Agriculture and Indicators of Skill Levels, 1880-1970 [12/]

| Year | Total Labor (000) | Hired and Unpaid Family Labor (000) | % of Population Literate | Educational Level (yrs of schooling) |
|---|---|---|---|---|
| 1880 | 184.6 | 92.2 | | |
| 1890 | 233.7 | 116.9 | | |
| 1900 | 309.3 | 154.7 | 95.9 | |
| 1910 | 312.3 | 156.1 | 96.3 | |
| 1920 | 357.0 | 178.5 | 98.2 | |
| 1930 | 426.0 | 240.2 | 98.9 | |
| 1940 | 434.2 | 236.5 | | 8.0 |
| 1950 | 322.4 | 143.3 | | 8.2-8.4 |
| 1960 | 247.6 | 102.0 | | 8.5-9.0 |
| 1970 | 188.3 | 77.5 | | |

large farms into smaller units to give children land in years when funds to purchase new land were not widely available. (I.e. splitting a 160 acre farm into two 80 cares or other size farms.) Clearly, the acreage increases include new farm formation, in the north central region of the state, with large amounts of forest, swamp, and waste lands.[9/]

The decline in total acreage after 1950/54 is accompanied by a decline in the numbers of farms. One result is an increase in acreage farm size. Another result is the elimination of commercially marginal farm lands, especially in the Northern part of the state. Waste land, woodland, and land in farmsteads declined. Acreage land quality increased as these non-crop, non-pasturage, and marginal lands were idled. The addition of fertilizers and other land-quality improving chemicals, which were increasingly used as total land declined, led to a further improvement of land productivity reflected in output per acre. Unfortunately, part of the decline in land and farms was due to highway construction, which took a significant amount of high value land out of production. This resulted in a lowering of output per acres.

Labor

The expansion of the labor force in agriculture is another primary factor in output growth in the early years in Minnesota. The farm labor force includes farmers, managers, hired workers, and unpaid family workers. Because of the leading role of labor in agricultural production, reliable estimates of size and change in size are needed. The labor force data in the U.S. Census of Population, Occupations[10/] and Census of Agriculture[11/] are not consistent, year to year. Census reports are usually for the single week or the month preceding enumeration. Unpaid labor is usually under-estimated, and hired workers are often not correct for the year. Man-years of labor are needed,

and the census data does not permit accurate determination of this series.

An estimated labor force man-years series is constructed in place of the census series. Based on farm management serivce reports of labor units worked, it is adjusted to include not only the farmer's labor, but also hired and unpaid family labor. These per farm estimates are then multiplied by the numbers of farms in each year.[13/] Trends in both the series are similar, but magnitudes are quite different.

One notable item is the post-1940 decline in the farm labor force. The census series declines more slowly than the estimated series. The largest part of the decline is in hired and unpaid family workers, with hired labor declining somewhat more than unpaid family workers. This experience is the reverse of the growth period trends where unpaid family workers grew somewhat faster than hired workers, and together these segments of the labor force grew faster than farmers.

Another important trend affecting the labor force is improved skills. Education, the investment in human capital formation, is a indicator of the skills levels of the population, and by inference, the labor force. Rural education in Minnesota was comming, though rarely more than basic reading, writing, and arithmetic skills were acquired by a growing portion of the children in the early years. Literacy data indicates that until the 1910s, education became more widespread, and presumably the labor force became more skilled. In the 1920-1940 period, literacy changed very little, but increasing numbers of children attended secondary schools. Agricultural training in the University's Schools of Agriculture [14/] and later in the rural high schools spread to increasing numbers of students, many of whom returned to farming.

After 1940, educational levels, of the rural population in years of schooling, has risen. Even though the University's Schools of Agriculture were closed, starting in the late 1950s, the rural secondary schools, adult vocational-technical schools, and community and university technical colleges have continued to train large numbers of future farmers. Increased skill levels are increasingly necessary as farm mechanizations, chemicals usage, and the complexity of agricultural operation increase.

Capital

Agricultural capital is divided into three main categories. Land, including clearing, drainage, and fencing, and building, both for housing and for farm operation, e.g. farms and other out-buildings form the first major group. Machines and implements are the second major division of capital. The third group is draft and breeding animals.

Land and Buildings

Earlier, the labor cost of land clearing and fencing, and of building construction were estimated as a part of the value of output series. Not Not included was the purchase price of the land, the fencing materials and drainage tiles, or the lumber, nails, and purchased inputs for building construction. Even imputing values for these various items is a tenuous exercise. The safest approximation of the value of this capital item is the value per acre or, better, the price per acre for farm land, including buildings (Table 2-6)[15/] A constant series is obtained by using the 1950 value per acre index.

Table 2-6: Value of Land and Buildings, Minnesota Agriculture, 1880-1970 16/
(in millions of dollars)

| Year | Current Value | Deflator (1947-49 = 100) | Constant Value (1947-49 Dollars) |
|---|---|---|---|
| 1880 | 193.7 | 16.7 | 1,159.9 |
| 1890 | 340.1 | 21.4 | 1,589.3 |
| 1900 | 669.5 | 31.0 | 2,159.7 |
| 1910 | 1,262.4 | 48.2 | 2,619.1 |
| 1920 | 3,301.2 | 137.4 | 2,402.6 |
| 1930 | 2,125.1 | 85.8 | 2,476.8 |
| 1940 | 1,443.0 | 55.5 | 2,600.0 |
| 1950 | 2,809.4 | 109.0 | 2,577.4 |
| 1959 | 4,806.8 | 181.0 | 2,655.7 |
| 1969 | 6,049.0 | 266.3 | 2,271.5 |

This series indicates the rising values of this capital component until 1940, consistent with the land clearing and new farm formation trends in the sector. Part of the rise in value and price per acre after 1950 is due to the general inflationary trends after World War II. Another part is due to the improvement of buildings, fences, additional drainage, and other changes in the quality of the land and buildings component.

Machinery and Implements

The second major capital component is machinery and implements. Over the period, implements have not changed greatly in function . In the early decades, home-made implements were more common. Over time, factory-made tools, usually more durable and initially more expensive, replaced those made on the farm. The introduction and adoption of machinery is very important.

In the 1870s, two companies in Minneapolis began manufacturing agricultural machinery. Over the years, a number of companies in the state have, for a time, manufactured farm machinery. National companies increasingly dominated this line of manufacture. The first major innovation to achieve rather wide acceptance was the steam-powered thresher. The steam power unit was self-propelled, but not suited, because of size and weight, for plowing and other field use. Its prime functions were to move the threshing unit from field to field, farm to farm, and to power the thresher.

In Minnesota, few individual farmers, especially outside the Red River Valley, owned steam rigs and used them solely on their own farms. Usually, steam threshing rigs were owned by custom threshermen, by an individual farmer who also threshed on other farms for cash payment, only a group of farmers. These machines made threshing a less labor-consuming job, made the process faster, and, all to frequently, killed numbers of threshermen, farmers, and other workers in the fields.[17/]

Horsedrawn plows, harrows, and harvesters were improved in design and efficiency, and became larger, necessitating mroe horses to draw the machines. Not until the 1910s did the internal combustion engine, fueled by kerosene, tractor fuel, or later, gasoline, begin to be widely used on Minnesota farms. During the 1920s, the light-weight, all-purpose tractor was introduced, and power take-off mechanisms were developed. This allowed use of tractors for seed bed preparation and cultivation, and as a power source for harvesting equipment such as silo elevators. In 1920, there was one tractor for every thirteen farms. By 1969, the average farm had two tractors.

Another major development, resulting from the widespread adoption of the tractor, was in harvesting and threshing machinery. Harvesters were combined with threshing units, the "combine," and first introduced in Minnesota in 1927.[18/] Later, self-propelled combines, with multi-crop use attachments, were developed. There was a series of changes in harvesting equipment, as in plows, planters, and cultivators, which tended to make labor more productive. The WPA National Research Project estimated that the combine, pulled by a tractor, saved 2.5 to 3.5 man-hours per harvested acre relative to earlier harvesting machinery with stationary threshers.[19/]

Machine capital equipment is a substitute for labor. Tractor power is a substitute for animal power. Consuming purchased fuels, tractors and other self-propelled equipment have reduced the need for animals, and the need to devote land, labor-time, and building space for feed storage and animal shelter. Steam-powered stationary threshers, combine harvesters, and other equipment reduced the numbers of workers needed, and increased the speed of planting and harvesting. One man could tend more acres, producing more crops.

Other equipment introduced during the period under study includes milking machinery, elevators, and a wide variety of other stationary machines. Powered by either tractors, stationary steam or petroleum fueled, or electrical motors, these machines also saved labor and lessened the need for draft animals and animal feeds. Again, one man could milk more cows, feed more animals, or move more ensilage. The most important impacts of the introduction of machine capital are: 1) labor saving; and 2) reducing the need for draft animals, with attendant reduction in labor-time and field space, in feed production and animal shelter and feed storage space in buildings.

The U.S. Census of agriculture collected data on the value of implement and machinery stocks. The data was collected in current prices. It can be converted to a constant dollar value series by using the appropriate index (Table 2-7 ). Both series indicate steady growth in the 1880s and 1920s, rapid growth 1890-1920 and 1940-1969. The 1880s were a decade of rapid expansion in farms and acreage, and, as a consequence, of implements and

Table 2-7 Value of Implements and Machines, Minnesota, 1880-1969[20/]

| Year | Current dollar value (millions of dollars) | Deflator (1950 = 100) | Constant dollar value (millions of dollars) |
|---|---|---|---|
| 1880 | 13.1 | 52.7 | 24.9 |
| 1890 | 16.9 | 43.0 | 39.3 |
| 1900 | 30.1 | 33.9 | 88.8 |
| 1910 | 52.3 | 39.7 | 131.7 |
| 1920 | 181.1 | 51.3 | 353.0 |
| 1930 | 181.8 | 55.6 | 227.0 |
| 1940 | 193.4 | 55.6 | 347.8 |
| 1950 | 480.7 | 100.0 | 480.7 |
| 1959 | 966.5 | 116.2 | 831.8 |
| 1969 | 1346.9 | 183.8 | 732.8 |

machinery, but the machinery cost more, limiting its acquisition. Between 1880 and 1900, prices fell, and the numbers of machines increased rapidly.

As prices rose between 1900 and 1930, two distinct movements occur. First, 1900-1920, an era of new horse-drawn machine acquisitions, and acquisitions of milking machines, etc. Second, in the 1920s, the acquisition of tractors and tractor-drawn and tractor-powered implements. In the 1930s, limited increases in stocks occurred, primarily on larger farms, and in the later part of the decade. After 1940, higher cost machinery, bought on credit, became widely used. This machinery was, from farmer behavior, desireable because of its impact on farm operation. A side-effect of machine purchase was to often force increased farm size (in acres, or in livestock raised or milked), to efficiently utilize the machinery.

Draft and Breeding Animals

The third major capital component is draft animals and breeding stock. Horses, mules, asses, and oxen are the four types of draft animals. Data on oxen are available from the U.S. Census of Agriculture only for 1880 and 1890. Data on horses and mules are available from the Crop and Livestock Reporting Service [21/] for 1867-1959. The draft animals increased until 1920, though mules increased by fifty percent between 1920-1930. The decline was slow in the 1920s, then rapidly increased to the 1950s, then tapered off.

Table 2-8 Draft Animals in Minnesota, 1880-1959[22/]

| Year | Horses (000) | Mules (000) | Decadal Change (000) | Average Yearly Change (in millions of 1950 dollars)[a/] |
|---|---|---|---|---|
| 1880 | 270 | 9 | | |
| 1890 | 487 | 9 | 217 | $0.96 |
| 1900 | 678 | 8 | 190 | 0.87 |
| 1910 | 753 | 6 | 73 | 0.34 |
| 1920 | 933 | 10 | 184 | 0.85 |
| 1930 | 807 | 15 | -21 | -0.1 |
| 1940 | 651 | | -171 | -0.8 |
| 1950 | 267 | | -384 | -1.8 |
| 1959 | 61 | | -206 | -0.95 |

a/ Valued at the 1950 average price of $46.00 per head

Draft animals are a power source, and begin declining as the numbers of tractors began to increase. The total power, in horsepower equivalents, available on Minnesota farms has increased rapidly. The World War I and 1940-1959 decades show massive increases. The 1920s period of credit stringency and agricultural distress are a decaee of very sizeable growth in total tractor horsepower. Doubling again in the 1930s, tractor horsepower has about doubled in each successive decade 1940-1959. By 1959, almost all farms had one, and many had two tractors. The expansion after 1959 was from increased horsepower per tractor, and the acquisition of a second, sometimes a third, tractor on farms.

Breeding stocks are the source of livestock expansion. The stock of breeding sheep is reported yearly in the Crop and Livestock Reporting Service series.[23/] Breeding sheep fluctuate in about ten-year cycles until 1924, when a steady expansion lasting to a 1936-42 plateau, which was followed by a decline to 1950, and then again by approximately ten-year cycles.

Breeding cattle, and all cattle, increased rapidly in the 1880s, 1895-1910, and from 1928-1945, and in the 1950s and early 1960s. The early 1890s, mid-1920s, the 1934-36 drought years, and the late 1960s were years of notable decline. All hogs and farrowing sows show discernable long-run trends, inspite of wide year-to-year fluctuations. From 1880 to 1910, farrowing sows increased at a consistent 75,000 head per decade, then rose significantly on the 1910-1930 decades. Like cattle, hogs dropped quite drastically in numbers, in the "dust-bowl 1934-36 period, and over the entire 1930s decade. Increasing again in the 1940s, farrowing sows and all hogs dropped by about 45,000 head in the 1950s, and precipitorsly (257,000 head) in the 1960s.[24/]

Table 2-9: Investment in Breeding Animals in Minnesota, 1880-1970 [25/]

| | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Change During Year in: (000) | | | | | | | | | | |
| Breeding Sheep | 14 | 65 | 15 | -32 | 20 | 64 | 103 | 51 | 22 | -9 |
| Breeding Cows | 9 | 2 | 22 | -10 | -20 | 11 | 20 | 7 | 19 | -2 |
| Farrowing Sows | 10 | -12 | 34 | 58 | 68 | 118 | 46 | 13 | -113 | 97 |
| Value of Change During Year (in millions of 1950 dollars): | | | | | | | | | | |
| Breeding Sheep | 0.24 | 1.10 | 0.26 | -0.54 | 0.34 | 1.09 | 1.75 | 0.87 | 0.37 | -0.15 |
| Breeding Cows | 1.26 | 0.28 | 3.08 | -1.40 | -2.80 | 1.54 | 2.80 | 0.98 | 2.66 | -0.28 |
| Farrowing Sows | 0.32 | -0.40 | 1.10 | 1.88 | 2.20 | 3.82 | 1.49 | 0.42 | -3.66 | 3.14 |
| Total: | 1.82 | 0.98 | 4.44 | -0.06 | -0.26 | 6.45 | 6.04 | 2.27 | -0.63 | 2.71 |

Table 2-10: Decadal Changes in Breeding Animals in Minnesota, 1880-1970 [26/]

| | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Stock for Year (000) | | | | | | | | | | |
| Breeding Sheep | 285 | 350 | 386 | 480 | 429 | 800 | 1,030 | 571 | 749 | 432 |
| Breeding Cows | 258 | 461 | 606 | 692 | 778 | 1,479 | 1,670 | 1,513 | 1,621 | 1,578 |
| Farrowing Sows | 157 | 233 | 310 | 388 | 738 | 972 | 950 | 1,030 | 983 | 726 |
| Value, per year, of Decadal Changes in Stocks: (in millions of 1950 dollars) | | | | | | | | | | |
| Breeding Sheep | | 0.11 | 0.06 | 0.16 | -0.09 | 0.63 | 0.39 | - 0.78 | 0.31 | - 0.54 |
| Breeding Cows | | 2.84 | 2.03 | 1.30 | 1.20 | 9.77 | 2.67 | -2.20 | 1.51 | -0.62 |
| Farrowing Sows | | 0.25 | 0.25 | 0.25 | 1.14 | 0.76 | -0.07 | 0.26 | -0.15 | -0.83 |
| Total per year: | | 3.2 | 2.34 | 1.61 | 2.25 | 11.16 | 2.99 | -1.16 | 1.67 | -0.91 |

Net decadal investment in breeding animals declined somewhat, in constant 1950 dollars, between 1880 and 1910, then rose 1910-1930. Net investment was greatest in 1920-1930, primarily because breeding cattle almost doubled in the decade. After 1940, the breeding stocks of cows and sheed have decreased, except in the 1950s, when only farrowing sows declined in number. Generally, in seven of the nine decades, breeding stocks have increased in value.

summary

It is not surprising, when capital stocks are aggregated (Table 2-11), that the decades of largest growth are 1880-1910. The 1920s and 1930s, and the 1950s, were also decades of sizeable growth. 1950 resembles 1880-1910 in size. This suggests massive investment flows during the decade to modernize farm equipment, increase farm size for more efficient operation, and to increase the size of livestock on the farm. The 1960s are the only decade of negative capital growth. Even the troubled 1920s and drought-stricken, depressed 1930s look, in capital terms, much better. Declining investments, in constant dollar terms, would bode ill for the future, if productivity were not rapidly growing. This 1960s trend is not only due to the shrinking numbers of farms and farm acreage. It is also due to smaller livestock breeding herds, and to less machinery and implements stock acquisition.

Table 2-11: Agricultural Capital, Minnesota, 1880-1970
(millions of 1950 dollars)

| Stocks | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Land & Buildings | 1159.9 | 1589.3 | 2159.7 | 2619.1 | 2402.6 | 2476.8 | 2600.0 | 2577.4 | 2655.7 | 2271.5 |
| Implements & Machines | 24.9 | 39.3 | 88.8 | 131.7 | 353.0 | 327.0 | 347.8 | 480.7 | 831.8 | 732.8 |
| Breeding Stock | | | | | | | | | | |
| Sheep | 4.8 | 5.9 | 6.6 | 8.2 | 7.3 | 13.6 | 17.5 | 9.7 | 12.7 | 7.3 |
| Cattle | 31.1 | 64.5 | 84.8 | 96.9 | 108.9 | 207.1 | 233.8 | 211.8 | 226.9 | 220.9 |
| Sows | 5.1 | 7.5 | 10.0 | 12.6 | 23.9 | 31.5 | 30.8 | 33.4 | 31.9 | 23.5 |
| Total | 46.0 | 77.9 | 101.4 | 117.7 | 140.1 | 252.2 | 282.1 | 254.9 | 271.5 | 251.7 |
| Total Value | 1230.8 | 1706.5 | 2349.9 | 2868.5 | 2895.7 | 3056.0 | 3229.9 | 3313.0 | 3759.0 | 3256.0 |
| Change Between Decades: | | 475.7 | 643.4 | 518.6 | 27.2 | 160.3 | 173.9 | 83.1 | 446.0 | -50.3 |
| Per year average | | 47.57 | 64.34 | 51.86 | 2.72 | 16.03 | 17.39 | 8.31 | 44.6 | -5.03 |

Intermediate Inputs

Intermediate agricultural inputs include feeds and seeds produced on the farm. These include cereals and other crops, especially wild and tame hay and alfalfa, and milk, Much of the seed used is grown on farms and saved for the next planting. Except for hybrids, it appears that new seed was purchased every three to five years. Purchases were less frequent in the early years. The percentages of some crops retained for feed or seed use are given in Table 2-12. The proportions used for seed and for feed are not available for most years, and no estimates were attempted. Similarly, estimates of milk fed to cattle are difficult since production data is not available for some years. Milk sold runs from 34% of production in 1900 to 11 % in 1920-1930. The value of these intermediate inputs, while unknown, are clearly quite large.

Non-farm Purchased Inputs

Purchased non-farm inputs include fertilizers, various chemical herbicides and pesticides (agter 1950 especially), and machine fuels. Estimation of fuel consumption is difficult and was abandoned. The various chemicals used

Table 2-12: The Percentage of Feed and Seed Usage for Selected Crops, 1880-1970[27/]

| | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Buckwheat | 41.7 | 37.5 | 35.3 | 38.5 | 51.8 | 52.9 | 66.9 | 59.9 | 73.8 | na |
| Oats | 69.7 | 69.9 | 69.9 | 71.5 | 74.5 | 82.7 | 81.1 | 79.0 | 69.0 | 53.0 |
| Barley | 49.4 | 50.2 | 49.8 | 50.0 | 61.9 | 74.2 | 63.6 | 25.0 | 28.0 | 18.0 |
| All Wheat | 15.0 | 15.5 | 14.9 | 16.3 | 18.6 | 26.9 | 21.2 | 17.7 | 5.1 | 1.9 |
| Rye | 26.3 | 25.0 | 26.9 | 31.4 | 28.1 | 42.7 | 46.7 | 15.3 | 10.4 | 9.3 |
| Flaxseed | 11.6 | 7.9 | 7.8 | 8.7 | 9.0 | 8.7 | 4.7 | 4.7 | 3.9 | 4.3 |
| Soybeans | -- | -- | -- | -- | -- | -- | 18.0 | 5.3 | 5.0 | 2.5 |
| Corn | 77.6 | 79.0 | 76.8 | 80.9 | 81.3 | 81.9 | 78.5 | 61.3 | 69.0 | 46.0 |
| Potatoes | 17.1 | 17.4 | 17.3 | 17.2 | 17.2 | 16.9 | 31.3 | 17.9 | 17.1 | 11.4 |

on insects and weeds, etc. are quite numerous, and the usage data scarce. Again, no estimates were attempted. Commercial fertilizer usage data is available.[28/] Both the quantities, and the values in constant 1950 dollars are given in Table 2-13. Use remained roughly constant until World War II, when, in 1944/45, it rose sixfold, making the start of the energy-intensive, land-saving phase of Minnesota agriculture.

Table 2-13: Fertilizer Usage in Minnesota, 1925-1970 [29/]
(000 tons, millions of constant 1950 dollars)

| Year | Quantity | Value |
|---|---|---|
| 1925 | 9.0 | $ 0.35 |
| 1930 | 14.6 | 0.56 |
| 1935 | 9.8 | 0.38 |
| 1940 | 18.4 | 0.71 |
| 1945 | 101.2 | 3.90 |
| 1950 | 219.4 | 8.45 |
| 1955 | 386.4 | 14.88 |
| 1960 | 564.2 | 21.72 |
| 1965 | 946.6 | 36.44 |
| 1970 | 1555.7 | 59.89 |

summary

To 1940, labor inputs expanded greatly, along with land. The physical expansion of agriculture after 1880 was made easier by the availability of labor-saving machinery. In the 1910s, conversion from animal to mechanical power began, and was essentially complete by the early 1950s. In the mid-1940s, energy-intensive, land-saving fertilizers and chemicals were introduced. By the mid-1960s, usage of these inputs, purchased off the farm was common and considerable. Labor-saving machinery was, after 1945, used with land-saving bio-chemical technologies. Operational costs, and the value of farm capital needed to enter farming rose.

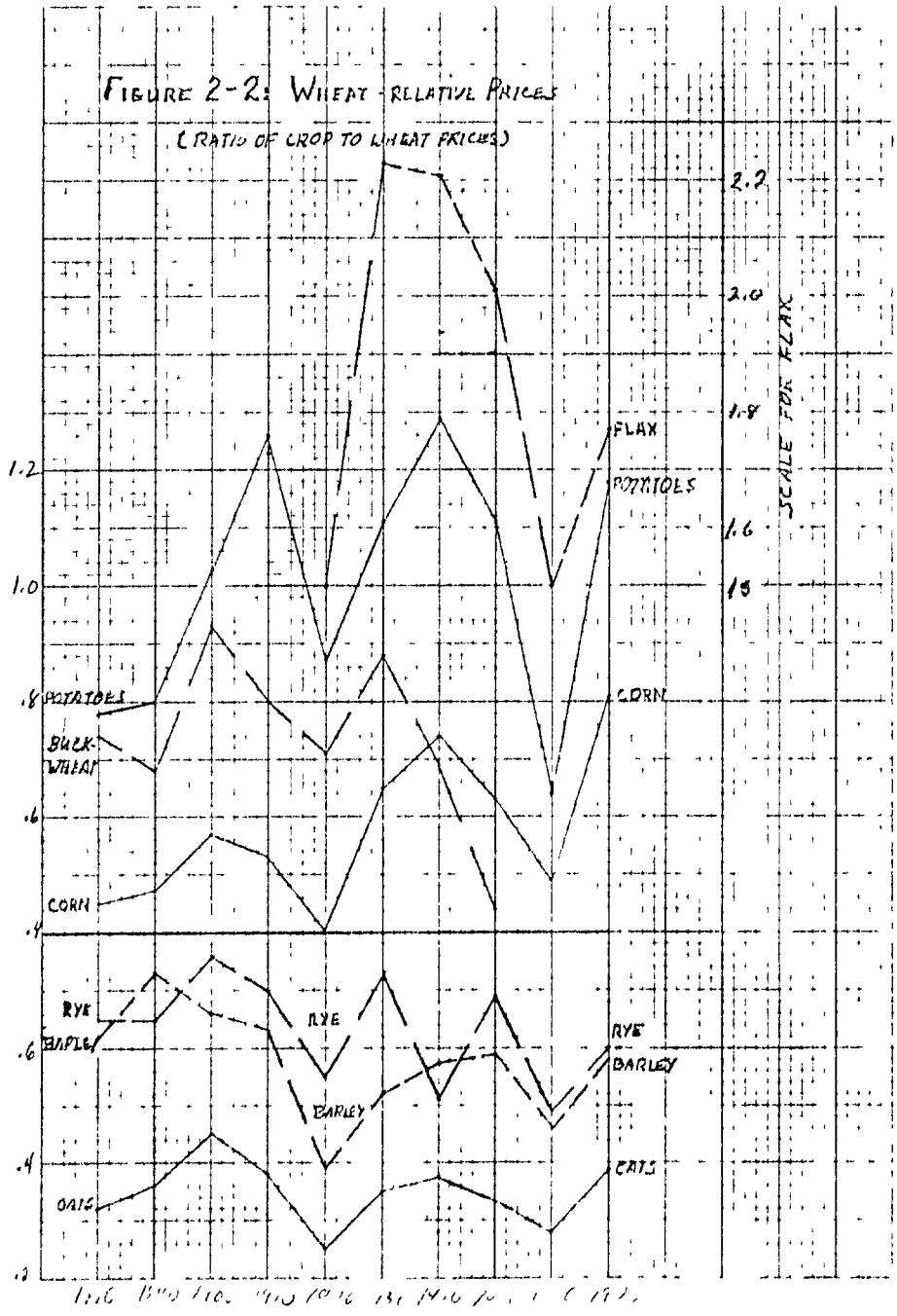


FIGURE 2-2: WHEAT - RELATIVE PRICES
(RATIO OF CROP TO WHEAT PRICES)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
SCALE FOR FLAX
FLAX
POTATOES
CORN
POTATOES
BUCK-WHEAT
CORN
RYE
BARLEY
RYE
BARLEY
RYE
BARLEY
OATS
OATS

## 2.3 RELATIVE PRICE TRENDS

Relative prices, for output commodities, and for inputs, are important. They measure the relative values of commodities produced, and the relative scarcity of inputs. The changes in relative prices of outputs induces farmers to change the composition of their production. Similarly, the usage of the various factors of production will change in response to changes in relative input prices.

### Relative Output Prices

Output prices are indexed to the corn and wheat prices for crops, and to the all cattle price per hundred weight. Using these wheat-relative (Figure 2-2) and corn-relative (Figure 2-3) indices, intercrop shifts can, to some extent, be explained. One limitation is that crops raised primarily for sale and crops raised primarily for feed are related through the livestock and products -- cereal crops decisions. Shifting from wheat to corn would be induced by either a decision to raise or fatten livestock for market, or a decision to produce livestock feeds for sale to cattle-raisers. Within the relevant crop groups, shifts can eb explained by price behavior. Other, non-price, factors will enter, e.g. the cereal rust problem and available rust-resistant varieties of wheat.[30/]

Between 1880 and 1900, Minnesota produced a large portion of the nation's wheat supplies, and wheat prices were largely determined on the Minneapolis Grain Exchange. Wheat prices fell over the two decades, while supplies rose, suggesting downward price adjustments to clear the market. Buckwheat was a marginal crop in the total cereals (i.e. human consumption crops) supply. Farmers increased production in the 1880s, prices fell relative to wheat (Figure 2-2), production was curtailed in the 1890s, and prices rose.

Demand for buckwheat forced prices up because supplies were low in the 'ninties. Rye, the third cereal crop, behaves differently. Production dropped in the 1880s, and prices did not change appreciably relative to wheat prices. In the 1890s, production began to increase, continuing to 1920. Between 1890 and 1900, the price of rye relative to wheat rose, as demand exceeded supply. After 1900, to 1920, demand fell relative to supply, pushing prices down.

While rye increased in supply between 1900 and 1920, wheat production decreased, falling to 1930. Prices for rye and buckwheat, relative to wheat prices, also fell, at a more rapid rate. The supply of buckwheat fell between 1900 and 1910, then rose to 1920. Some shifting between the cereals occurred, stimulated by the approximate doubling of buckwheat prices in 1910-1920, and of rye prices 1900-1920.

Wheat prices fell in the 1920s, then rose in the 1940s, not changing very much in the intervening decade. After 1940, wheat prices again dropped. During the 1920s, wheat production fell, but not fast enough to match the declining demand for Minnesota hard spring wheats. Wheat supplies increased in the 1930s, but dropped in the 1940s. In the 1950s, supplies again rose, and held constant over the 1960s. During the 1930s, demand for wheat increased, maintaing price levels somewhat. In the 1940s, as production fell, demand rose, forcing prices up. After 1950, the demand decreased relative to a constant supply forcing prices down because of national wheat market supply conditions.

Buckwheat prices rose in the 1920s relative to wheat prices, and then dropped in 1950 as did production. After 1950, because of the very low levels of production (less than 270,000 bushels), the U.S. Department of Agriculture and the U.S. Bureau of the Census stopped reporting data on buckwheat production. It is clear that demand for buckwheat fell off rapidly

after 1930, more rapidly than supplies declined, forcing prices down relative to wheat prices.

Prices of rye, relative to wheat prices, rose in the 1920s, 1940s, and in the 1960s, falling in the 1930s and '50s. Since the production of rye fell consistently from 1920 to 1960, demand rose in the 1920s and 1940s relative to supply. Demand again rose in the 1960s, and supplies also increased. During the 1960s, downward price pressures from increased supplies were offset by the growth in demand.

Partially due to the movement of flour milling out of Minnesota to Kansas City and Buffalo, the demand for Minnesota cereal grains has dropped. Increased transport costs, resulting from termination of milling-in-transit privileges by the Interstate Commerce Commission in the 1920s, was responsible for the decline of milling in the state. Another factor in the decline of cereals production was the increased livestock, dairy, and poultry production, combined with a notable shift to the production of feed grains.

Feed grains (corn, oats, etc.) production was stimulated by rising wheat relative to prices. Cattle prices per hundred weight (Table 2-14) relative to wheat rose between 1880 and 1900, fell 1900-1920, and then increased to 1970. Corn and oat prices fell relative to wheat prices in the 1900-1920 period, rose again in the 1920s and 1930s before falling in the 1940s and 1950s. These movements induced a shift into livestock and feed crops.

Examing feed grains behavior relative to corn prices (Figure 2-3) indicates some of the shifts between feed components. The corn-relative price of oats was almost constant between 1880 and 1900, while production more than doubled. From 1900 to 1940, the corn-relative price fell from .79 to .51. Supplies of oats continued to rise, because of the high feed value of oats and the lower price relative to corn. Marketing oats through

Table 2-14: Relative Output Prices, Minnesota Agriculture, 1880-1970

| | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| WHEAT-RELATIVE PRICES | | | | | | | | | | |
| Oats | .32 | .36 | .45 | .38 | .25 | .35 | .375 | .33 | .28 | .39 |
| Barley | .62 | .73 | .66 | .63 | .39 | .52 | .575 | .59 | .46 | .58 |
| Flax | -- | -- | -- | 1.73 | 1.50 | 2.23 | 2.21 | 2.01 | 1.50 | 1.77 |
| Corn | .45 | .47 | .57 | .53 | .40 | .65 | .74 | .63 | .49 | .81 |
| Rye | .65 | .65 | .76 | .70 | .55 | .73 | .51 | .69 | .49 | .60 |
| Buckwheat | .74 | .68 | .93 | .80 | .71 | .88 | .69 | .44 | -- | -- |
| Soybeans | | | | | | | 1.70 | 1.18 | 1.08 | 1.90 |
| Sugarbeets | | | | | | 8.37 | 6.40 | 5.53 | 5.56 | 9.91 |
| Potatoes | .78 | .80 | 1.03 | 1.26 | .87 | 1.11 | 1.29 | 1.11 | .64 | 1.18 |
| All Cattle | 4.1 | 4.4 | 7.0 | 4.5 | 4.4 | 10.0 | 9.0 | 10.8 | 11.3 | 16.3 |
| Swine | 5.2 | 7.7 | 10.3 | 9.0 | 7.4 | 11.6 | 6.5 | 8.4 | 7.0 | 14.7 |
| CORN-RELATIVE PRICES | | | | | | | | | | |
| Oats | .79 | .77 | .79 | .72 | .61 | .53 | .51 | .53 | .58 | .48 |
| Barley | 1.39 | 1.41 | 1.15 | 1.19 | .97 | .80 | .78 | .94 | .93 | .71 |
| Wheat | 2.24 | 2.14 | 1.76 | 1.89 | 2.50 | 1.53 | 1.36 | 1.58 | 2.03 | 1.23 |
| Flax | -- | -- | -- | 3.28 | 3.74 | 3.41 | 3.0 | 3.18 | 3.04 | 2.17 |
| Rye | 1.45 | 1.40 | 1.33 | 1.32 | 1.37 | 1.12 | .69 | 1.09 | .99 | .74 |
| Soybeans | | | | | | | 2.31 | 1.87 | 2.20 | 2.34 |
| Sugarbeets | | | | | | | 12.82 | 8.68 | 8.76 | 11.19 |
| Potatoes | 1.74 | 1.71 | 1.82 | 2.38 | 2.19 | 1.69 | 1.75 | 1.75 | 1.30 | 1.45 |
| All Cattle | 9.1 | 9.4 | 12.3 | 8.5 | 11.0 | 15.3 | 12.2 | 17.1 | 22.9 | 20.1 |
| Swine | 11.7 | 16.5 | 18.1 | 17.0 | 18.4 | 17.8 | 8.8 | 13.3 | 14.1 | 18.3 |
| CATTLE-RELATIVE PRICES | | | | | | | | | | |
| Swine | 1.29 | 1.74 | 1.47 | 2.0 | 1.68 | 1.16 | .72 | .78 | .62 | .91 |
| Sheep | .53 | .61 | .60 | 1.13 | 1.0 | .55 | .43 | .48 | .26 | .32 |

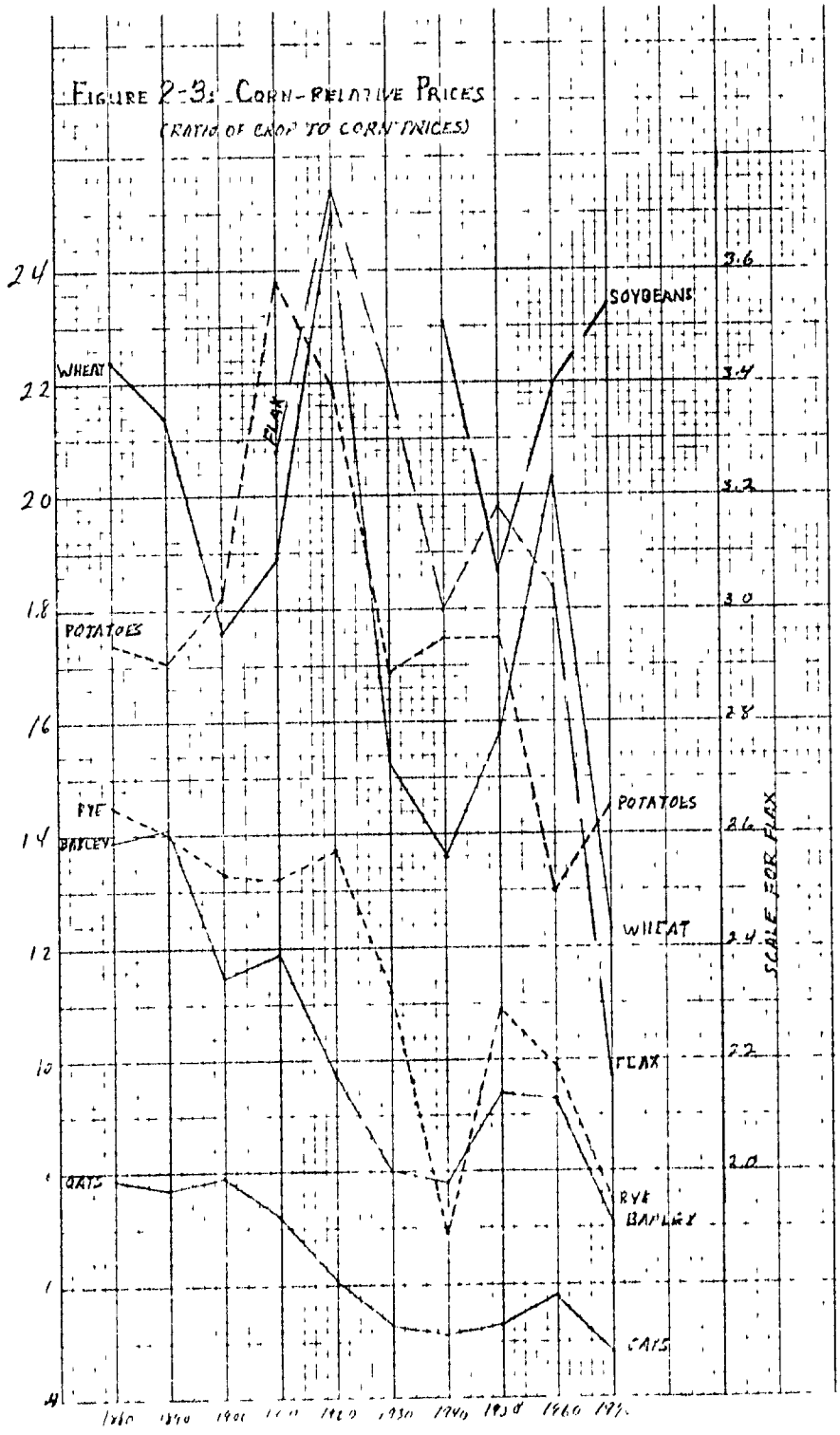


FIGURE 2-3: CORN-RELATIVE PRICES
(RATIO OF CROP TO CORN PRICES)
24
22
20
1.8
16
14
12
10
8
4
WHEAT
FLAX
POTATOES
RYE
BARLEY
OATS
SOYBEANS
POTATOES
WHEAT
FLAX
RYE
BARLEY
OATS
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
SCALE FOR FLAX

livestock increased the crop value more than the corn feed increased in value by being marketed as livestock. From 1940 to 1960, the corn-relative price of oats increased somewhat (.51 to .58), then dropped in the 1960s. Oat production peaked in 1950, and declined during the decade. In the 1960s, the supply of oats changed marginally. As oats declined in quantity produced, the volume of corn production rose. Marketing corn through livestock or polutry was a response to the rising corn-relative price of livestock and poultry.

Barley prices relative to corn prices rose in the 1880s and between 1900-1910, dropping in the 1890s and 1910-1940. Barley production doubled during each decade, 1880-1910, dropped by a third in the 1910-1920 decade, doubled in the 1920s, was constant in the 1930s, and then dropped by almost fifty percent in the 1940-1960 period. Excess supply pressed corn-relative prices down in the 1890s and 1920s. Slight excess demand in the 1880s and 1900-1910 pushed relative corn prices up slightly. In the 1940s, demand greatly exceed supply, and both per bushel and corn-relative prices for barley dropped somewhat as production by sixteen percent. Demand for barley decreased, but at a lower rate than supply decreased. In the 1960s, supplies of barley increased, to above 1950 levels, and the corn-relative price fell.

Over the entire period, production of feed grains has increased. Feed grain prices usually were less than cereal grain prices, on a per bushel basis. The transition from cereals to feed grain production was stimulated, in large measure, by the shift to livestock and poultry raising and dairying. Wheat-and corn-relative prices of cattle and swine (per hundred weight) suggest that the 1890s, 1920s, and the decades of the 1940s-1970s were periods of growing demand for cattle and dairy products. Except for the 1950s, demand for park and hog renderings also expanded. The cattle-relative

prices of swine suggest major expansions of demand for beef, relative to pork, in the 1880-1970 decades, and for pork relative to beef after 1930. Mutton, a less popular meat, enjoyed increased demand in the 1880-1910 period, and again in the 1950s and 1960s.

Relative Input Prices

Relative input prices are not readily available for machinery and fertilizer. The labor-relative price of land is available. Labor wages changed very little before 1900, and are assumed to include board. From wage data alone (Table 2-15), the decade of World War I was a decade of labor scarcity. After the 1930s hiatus in the economy, labor scarcity returned, as money wages jumped 340 percent. Again in the 1960s, labor scarcity forced per day wages up 147 percent.

Table 2-15: Daily Wages of Hired Labor, 1880-1970 31/

| | | | | | |
|---|---|---|---|---|---|
| 1880 | $1.00 | 1910 | $1.45 | 1950 | $5.60 |
| 1890 | 1.00 | 1920 | 2.65 | 1960 | 7.70 |
| 1900 | 1.00 | 1930 | 2.10 | 1970 | 11.30 |
| | | 1940 | 1.65 | | |

Relative land prices indicate that, while the opening of new farms continued into the 1945-54 period (in Northern and North Central Minnesota), after 1920, the price of land fell. Demand for land pushed prices up between 1880 and 1920, the years of rapid physical expansion of agriculture. As the supply of good land was exhusted in the 1920s and 1930s and as marginal lands became less available, prices dropped rapidly relative to labor, due

to declining effective demand. In the 1950s, with sub-urbanization and highway construction both impacting upon the supply of good agricultural land, relative prices rose. Demand again pushed prices, both nominal and relative, upwards. From 1920 to 1950, the relative price of land fell by over half (39.3 to 15.2), indicating that demand had fallen off relative to supply.

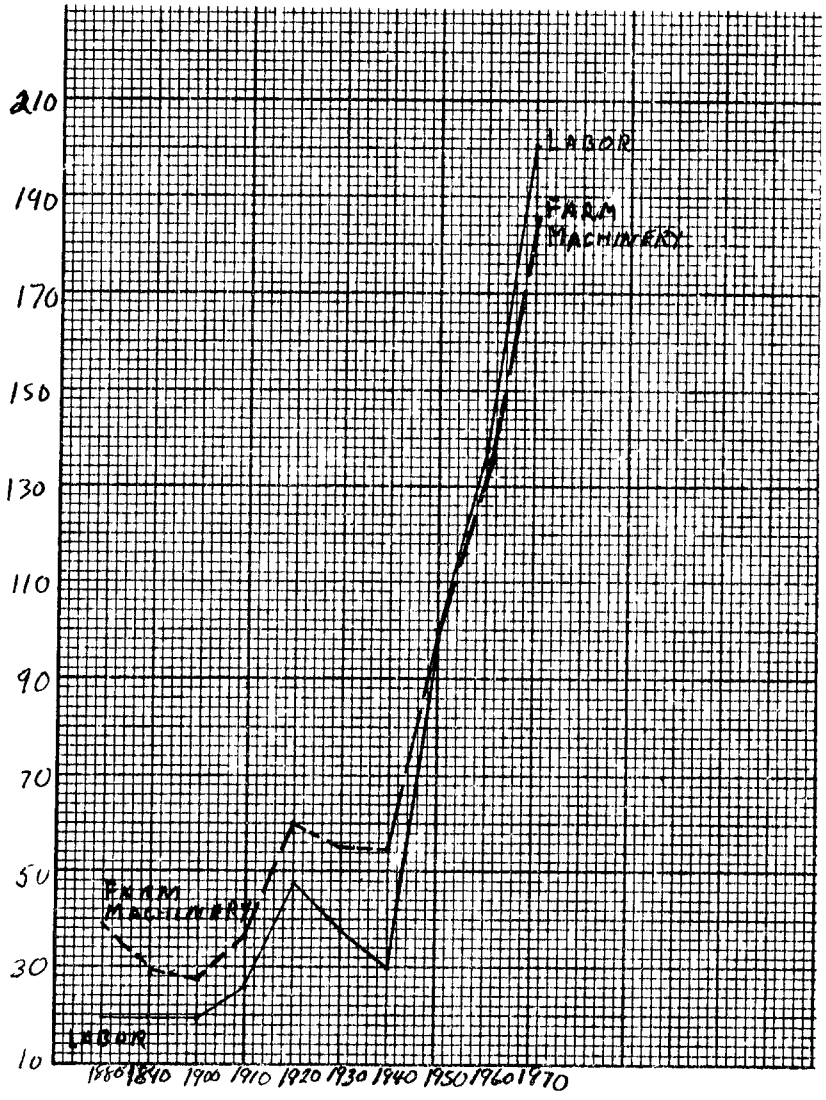
Table 2-16: Land Prices and Labor-Relative Land Prices, 1880-1960 32/

| | Land Price (dollars per Acre) | Relative Price of Land (Land Price/Labor Wage) |
|---|---|---|
| 1880 | $14.00 | 14.0 |
| 1890 | 18.00 | 18.0 |
| 1900 | 26.00 | 26.0 |
| 1910 | 41.00 | 28.3 |
| 1920 | 104.00 | 39.3 |
| 1930 | 60.00 | 28.6 |
| 1940 | 43.00 | 26.1 |
| 1950 | 85.00 | 15.2 |
| 1960 | 157.00 | 20.4 |
| 1970 | 223.00 | 19.7 |

While price data for farm mechinery and for fertilizers are unavailable in sufficient quantity over the period, national price indices are available.33/ Plotting the index of labor's daily wage in Minnesota (derived from Table 2-4), it is clear that machinery prices fell relative to labor prices between 1880 and 1900. Also, between 1900 and 1920 when both sets of prices rose, the price of labor rose faster than machine prices. Again, machines were relatively less expensive. Between 1880 and 1920, farmers would be induced to replace men with machinery since machines were relatively less expensive.

Between 1920 and 1940, labor's wage falls more rapidly than machine prices, making labor relatively less expensive. Mechanization would be

Figure 2-4: Price Indices for Labor and Farm Machinery
(1950 = 100)



slower because of this price relationship. Other factors would help explain the rapid mechanization of farm power (e.g. livestock feed-machine fuel cost relationships). After 1940, labor prices rose faster than machine prices, and labor becomes scarce. Machines are in high demand, to replace labor, accounting for the rise in prices.

National fertilizer prices, indexed on 1950=100, are available since 1910. They are compared with an index of Minnesota land prices (derived from Table 2-5). The use of commercial fertilizers was not widespread in 1910. From data presented by Yuiro Hayami and Vernon Ruttan,[34/] it appears that the land-relative price of fertilizer fell between 1880 and 1930, rose in the 1930s, and fell after 1940. Between 1910 and 1920, as land prices rose, so did fertilizer prices, but relative to land, fertilizer became less expensive. Fertilizer useage should increase in the decade.[35/] Between 1920 and 1940, prices for land fell faster than fertilizer prices (using the index of prices), making fertilizers relatively mroe expensive and less desireable. After 1940, land-relative fertilizer prices fall and useage (Table 2-13) increases significantly. Supplies of fertilizers clearly outran demand, pushing actual prices in the 1960s and relative prices (after 1940) down. The 1920-1930 discrepancy between the two data sources is resolved by assuming the index is more correct.

Between 1880 and 1920, under demand pressures, land became more expensive; and, in spite of increased demand, machinery less costly, relative to labor. More labor-intensive crops, such as corn, became more common, and livestock and dairy farming, also labor intensive, was increasing. As land became more costly, fertilizers became less expensive, relative to land. Some increases in fertilizer use occurred, but the level of demand remained low. Machines replaced labor, allowing more production and output-

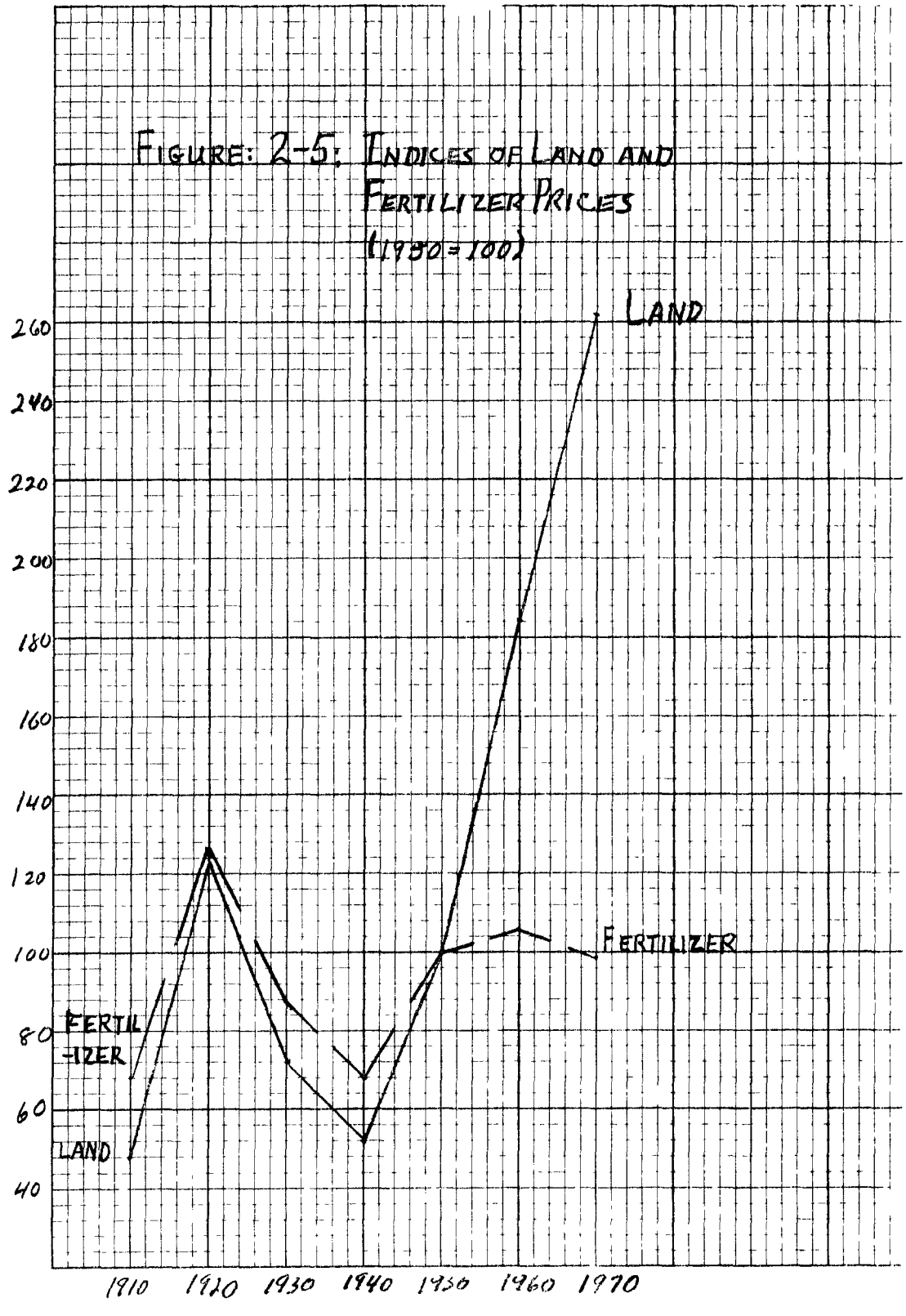


FIGURE: 2-5: INDICES OF LAND AND FERTILIZER PRICES (1950=100)
LAND
FERTILIZER
FERTIL-IZER
LAND
260
240
220
200
180
160
140
120
100
80
60
40
1910
1920
1930
1940
1950
1960
1970

From 1920 to 1950, as demand pressures eased, land became less expensive, relative to labor. Between 1920 and 1940, machinery became somewhat more expensive per unit, but also more efficient. On a per horsepower basis, machine prices actually dropped relative to labor costs, and relative to the cost of animal horsepower. Fertilizers became more expensive in the 1920s and 1930s, and the land-saving chemical technology (i.e. fertilizer usage) was even less attractive. In the 1940s, fertilizer prices relative to land prices dropped substantially, and usage increased notably. Labor-saving continued during these thirty years, though at a lower rate in the 1920s and 1930s. Land-saving technology was not favored, economically, until the 1940s.

During the 1950s and 1960s, per unit machinery prices fell relative to labor; and fertilizer prices relative to land also fell. Demand for both machinery and fertilizers rose, as did the supplies. In the 1950s, land prices rose relative to labor, favoring the adoption of land-saving fertilizers, chemicals, and land conservation practices. In the 1960s, land prices relative to labor dropped slightly, but not so much that extensive land use was favored over land-conserving practices. Labor remained expensive, encouraging the continuation of labor-saving practices, such as using machines in place of workers.

## 2.4 STRUCTURAL CHANGE IN AGRICULTURE

Structural change in Minnesota agriculture is the shifting of the output mix. The change in composition of output results from the interaction of several things. First, the relative output prices, as they change, induce shifts in output. Second, each type of output uses different proportions of the factors of production, and the relative scarcity, reflected in relative prices of the factors will effect the output mix. Changes in the available production technology, which effects factor scarcity, and which makes production of some crops less costly in money, or in time, also effects the production mix.

One notable output shift occurs between 1880 and 1920. Output of small grains, especially wheat, declines rapidly. Especially between 1910 and 1920, wheat output drops considerably (from 23 percent to 9 percent of total output). Livestock production for sale and home use increases to 1910, then drops somewhat. Milk production (dairying) increased rapidly in the 1880s, dropped between 1900 and 1910, and then jumped in the 1910-1920 decade. Another output shift in this era is from the creation of overhead capital to traditional agricultural output (Table 2-2). This represents a building up of the necessary capacity and capabilities for agricultural production, and the freeing of labor time for use in crop and livestock pursuits. During the decades 1880-1920, the commercial agricultural sector shifted from specialization in wheat to a diversified, livestock and dairy products based farming system.

The decade of World War I (1910-1920) is especially notable for the decline of wheat and the great rise in milk output. Production data (Table 2-18) confirms this shift away from wheat to livestock. During this decade

Table 2-17: Commodity Shares of Minnesota Agricultural Output, 1880-1970 [36/]

(as a percentage of output in constant 1950 dollars)

| Commodity | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Small Grains[a/] | 59.11% | 46.6% | 40.9% | 33.2% | 16.1% | 9.9% | 9.6% | 8.3% | 7.8% | 8.4% |
| Spring Wheat | 52.58 | 38.36 | 37.36 | 23.71 | 9.25 | 3.95 | 4.16 | 2.56 | 3.17 | 2.53 |
| Durum Wheat | | | | | | 0.54 | 0.20 | 0.13 | 0.17 | 0.23 |
| Winter Wheat | | | | | | 0.62 | 0.52 | 0.20 | 0.10 | 0.08 |
| Other Crops[b/] | 4.41 | 3.2 | 2.9 | 6.9 | 6.4 | 7.1 | 10.56 | 18.90 | 17.90 | 28.60 |
| Corn | 4.41 | 3.2 | 2.9 | 3.81 | 4.7 | 4.21 | 5.24 | 10.59 | 8.47 | 16.94 |
| Soybeans | | | | | | | 0.25 | 3.55 | 7.63 | 10.73 |
| Potatoes | 5.3 | 6.6 | 4.7 | 6.8 | 5.6 | 4.3 | 1.8 | 1.4 | 1.7 | 1.7 |
| Vegetables & Fruits | | | | | 0.19 | 0.9 | 1.2 | 1.3 | 1.4 | 2.1 |
| Livestock | 27.6 | 34.4 | 39.8 | 46.1 | 40.5 | 48.6 | 48.5 | 40.8 | 38.8 | 33.8 |
| Poultry[d/] | 1.0 | 1.2 | 1.0 | 0.9 | 1.0 | 2.1 | 2.8 | 3.3 | 7.1 | 6.4 |
| Milk | 0.28 | 6.65 | 7.38 | 2.90 | 26.2 | 22.85 | 20.78 | 17.99 | 19.00 | 15.47 |
| Eggs | 1.61 | 2.4 | 2.87 | 2.74 | 3.67 | 3.85 | 4.29 | 7.67 | 5.89 | 3.21 |
| Other[e/] | 0.66 | 0.63 | 0.46 | 0.41 | 0.26 | 0.46 | 0.49 | 0.26 | 0.49 | 0.30 |

a/ Wheat, oats, barley, rye, and buckwheat

b/ Corn, soybeans, and flax

c/ Field peas, sugarbeets, sweet corn, onions, cabbages, and apples

d/ Chickens and turkeys on farms

d/ Wool, honey, and beeswax.

one important shift begins. Hay, an on-farm produced fuel, drops from 12.3 percent to 9.7 percent of production. The decline in hay production is matched by an increase in cash purchases by farmers for fuel. This decline is especially related to the relative operational costs of machinery and horses, and technological change. Before World War I, horses were the prime power source and hay the main fuel. After the War, tractors replaced horses slowly through the 1920s and early 1930s, then with increasing speed into the late 1940s. Hay was replaced by tractor fuel, kerosene, gasoline, and fuel oil.

From 1920 to 1960, the diversified, livestock and products and feed emphasis continued. Small grains declined by two thirds. Livestock output share increased in the 1920s and 1930s, then dropped back to almost the 1920 share. After a decline in the 1920s, milk output as a share of total output stayed about constant. Soybean production increased from less than one percent of output in 1940 to over seven percent in 1960, and sugarbeet production similarly expanded. From the mid-1920s to the 1960s, livestock, poultry, and products made up over half of total production, and over seventy percent of corn, oats, hay, the main feeds, are included.

In the 1950s the last major trend began, taking full shape in the 1960s. This trend is towards specialization rather than diversified farming. Though not shown in commodity shares, it is a return to the specialization characteristic of the 1880s wheat farms. In the 1960s, crop production was again over fifty percent of total production, though about half of crop production was intended for livestock and poultry as feed. One example of this trend is for feed to be grown for sale to livestock raisers (e.g. corn and oats in Table 2-17). Another example, signified by the decline in poultry, is for chickens and turkeys to be raised in factory-like facilities, with a rather controlled environment.

Table 2-18: Commodity Shares of Minnesota Agricultural Production, 1880-1970[37/]

(as a percentage of production, in constant 1950 dollars)

| Commodity | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 |
|---|---|---|---|---|---|---|---|---|---|---|
| Small Grains | 49.2% | 41.6% | 43.7% | 35.6% | 21.2% | 19.1% | 16.9% | 14.0% | 10.4% | 12.6% |
| All Wheat | 38.0 | 27.7 | 30.9 | 19.1 | 7.7 | 4.6 | 4.4 | 2.3 | 2.5 | 3.6 |
| Other | 12.1 | 9.2 | 8.9 | 15.8 | 17.6 | 17.6 | 20.5 | 26.2 | 27.5 | 33.0 |
| Corn | 12.1 | 9.2 | 8.9 | 13.4 | 16.4 | 15.5 | 16.7 | 19.8 | 20.2 | 23.9 |
| Potatoes | 3.9 | 4.8 | 4.0 | 5.5 | 4.4 | 3.4 | 1.8 | 1.3 | 1.5 | 1.5 |
| Hay | 15.7 | 16.7 | 15.2 | 12.3 | 9.7 | 7.5 | 7.9 | 6.7 | 6.7 | 6.3 |
| Vegetables and Fruits | 0 | 0 | 0 | 0 | 0.1 | 0.6 | 0.8 | 0.9 | 1.0 | 1.6 |
| Livestock[a/] | 16.9 | 21.0 | 27.9 | 31.1 | 26.5 | 32.7 | 33.2 | 29.6 | 28.8 | 25.8 |
| Livestock Products[a/] | 0.5 | 4.4 | 5.5 | 2.2 | 17.3 | 15.5 | 14.5 | 13.2 | 14.3 | 11.9 |
| Poultry & Eggs[a/] | 1.7 | 2.2 | 2.7 | 2.4 | 3.1 | 3.9 | 4.9 | 8.0 | 9.7 | 7.3 |
| Other[a/] | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 | 0.18 | 0.1 |
| Crops - Total | 80.9 | 72.5 | 63.9 | 64.2 | 53.2 | 48.2 | 47.3 | 49.1 | 47.1 | 54.9 |
| Non-Crops - Total | 19.1 | 27.5 | 36.1 | 35.8 | 46.8 | 51.8 | 52.7 | 50.9 | 52.9 | 45.1 |

a/ These are the same as the entries in Table 2-1, Livestock Products are milk and wool, Other is honey and beeswax.

b/ The basic data is in Table 2-1. Note that all non-crop entries on Table 2-1 are from Table 2-2 output figures.

The shift in production from cereals for human consumption to livestock and poultry, their products, and feed can be traced to: output price (and, indirectly, demand) shifts; factor of production utilization, scarcity, and price, and technology. The relative prices of cereals fell as demand slackened; relative prices of livestock and feed crops rose, encouraging farmers to shift their output mix. Cereal crops demand less constant attention but must be planted and harvested in rather short periods of time, using large amounts of labor, which is scarce and relatively expensive. The technology available for harvesting cereals improved rapidly, but so did feed crop technology.[38/]

The shift from the production of overhead capital output (land clearing, fencing, buildings, etc.) to full crop and for livestock farming occurred between 1880 and 1920. Before a farm can be fully operational, the land must be cleared, sod broken, fenced, and, if necessary, drained. Buildings, to shelter the farmer, his family, and his hired labor, the animals, and the implements, and to store feed and crops in storage, had to be constructed. By 1920, most of the basic overhead capital was in place, and almost full labor time could be devoted to crop and livestock production.

During the 1910-1920 decade, wheat demand slackened. The 1914-1918 war years brought a temporary resurgence of demand and a lesser supply response. The recovery was short-lived, and after 1918, the decline in supply resumed, accelerating as the Minneapolis flour mills began to decline in the 1920s.[39/] Milk production rose, and output also expanded. Improved refrigerated transport and better creamery technology led to increased urban demand for milk for human consumption. The potential supply area also expanded, as technology improved.

In the war decade, hay for draft animal feed began to decline. Draft animals increased during the decade, then declined after 1920. As the need for hay dropped, production declined. This farm-produced fuel formed a significant part of total agricultural production. It was rapidly replaced, as tractors, trucks, and automobiles increased in numbers after 1920, by purchased off-farm fuels.[40/] The adoption of trucks and automobiles meant that farmers could move their produce further and faster; and they could break out of the local area for shopping and other journeys. The use of tractors in field work, and electric and stationary gasoline motors in buildings rapidly increased, and farmer productivity increased. As an example, by 1936, a savings of fifty percent in pre-harvest corn cultivation was achieved by using the two-row tractor cultivator rather than a horse-drawn two-row cultivator.[41/]

Between 1920 and 1960, the most notable changes occurred in production technology. Between 1920 and 1960, tractor horsepower multiplied (Table 2-19)

Table 2-19: Animal and Machine Horsepower, 1880-1970 [42/]

| Year | Animal Horsepower[a/] (000) | Tractor Horsepower (000) | Total Horsepower (000) |
|---|---|---|---|
| 1880 | 284.0 | -- | 284.0 |
| 1890 | 497.0 | -- | 447.0 |
| 1900 | 676.6 | -- | 676.6 |
| 1910 | 773.2 | -- | 773.2 |
| 1920 | 955.2 | 398.7 | 1,354.2 |
| 1930 | 815.2 | 1,187.6 | 2,003.2 |
| 1940 | 653.0 | 2,816.0 | 3,469.0 |
| 1950 | 268.0 | 5,533.8 | 5,801.8 |
| 1960 | -- | 9,201.3 | 9,201.3 |
| 1970 | -- | 10,929.8 | 10,929.8 |

a/ Horses and mules, centered five-year averages

Accompanying the expansion of tractors and tractor horsepower was a set of changes in tractors, and in implements. The power take-off, hydraulic lifts, and other refinements made tractors more widely useful on the farm. While horsedrawn implements could be adapted for use with tractors, most were redesigned and improved to make full use of the new power source. Self-propelled combined harvester-thresher units (combines) were developed in the 1950s.

These changes in technology effected farm labor demand. They also had significant impact on the crop production processes. Milking machines, better building design, automated feeding machinery, and other changes improved livestock and poultry raising and dairy operations. In the late 1940s and the 1950s, biochemical technology changed drastically as improved fertilizers, together with other chemicals to control weeds, insects, and bacteria became widely available at decreasing cost. Crop breeding to resist disease and to improve yields; with animal breeding for better yield and faster weight gain, etc; and improved medical care for livestock and poultry all showed impressive results in the late 1950s and the 1960s.

As technology changed, reducing the labor costs of production and, to some degree, the risks to crops, livestock, and poultry from diseases, yields increased. Labor productivity rose (Table 2-20), over the entire period, reflecting attempts by farmers to reduce use of the most expensive factor of production. Land was expensive, and within the limits of available technology, farmers tried to make land more productive. When faced with the choice of making land or labor more productive, they rationally chose to conserve the more expensive, more scarce factor, labor. Labor-saving is especially evident, illustrating the impact of machine technology, in the rise in acres per farm worker. Land-saving technology, fertilizers and

Table 2-20: The Partial Productivities in Minnesota Agriculture, 1880-1970 [43/]

| Year | Output per Worker (in constant 1950 dollars) | Output per Acre (in constant 1950 dollars) | Acres per Worker (improved acres per laborer) |
|---|---|---|---|
| 1880 | $623.0 | $16.0 | 39.0 |
| 1890 | 828.4 | 17.4 | 47.5 |
| 1900 | 1,095.1 | 28.7 | 38.2 |
| 1910 | 1,218.7 | 19.4 | 62.8 |
| 1920 | 1,889.1 | 31.4 | 60.2 |
| 1930 | 1,902.6 | 29.3 | 65.0 |
| 1940 | 2,321.7 | 46.0 | 50.4 |
| 1950 | 3,589.0 | 38.6 | 93.0 |
| 1960 | 5,802.1 | 65.0 | 89.3 |
| 1970 | 9,105.2 | 75.9 | 120.0 |

chemicals, is evident after 1950, when public and private researchers began providing new technology, and the private sector made these new technologies commercially available at prices which favored their adoption by farmers.

Footnotes

1/ Only a few good studies, notably those by Robinson, Jarchow, and, for the Red River Valley, Drache are available. Edward Van Dyke Robinson, Early Economic Conditions and the Development of Agriculture in Minnesota (to 1910). (Minneapolis: University of Minnesota, 1915). Merril E. Jarchow, The Earth Brought Forth: A History of Minnesota Agriculture to 1885. (St. Paul: Minnesota Historical Society, 1949). Hiram M. Drache, The Day of the Bonanza Farming on the Red River Valley of the North. (Fargo, North Dakota Institute for Regional Studies, 1964); and The Challenge of the Prairie: Life and Times of Red River Pioneers. (Fargo: North Dakota Institute for Regional Studies, 1970).

2/ Each physical quantity was multiplied by the 1948-52 average price for the quantity, and the totals, for production and output, are therefor in 1950 dollars. Milk, eggs, wool, honey, and bees wax are weighted by the 1950 prices rather than the 1948-52 average prices.

3/ Hay production does not drop as swiftly as animals on farms, and the hay produced per animal (horses and mules) data used to calculate total production indicates that there is serious under-counting in 1890-1910. The hay per animal data is:

| | | | |
|---|---|---|---|
| 1880 | 6.12 tons | 1920 | 6.08 tons |
| 1890 | 5.70 | 1930 | 6.36 |
| 1900 | 3.70 | 1940 | 10.20 |
| 1910 | 2.70 | 1950 | 22.60 |

4/ In William N. Parker, ed. Trends in the American Economy in the Nineteenth Century. (Princeton: Princeton University Press for the National Bureau of Economic Research, 1960), pp. 255-312.

5/ The Challenge of the Prairie; Life and Times of Red River Poineers (Fargo: North Dakota Institute for Regional Studies, 1970), pp. 61,69.

6/ Drache, Challenge of the Prairies, pp. 35-44; the frame house was usually 1½ stories, four rooms, and 24 x 24 feet. In the Valley, houses were smaller, 16 x 16, and the price higher. In 1892, a two story, 32 x 42 frame house cost $1600, of which $800 was for lumber, and $800 for the furnace, fixtures, and labor, p. 40. Wages in 1872 were $1.25 per day for skilled carpenters.

7/ University of Minnesota, Department of Agricultural (and Applied) Economics Annual Report of the Southwestern Farm Management Association ... etc.

8/ U.S. Bureau of the Census, Census of Agriculture, 1950, 1960, 1970.

9/ My thanks to Drs. William Delehanty and Willis Peterson for suggestions in this section.

10/ U.S. Bureau of the Census, Census of Population, Occupations, 1880-1970.

11/ U.S. Bureau of the Census, Census of Agriculture, 1880-1969.

12/ Total labor force estimate on the basis of farm management reports (Southwestern, Southeastern, and West Central Farm Management Association Reports for the 1920s-1970s) of total labor units and labor units per worker for the year. Literacy is from U.S. Bureau of the Census, Census of Population, 1910-1930; and years of schooling is from Census of Population, 1940-1960.

13/ A more detailed discussion is given in Joseph C. Fitzharris, Minnesota Agricultural Growth, 1880-1970: Appendix. (hereafter referred to as Appendix) University of Minnesota Department of Agricultural and Applied Economics Staff Paper P76- , January, 1976.

14/ Established to train future farmers and homemakers, and to provide the basic college preparatory education. Schools were established at the University Farm in St. Paul in 1888, at Crookston in 1905, Morris in 1910, Grand Rapids in 1926, and Waseca in 1952. University of Minnesota Institute of Agriculture, A Study of the Outlying Schools of Agriculture (St. Paul, 1958) pp. 6-8.

15/ Values, reported in the U.S. Census of Agriculture, are given by county in Thomas J. Pressly and William H. Scofield, eds. Farm Real Estate Values in the United States by Counties, 1850-1959 (Seattle: University of Washington Press, 1965), pp. 33-34. Prices per acre are given in Maurice Mandale and Philip Raup, The Minnesota Rural Real Estate Market in 1973, Economic Report 74-1, University of Minnesota Department of Agricultural and Applied Economics (St. Paul: 1974), p. 42.

16/ Current values are from the U.S. Bureau of the Census, Census of Agriculture, 1880-1910, 1959, 1969; the deflator is based on average values per acre (1880-1910), and the index of rural real estate (land and buildings) values from U.S.D.A., Agricultural Statistics, 1950, p. 569, 1964, p. 439, 1972, p. 510.

17/ Raymond M. Wik, Steam Power on the American Farm. (Philadelphia University of Pennsylvania Press, 1953), 128; Drache, Challenge of the Prairies, 68, 182-186.

18/ A. J. Schwantes, "The Combine in Minnesota," American Society of Agricultural Engineers, Power and Machinery Division, Present Status of "Combine" Harvesting (St. Joseph, Michigan: the Society, 1928) pp. 8-11, notes that eleven "combines" were in use in 1927.

19/ Robert B. Elwood, Lloyd E. Arnold, D. Clarence Schmutz, and Eugene G. McKibben, Changes in Technology and Labor Requirements in Crop Production: Wheat and Oats, National Research Project Report No. A-10, (Philadelphia: Works Progress Administration, 1939), pp. 26-27; and Eugene G. McKibben, John A. Hopkins, and R. Austin Griffin, Changes in Farm Power and Equipment Field Implements., National Research Project Report No. A-11 (Philadelphia: Works Progress Administration, 1939), pp. 74-79. Tractor horsepower data are given in Table 2-19 below.

20/ U.S. Bureau of the Census, Census of Agriculture, 1959, 1969; 1950 and 1959 current values linearly intrapolated on the basis of value per tractor-horsepower, 1940 and 1969. See Appendix.

21/ David O. Mesick, Minnesota Agriculture -- Livestock, 1858-1959 (St. Paul: Minnesota Crop and Livestock Reporting Service, 1959), p. 45.

22/ Mesick, Livestock, p. 45. The CLRS and Census Bureau both stopped collecting such data in 1960.

23/ Mesick, Livestock, p. 19.

24/ Mesick, Livestock, pp. 4-5, and 11-15.

25/ Yearly data on Breeding Sheep from Mesick, Livestock, p. 19; valued at the 1950 price of $17.00. Breeding cattle are assumed equal to the numbers of calves born. A percentage factor, of calves to total cattle, was used to estimate the numbers of calves and breeding cows. (The Appendix has greater detail) for 1880-1920. After 1920, from Mesick, Livestock, pp. 4-5. Breeding cows are valued at the 1950 all cattle price of $140.00. Farrowing sows are estimated for 1880-1920 using the 1924-1929 ratio of "saved pigs" to January 1 stocks (1.55), divided by the assumed average litter size (5.0), using yearly stock of 1 January data. After 1920, from Mesick, Livestock, pp. 11-15, and from Minnesota Agricultural Statistics, 1963, 1972. Farrowing sows are valued at the 1950 price of $32.40 per head.

26/ Stock data are from Mesick, Livestock, pp. 4-5 (Cattle), 11-12, 14-15 (Sows), and 19 (Breeding Sheep); and from Minnesota Agricultural Statistics, 1963, 1972, with 1950 prices.

27/ 1880-1930 from Frederick Strauss and Louis H. Bean, Gross Farm Income and Indices of Farm Production and Prices in the United States, 1869-1937, U.S.D.A. Technical Bulletin 703 (Washington, D.C.: 1940), passim; 1940-1970, U.S.D.A., Statistics of Agriculture, 1942, 1951, 1961, 1971.

28/ U.S.D.A., Agricultural Statistics, 1937-1973.

29/ U.S.D.A., Statistics of Agriculture, 1937-1973. The 1950 price for 2-12-6 mixed fertilizer was used ($38.50) since it was the lowest price recorded in Agricultural Statistics, 1952, p.689. Except for 1925 and 1970, all figures are five year centered averages. 1970 is a three year average.

30/ Prices are from Robert E. Marquardt, Minnesota Agriculture -- Prices, 1867-1959 (St. Paul: Minnesota Crop and Livestock Reporting Service, 1959); and S. Hundley, Minnesota Agriculture -- Prices, 1959-1970 (St. Paul: Minn. Crop and Livestock Reporting Service, 1972). Relative prices are current prices of a crop, e.g. oats, divided by the price of wheat or corn for the same year. Relative prices for livestock are compiled as wheat-, corn-, and cattle per hundred weight-relative prices.

31/ 1880-1900, based upon wage data in Minnesota Bureau of Labor Statistics, Biennial Report of the Commissioner ... 1901-1902, and discussions with Rodney P. Loehr. The 1910-1970 data are from Minnesota Crop and Livestock Reporting Service, Minnesota Agricultural Statistics, 19.

32/ 1880-1900, From T.Pressly and W.Scofield, Farm Real Estate Values in the United States by Counties, 1959, p.33-34; 1910-1970, from Maurice E. Mandale and Philip M. Raup, The Minnesota Rural Real Estate Market in 1973, p. 42.

33/ U.S.D.A., Agricultural Statistics, 1974, p. 457; U.S. Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1957 (Washington, D.C.: U.S. Government Printing Office, 1967), Series E7 and E 20, pp. 115-17.

34/ Agricultural Development: an International Perspective (Baltimore: Johns Hopkins Press, 1971), series U24, p. 340.

35/ Regretably, there is no way to test this assertion because the necessary data does not, so far as I know, exist.

36/ Output includes home consumption. The basic data is in Table 2-2.

37/ The basic data is in Table 2-1. Note that all non-coop entries in Table 2-1 are (from Table 2-2) output figures.

38/ See Robert B. Elwood, Lloyd Arnold, D. Clarence Schmutz, and Eugene G. McKibben, Changes in Technology and Labor Requirements in Crop Production: Wheat and Oats, National Research Project Report A-11 (Philadelphia: Works Progress Administration, 1939); and Loring K. Macy, Lloyd E. Arnold, and Eugene G. McKibben, Changes in Technology and Labor Requirements in Crop Production: Corn, National Research Project Report A-5, (Philadelphia: Works Progress Administration, 1938).

39/ See Charles B. Kuhlmann, The Development of Flour Milling Industry in the United States; with Special Reference to the Industry in Minnespolis (New York: Houghton, Mifflin, Co., 1929); and Joseph C. Fitzharris, A Model of Urban Growth and Transition: the Twin Cities, 1870-1930, (unpublished Ph.D. dissertation, University of Wisconsin, Madison, 1975), chapter 4.

40/ See Eugene G. McKibben and R. Austin Griffin, Changes in Farm Power and and Equipment: Tractors, Trucks, and Automobiles, National Research Project Report A-9 (Philadelphia: Works Progress Administration, 1938).

41/ Macy, Arnold, and McKibben, Changes in Technology in Crop Production: Corn, pp. 37-41, and Eugene G. McKibben, John A. Hopkins, and R. Austin Griffin, Changes in Farm Power and Equipment: Field Implements, National Research Project Report A-11 (Philadelphia: Works Progress Administration, 1939), pp. 68 ff; following Hayami and Ruttan, Agricultural Development, pp. 334-336.

42/ Horses and Mules from David O. Mesick, Minnesota Agriculture - Livestock; tractors from U.S. Census of Agriculture, 1959, 1969, times average horsepower per tractor from U.S. Department of Agriculture, Changes in Farm Production and Efficiency, a Summary Report, (Statistical Bulletin 233), 1963, pp. 30-31; and 1972, p.21.

43/ See Hayami and Ruttan, Agricultural Development, pp. 115-122. Output is crops, livestock, poultry, and their products, from Table 2-2 ("traditional output"), divided by labor from Table 2-5, and by "improved acres" from Table 2-4. Acres per worker is improved acres (Table 2-4) divided by labor (Table 2-5).