Rainfall and Farm Income

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One of the most difficult aspects of farming is dealing with issues that are beyond the farmer's control. Given the market structure of most major agricultural commodities, farmers are typically price takers, meaning that the price they receive for their commodities is determined by the relationship between supply and demand. Under this nearly perfectly competitive market structure, individual producers usually cannot do a great deal to influence the price of the commodity. Consequently, farmers are subject to equilibrium prices that are more-or-less beyond their control. Multiplying the frustration of a lack of control over the prices of the products they produce is the instability of many agricultural commodity prices. This price instability is often the result of fluctuations in agricultural production.

Commodity yields can frequently exceed or fall short of expectations as a result of precipitation, temperature, and pest and disease pressure. In Kansas, precipitation is typically the main cause of variability, and thus risk, in crop production. As a result of the variability that precipitation or rainfall poses, it is often the subject of countless conversations and management decisions. Along these lines, there are many commonly held beliefs regarding the importance of rainfall. For example, there is a popular expression that "rain can make anyone a good farmer." Similarly, some have stated that success in farming is pure luck. Statements like this can often lead to short-sited management decisions based on recent weather events. In other words, perceptions tend to get distorted on the memory of rainfall of the last year or two. This paper will examine weather trends for eight locations in Kansas and determine the relationship between rainfall, yields, and farm income.

Data

Weather data from eight K-State Research and Experiment Stations were used in this study. These stations include: Colby, Tribune, Garden City, Hays, Hutchinson, Manhattan, Ottawa, and Parsons. Average monthly rainfall and maximum and minimum temperatures were available for the 1900-2002 period for Colby, Hays, Manhattan, and Ottawa. Data from Tribune ranged from 1925-2002. The Garden City, Hutchinson, and Parsons data covered the 1949-2002 period. In addition to the weather data, county crop yield data for wheat, sorghum, corn, and soybeans were obtained from Kansas Agricultural Statistics for the years 1970-2001 (data for all crops, all years were not available). Finally, average market year crop price data for wheat, sorghum, corn, and soybeans were used on a state-wide basis to estimate crop receipts.

Weather Trends in Kansas

Precipitation varies considerably across Kansas. It ranges from less than 16 inches/year in several counties on the border of Colorado to over 42 inches/year in extreme southeast Kansas. Table 1 shows the average annual precipitation (rainfall) and variability in that precipitation for the eight specified locations from 1949-2002. Tribune, in west central Kansas, had the lowest average annual rainfall at 16.48 inches/year. Parsons, in southeast Kansas, had the highest average annual rainfall at 40.01 inches/year.

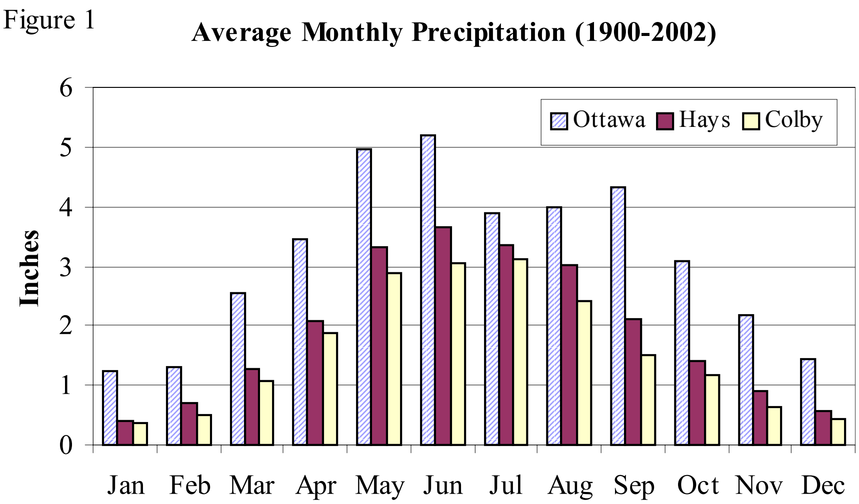
Two statistical methods were used to measure precipitation variability at the eight sites. The first of these methods is standard deviation, which is the measure of variability around the mean of a data set. Tribune had the lowest standard deviation, at 4.77 inches/year, while Manhattan had the highest standard deviation, at 8.83 inches/year. It would be expected that the sites in eastern Kansas would have a higher standard deviation than those in western Kansas since eastern Kansas typically receives much more rain. Therefore, another statistical method was employed to measure the relative variability of precipitation at each site. That measure is coefficient of variation (CV). Although Tribune had the lowest standard deviation, it had the highest CV at 0.289. This means that it had the highest amount of variability in relation to average rainfall. Parsons had the lowest CV at 0.206, and therefore had the lowest variability. Ottawa had the highest annual precipitation total of all locations—61.24 inches in 1951. At 6.54 inches in 1956, Tribune recorded the lowest amount of precipitation of all locations. Finally, it is interesting to note that the minimum recorded precipitation totals for Ottawa and Parsons are greater than the average annual precipitation for the three western Kansas locations.

Table 1. Precipitation Data for Eight Representative Sites in Kansas

Location	Average	Std. Dev.	C.V.	Maximum	Minimum
Colby	19.54	5.04	0.258	30.79	8.68
Tribune	16.48	4.77	0.289	30.06	8.75
Garden City	18.63	4.88	0.262	28.37	6.54
Hays	22.74	6.04	0.266	43.34	9.21
Hutchinson	29.00	7.26	0.250	47.64	15.40
Manhattan	33.73	8.83	0.262	60.38	15.42
Ottawa	38.73	8.40	0.217	61.24	20.12
Parsons	40.01	8.23	0.206	55.87	21.91

In addition to the differences in average annual precipitation across the state, there are also some differences in terms of when that precipitation typically occurs. Figure 1 shows the average monthly precipitation for Ottawa, Hays, and Colby. All sites are

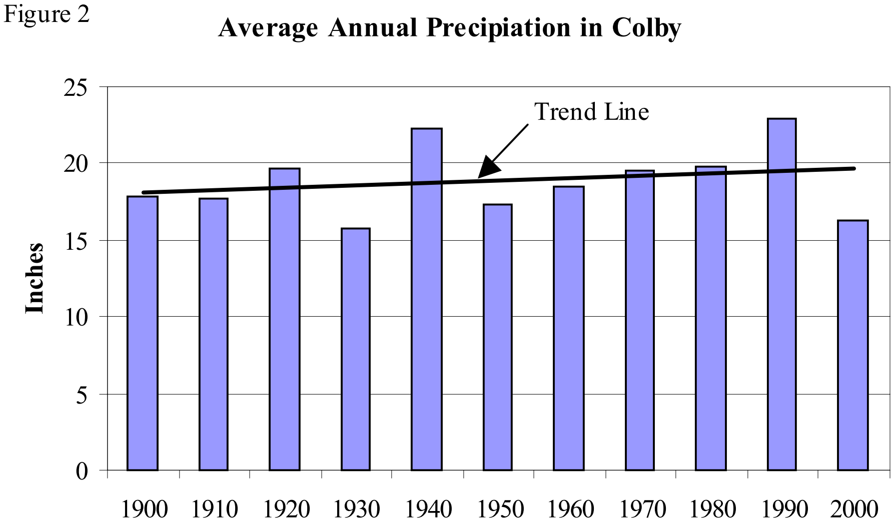
Figure 1



similar in that they receive more rainfall in the late spring and summer months (May – August) than in other months of the year. Hays and Colby have nearly identical precipitation patterns. Ottawa, however, receives a higher percentage of annual precipitation in the fall and winter than the other sites. In fact, Hays and Colby each receive about 60% of total rainfall in May – August. Ottawa receives only 48% of total rainfall in the same time frame.

Figures 2 and 3 show the average annual precipitation and standard deviation, by decade, for Colby. Average precipitation has trended slightly upward during the 20th Century (Figure 2). However, precipitation variability, in terms of standard deviation, has trended down during the same period (Figure 3). Tribune and Garden City follow the same general pattern (Appendix A). Precipitation is flat to trending slightly upward, while variability in precipitation trends downward. It is important to note that precipitation was above average for each location during the 1990s while standard deviation was lower than expected.

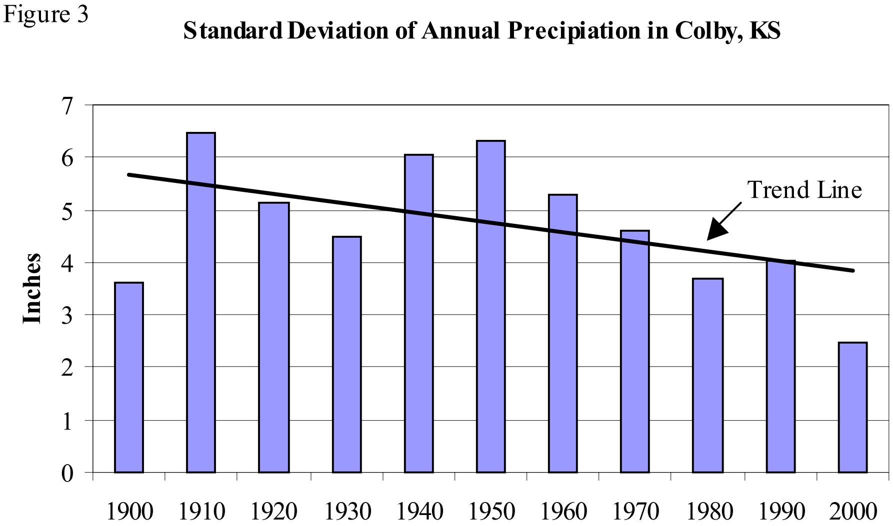
Figure 2



Precipitation trends in the central part of the state were similar, but not identical to those in the west (Appendix A). In Hays, average precipitation and variability were flat over time. Precipitation in Hutchinson varied greatly from the 1950s to today. Rainfall in the 1950s was slightly below average, but was highly variable. The 1960s had an even lower average, while the 1970s had an average of over 31 inches/year. The 1980s and 90s had precipitation levels closer to average. Variability decreased over time.

The eastern Kansas locations also had some mixed results (Appendix A). Average precipitation in Manhattan was generally flat. Variability was unique in that it trended upward over time. This is partly due to very high variability in the 1950s. Precipitation trends in Ottawa were flat over time, but there were actually significant differences in rainfall from one decade to the next. Consequently, there were ups and downs in standard deviation as well. Finally, Parsons is consistent in that precipitation increases and variability decreases from the 1950s on.

Figure 3



The Relationship Between Rainfall and Farm Income

In crop production, gross revenue equals yield times price. Yield is a function of many factors including: precipitation, fertility, variety/hybrid selection, seeding rate, weed and insect management, soil quality, and tillage practices. Many of these factors are controlled directly by the producer. Price is a function of supply and demand fundamentals for the relevant commodity. While weather events can affect price in terms of supply, these events typically must take place on a national or international basis. Without question, these "macro" events can affect farm income on a "micro" level. However, the focus of this research is on the relationship between precipitation and farm income on a local or "micro" level. Therefore, the relationship between precipitation and yield is the relevant issue to study.

Crop Yields

One of the biggest potential benefits of determining the relationship between precipitation and crop yields is the ability to predict crop yields. Research was conducted at the K-State Research and Extension Center in Tribune by agronomists Loyd Stone and Alan Schlegel. From this research, formulas were developed to estimate yield based on the evapotranspiration (ET) requirements of wheat, grain sorghum, corn, soybean, and sunflower. Table 2 provides the factors from the research that are needed to estimate yields. Equation (1) shows the formula for estimating yields.

(1) Yield = (Available Soil Water + (Growing Season Rainfall * Effective Precipitation) – Threshold ET) * Yield Factor,

where: Available Soil Water + Rainfall * Effective Precipitation cannot exceed the Maximum ET.

Available Soil Water is the water available to the crop during the growing season from the soil profile. This factor will vary considerably based on soil type and quality. *Growing Season Rainfall* is the amount of precipitation that fell during the growing season. Wheat has a growing season of September/October through May/June. The growing season for corn is April/May through August or September, and the growing season for grain sorghum and soybeans is typically May to early June through September. *Effective Precipitation* is the percentage of a rainfall event that would be available to a crop. This accounts for runoff and evaporation losses. Research in western Kansas has indicated effective precipitation will average approximately 85%. Data in eastern Kansas are limited, but expert opinion suggests that effective precipitation would be in the 70-75% range since eastern Kansas receives larger and more frequent rainfall events. *Threshold ET* is the point from which a crop will begin to yield. *Yield Factor* is the yield produced from each additional inch of water over the Threshold ET.

Table 2. Yield Prediction Factors for Kansas Crops

Crop	Maximum ET (inches)	Threshold ET (inches)	Yield Factor (bu/acre inch)*
Wheat	24	10.0	4.6
Grain Sorghum	21	6.9	9.4
Corn	25	10.9	13.3
Soybean	24	9.0	4.5
Sunflower	22	5.4	150

* The yield factor for sunflowers is based on lb/acre inch.

Wheat, grain sorghum, corn and soybean yields were predicted for the eight locations in Kansas using the yield prediction formulas and historical monthly precipitation. The predicted yields were then compared to the actual county average yield for a given crop and year. Crop yield data are limited to 1970-2001 for wheat and sorghum. Non-irrigated corn and soybean data were even more limited. Most non-irrigated corn data did not start until 1972 with most sites not having a complete set of data through 2001. Because there were only a few years of data for Garden City, corn yields were not estimated. The three western Kansas locations and Hays did not have any yield data for soybeans. Data for the other four sites were limited to 1984-2001.

Using Manhattan as an example, in 2000 the growing season *Rainfall* for sorghum (May – September) was 12.20 inches. *Available Soil Water* was assumed to be 2 inches, and *Effective Precipitation* was assumed to be 70%. Using Equation 1, the predicted sorghum yield for is Manhattan (Riley County) is:

$$(3 + (12.20 * 0.70) – 6.9) * 9.4 = 43.6 \text{ bu/acre.}$$

For comparison purposes, yields were predicted each year, for each relevant crop, at each location. These predictions were based on *Growing Season Rainfall* and the following assumptions. Based on research in Tribune, *Available Soil Water* was assumed to be 4 inches for sorghum, corn, and soybeans and 6 inches for wheat for the three locations in western Kansas. Because of shallower soils in central and eastern Kansas, *Available Soil Water* in Hays, Hutchinson, and Manhattan was 3 inches for sorghum, corn, and soybeans and 4.5 inches for wheat. The *Available Soil Water* in Ottawa and Parsons was 2 inches for sorghum, corn, and soybeans and 3 inches for wheat. Effective precipitation was assumed to be 85% for Colby, Tribune, Garden City, and Hays; 75% for Hutchinson; and 70% for Manhattan, Ottawa, and Parsons. The typical growing season for each crop is shown in Table 3.

Table 3. Typical Growing Seasons for Wheat, Sorghum, Corn, and Soybeans

Location	Wheat	Sorghum	Corn	Soybeans
Colby	Sept. – June	June – Sept.	May – Aug.	--
Tribune	Sept. – June	June – Sept.	May – Aug.	--
Garden City	Sept. – June	June – Sept.	--	--
Hays	Sept. – June	June – Sept.	May – Aug.	--
Hutchinson	Sept. – May	May – Sept.	April – Aug.	May – Sept.
Manhattan	Oct. – June	May – Sept.	April – Aug.	May – Sept.
Ottawa	Oct. – May	May – Sept.	April – Aug.	May – Sept.
Parsons	Oct. – May	May – Sept.	April – Aug.	June – Sept.

Table 4 shows the actual and predicted yields for wheat, sorghum, corn, and soybeans in Manhattan (Riley County). Tables showing actual and predicted yields for the other locations are available in Appendix B. Looking at the averages, predicted yields for corn, sorghum, and soybeans were more accurate than wheat. Although looking at the overall average may be interesting, another method gives a more accurate indication of forecast accuracy. The method that will be used to determine the accuracy of the yield predictions is mean absolute percentage error (MAPE). The formula for this forecast accuracy measure is found in Equation 2.

(2) $APE = |(P-A)/A| * 100$,

where: APE = absolute percentage error, P = predicted yield, and A = actual yield.

MAPE is simply the average (mean) of the APE values corresponding to each yield prediction. Table 5 shows the average error (P-A) for each crop and location. Based on the averages in the table, the yield predictions are very accurate for wheat across the state. The yield predictions were also accurate for sorghum in Colby, Tribune, Garden City, and Hays. Predicted sorghum yields were much less accurate in the other four locations. Predicted corn yields in Colby were, on average, 18.6 bu/acre higher than actual yields, while predicted yields in Tribune were 20.4 bu/acre lower than actual. Hays, Manhattan, and Ottawa were relatively close in terms of predictive accuracy for corn, but Hutchinson and Parsons were less accurate, although Parsons was more accurate than Colby and Tribune. Soybean yield predictions were fairly accurate for Parsons, but not very accurate for Hutchinson, Manhattan, and Ottawa.

Table 4. Actual and Predicted Yields for Manhattan, KS

	Wheat		Sorghum		Corn		Soybeans	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	31.0	37.7	34.0	101.5				
1971	47.0	42.1	54.0	89.7				
1972	34.0	52.0	69.0	89.1	78.0	40.1		
1973	39.0	52.0	67.0	101.5	75.0	75.1		
1974	31.8	52.0	44.0	62.8	45.0	73.1		
1975	34.6	52.0	40.0	101.5	32.0	82.2		
1976	32.9	52.0	56.0	52.2	48.0	55.4		
1977	30.6	36.9	62.0	101.5	67.0	127.7		
1978	34.4	35.2	56.0	87.3	86.0	41.5		
1979	32.1	40.9	83.0	65.7	92.0	41.4		
1980	32.6	52.0	24.0	37.5	15.0	0.0		
1981	32.1	52.0	82.0	101.5	103.0	119.9		
1982	30.8	52.0	72.0	101.5	88.0	92.2		
1983	42.1	52.0	41.0	52.4	44.0	45.4		
1984	34.2	52.0	54.0	101.5	84.0	121.1	19.7	48.6
1985	42.7	52.0	81.0	101.5	100.0	98.1	30.0	42.7
1986	27.1	52.0	83.0	101.5	97.0	127.7	39.0	48.6
1987	39.7	29.2	70.0	86.7	74.0	76.7	29.0	32.1
1988	44.0	10.6	74.0	54.9	49.0	36.6	22.0	16.8
1989	19.6	48.1	36.0	101.5	72.0	14.2	20.0	40.7
1990	39.7	33.3	79.0	101.5	74.1	117.4	29.0	48.0
1991	34.0	34.2	52.0	48.2	51.9	38.1	26.0	13.6
1992	31.5	52.0	90.0	101.5	114.4	92.3	41.0	48.6
1993	21.8	30.1	54.0	101.5	93.2	127.7	31.0	48.6
1994	43.5	52.0	91.0	72.3	109.0	83.9	39.0	25.2
1995	26.0	29.0	59.0	101.5	68.0	127.7	24.0	48.6
1996	41.0	35.8	82.0	101.5			35.0	46.2
1997	58.0	44.3	84.0	62.9			34.0	20.7
1998	50.0	52.0	92.0	101.5			34.0	43.7
1999	44.0	33.4	86.0	100.1			34.0	38.5
2000	41.0	52.0	72.0	52.0			18.0	11.4
2001	46.0	20.0	81.0	101.5			31.0	48.6
Avg	36.5	42.9	65.8	85.4	73.3	77.5	29.8	37.3

Table 5. Mean Error of Predicted Yield by Crop and Location

Location	Wheat (bu/ac)	Sorghum (bu/ac)	Corn (bu/ac)	Soybeans (bu/ac)
Colby	0.5	5.2	18.6	--
Tribune	-3.5	5.7	-20.4	--
Garden City	0.8	2.4	--	--
Hays	5.6	6.0	-0.9	--
Hutchinson	6.4	28.3	23.2	8.4
Manhattan	6.4	19.6	4.2	7.5
Ottawa	0.3	30.3	9.3	8.1
Parsons	5.7	19.2	12.7	3.4

As previously mentioned, mean errors can be instructive in determining forecast accuracy, but really only show whether or not a forecast tends to be biased. On the other hand, MAPE may be a superior accuracy measure because it conveys magnitude of the error. Since MAPE measures the relative size of an error, larger MAPE values mean that the yield prediction is less accurate. A value of 38.7% for wheat in Colby indicates that, on average, predicted yields were off 38.7%. The MAPE values presented in Table 6 indicate that the yield formulas are not as accurate as Table 5 indicates. In fact, predicted wheat yields, which had the lowest MAPE values, were still off by a minimum of 35.6%. Predicted corn yields in Hutchinson had a MAPE value of 87.8%.

Table 6. Mean Absolute Percentage Error (MAPE) of Predicted Yield

Location	Wheat	Sorghum	Corn	Soybeans
Colby	38.7	51.2	84.2	--
Tribune	40.9	49.4	44.8	--
Garden City	48.2	38.2	--	--
Hays	59.3	58.0	65.7	--
Hutchinson	42.8	61.6	87.8	47.3
Manhattan	39.5	49.2	43.3	49.1
Ottawa	35.6	59.8	55.2	47.5
Parsons	36.6	47.5	66.0	65.1

The results of this analysis indicate that average yield predictions, on a per bushel basis, are fairly accurate for wheat across the state; sorghum in western Kansas, and corn, in Hays and Manhattan. However, according to the MAPE measure, it is apparent that a prediction may be very inaccurate in a given year. There are many possible explanations for this phenomenon, which will be discussed later.

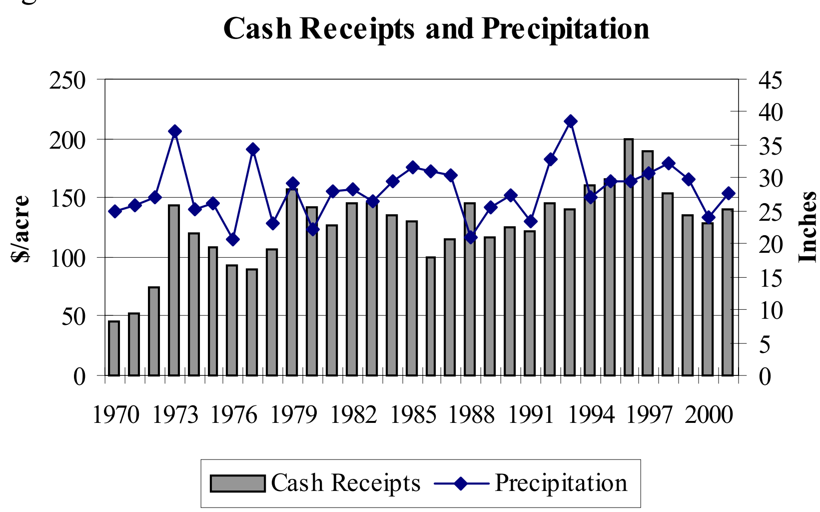
Farm Income

The ultimate goal of this research was to determine the correlation between precipitation and farm income. Figure 4 shows state level crop receipts per acre in relation to average precipitation (for the eight locations) from 1970-2001. According to the figure, there appears to be a relationship between crop receipts and precipitation in some years, but not in others. For example, crop receipts tend to increase with precipitation in the early 1970s, but decrease with steady precipitation in the mid 1980s. One explanation for a negative correlation between income and precipitation in a given year is price. This is apparent in 1986-87 when precipitation and yields were constant but price decreased.

To verify the observations made from the figure, another simple statistical measure was used to quantify the relationship between crop income and precipitation. In this instance a correlation coefficient was calculated, comparing crop income with precipitation. Correlation coefficients can be interpreted as follows. A value of "1" means that there is a perfect, positive correlation between the two sets of data being compared. A value of "–1" means that there is a perfect, negative correlation between the two data sets. A value of "0" means there is no correlation between the data sets.

Since crop yields typically increase with more rainfall, one would expect the correlation coefficients to be positive. When annual prices are used to calculate crop receipts in Figure 4, the correlation coefficient is 0.268. However, when average 1970-2001 prices are used to calculate crop receipts, the correlation coefficient increases to 0.392, indicating that prices are influenced by outside factors.

Figure 4



Correlation coefficients were also calculated to determine the relationship between growing season precipitation and crop receipts for each relevant crop at each location (Table 7). Wheat in Colby, Garden City, and Hays were all negatively correlated, although not by a large degree. On a crop basis, corn has the highest correlation between income and rainfall. That would be expected since corn typically has the greatest yield response to moisture. Wheat has the lowest correlation, which is also not surprising. What is surprising is the there is a higher correlation in eastern Kansas than western Kansas. One might expect western Kansas to have a higher correlation since precipitation is more limited, but the results do not indicate that. On a location basis, Tribune had the highest correlation while Manhattan had the lowest. In addition to comparing crop income with growing season precipitation for that crop, the “All Crops” column in Table 7 correlates the total receipts of the four major crops with the average growing season precipitation for those crops. In this case, Ottawa had the highest correlation of all locations at 0.503. Tribune had the second highest correlation at 0.304. Manhattan and Colby, with correlation coefficients of 0.070 and 0.136, respectively, had the lowest relationship between income and precipitation. Finally, when statistical regression models were estimated to determine the relationship between crop income and precipitation, Ottawa was the only location in which precipitation was a statistically significant variable in estimating crop income.

Table 7. Correlation Coefficient for Precipitation and Crop Receipts per Acre

Location	Wheat	Sorghum	Corn	Soybeans	All Crops*
Colby	-0.014	0.419	0.442	--	0.136
Tribune	0.159	0.457	0.545	--	0.304
Garden City	-0.090	0.489	--	--	0.253
Hays	-0.191	0.340	0.481	--	0.243
Hutchinson	0.039	0.269	0.225	0.437	0.146
Manhattan	0.144	0.052	0.358	0.105	0.070
Ottawa	0.147	0.385	0.493	0.460	0.503
Parsons	0.248	0.289	0.237	0.117	0.281

* All Crops correlates the total receipts of the four major crops with the average growing season precipitation for those crops.

Discussion

The results of this study indicate that there is not a very strong relationship between precipitation and crop yields/income. Can that be true? The 2002 drought would seem sufficient to prove that crop production and income is highly correlated with precipitation. In actuality, both statements have some merit. Precipitation is an important factor, but there are many other factors that are as important, or maybe even more important than total precipitation.

One of the reasons precipitation is not strongly correlated to crop yield may be due to the nature of the precipitation. Large, heavy rain events may not be very useful to the crop because of runoff and evaporation, but can often make up a large percentage of total rainfall. Similarly, a number of small rain events may pad total precipitation, but may not be very useful to the crop in high ET situations. Finally, one of the most important factors concerning precipitation and crop yields is timeliness. As with comedy, timing is everything. This is especially important in western Kansas where total rainfall is limited. Rains during the reproductive period are critical for yields in western Kansas. Although rainfall is typically more plentiful in eastern Kansas, timely rains are also important. As some agronomists would say, because of more shallow soils, portions of eastern Kansas are always two weeks away from a drought.

That leads to another important issue regarding precipitation and crop yields—soil type and topography. "Deeper" soils that can provide greater water storage capacity will allow crops to use rain events more efficiently, thus making it possible, at times, to endure drier periods. Likewise, rolling, uneven land with poorer quality soils will never have the yield potential of higher quality land, even with optimal rainfall.

Crop production management is obviously another key item in regards to precipitation and yields. Technological advancements in crop production have allowed farmers to use available water more efficiently. Probably the best example of a technological improvement that has made rainfall more efficient is conservation tillage. Research in western Kansas has demonstrated that reducing tillage prior to planting summer crops has resulted in higher yields and has allowed farmers to increase cropping intensity. Not only is the additional residue from reduced tillage an important factor in determining yields in drier areas, but so is weed control. Effective weed control programs are essential for successful reduced tillage systems. Reduced tillage has not had the same effect in parts of central and eastern Kansas where rainfall is more plentiful. Improved seed varieties and hybrids, that have more yield potential and drought hardiness, have also changed the relationship between precipitation and yields. Many of these varieties will take advantage of moisture when it is available to produce high yields, and/or will survive in dry times to yield when other varieties may not. Another important factor in production is fertility. Well managed fertility programs will enable producers to enhance yields at a given level of moisture.

Another reason for the weak relationship between yields and precipitation is data. By necessity, the data used in this study are aggregated. Farm- or field-specific data may indicate a stronger relationship. County level precipitation and yield data are useful, but may not accurately account for variations across the county.

When price is added to the gross income equation, another set of variables is also added to the equation. Consequently, it is not surprising that the correlation between precipitation and farm income is weak. Price, as mentioned before, is a function of worldwide supply and demand fundamentals. Since Kansas is the leading wheat producing state in the U.S., a small or large crop resulting from poor or favorable precipitation, may influence price. However, Kansas' production is not likely to have much of an impact in the price of the other commodities.

How is the information relevant? Weather plays a big role in the decision making process for most producers. It is undoubtedly a primary topic of conversation at local farmer social centers. A common problem with our fascination with weather is that we tend to have short, distorted memories about the past. This can lead to short-sighted management decisions. Oftentimes there is a tendency to give up on a failed crop or production technique based on what happened in one year. In many cases, weather is blamed for the failure. As 2002 indicates, weather can certainly cause failures. But as this research indicates, there are many other factors that determine the success or failure of crops in Kansas.

Appendix A

Figure A1

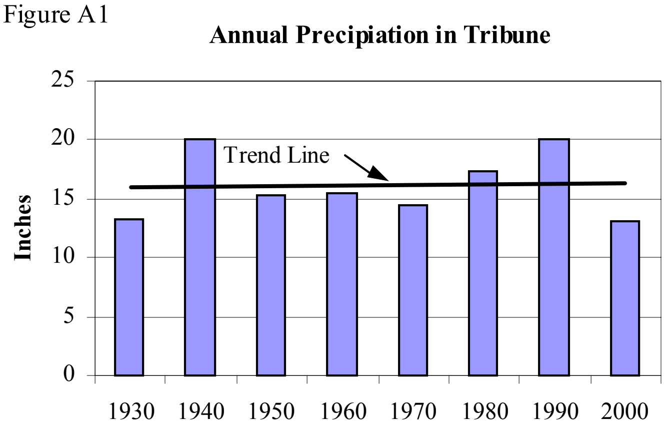


Figure A2

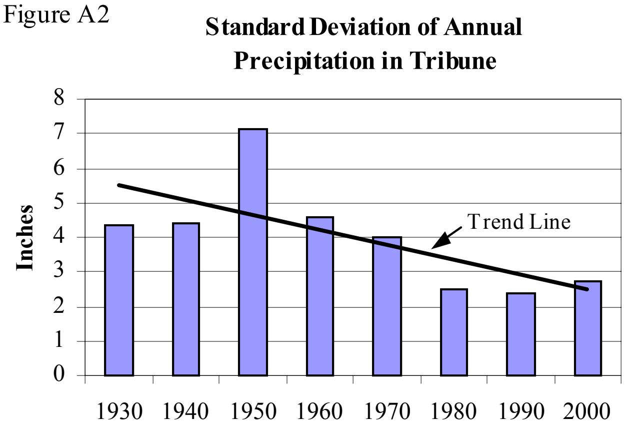


Figure A3

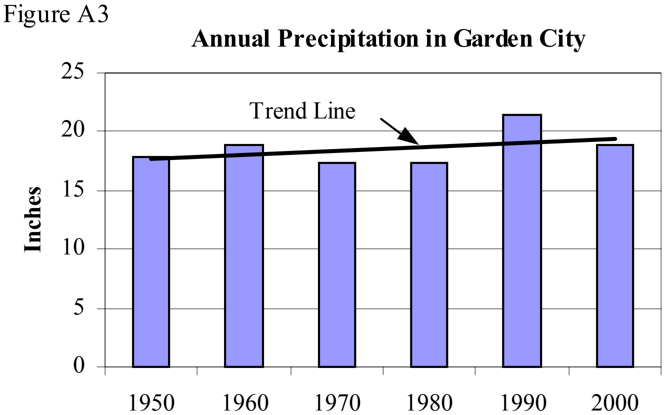


Figure A4

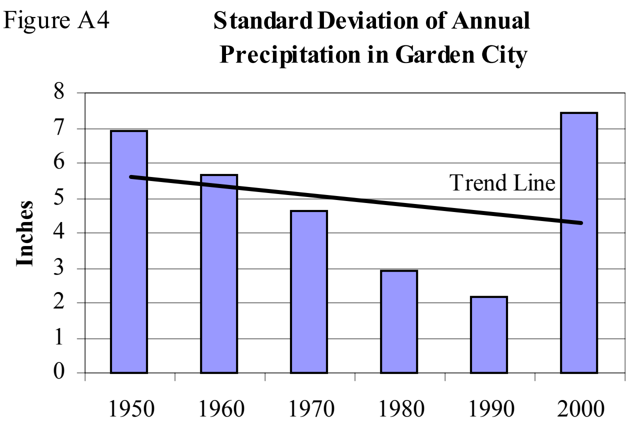


Figure A5

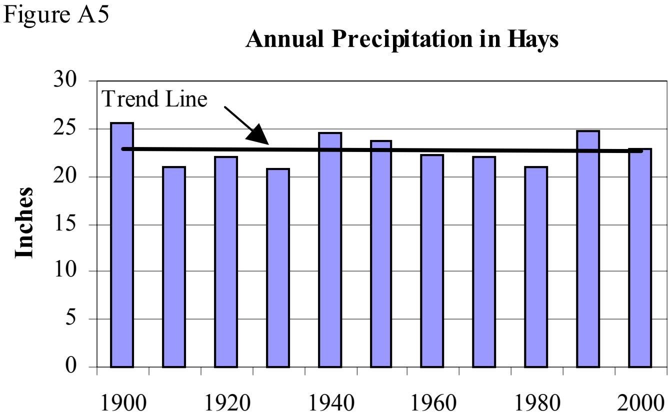


Figure A6

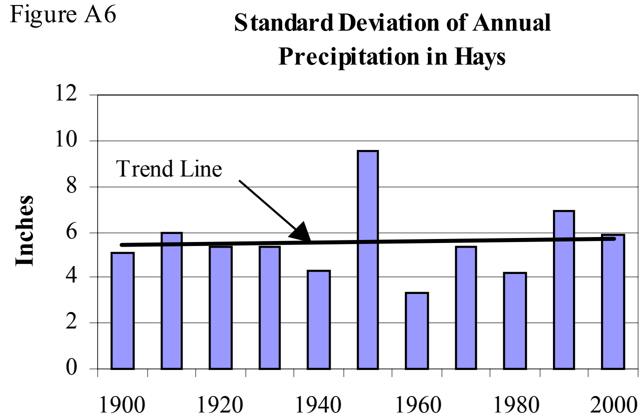


Figure A7

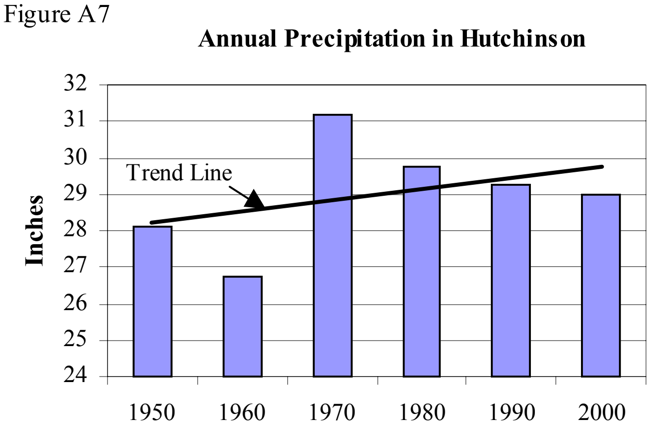


Figure A8

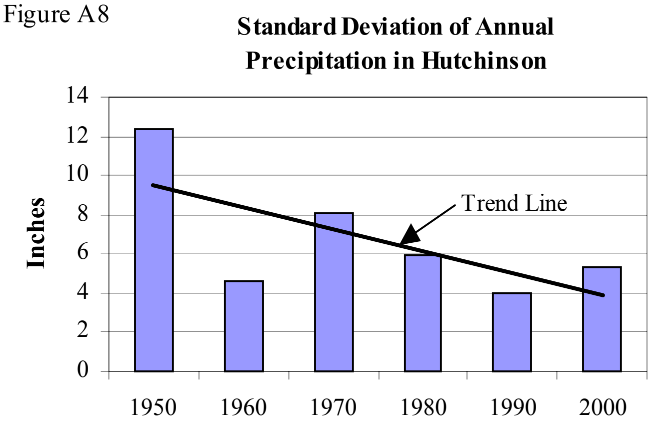


Figure A9

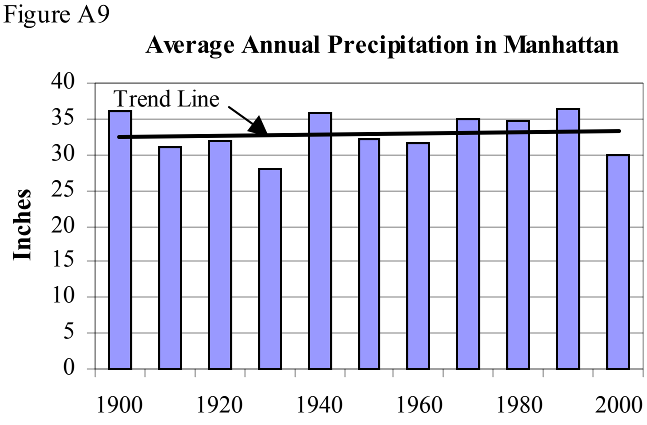


Figure A10

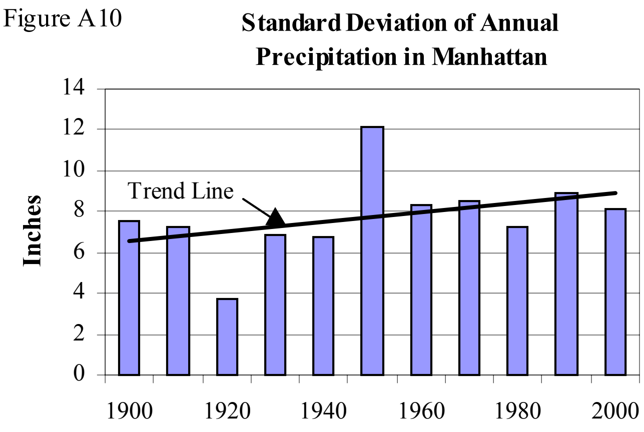


Figure A11

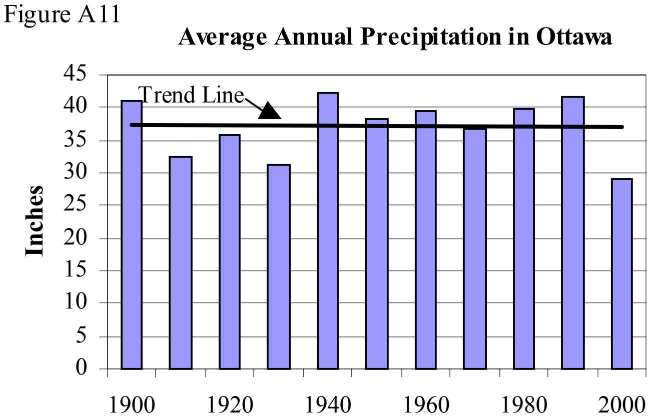


Figure A12

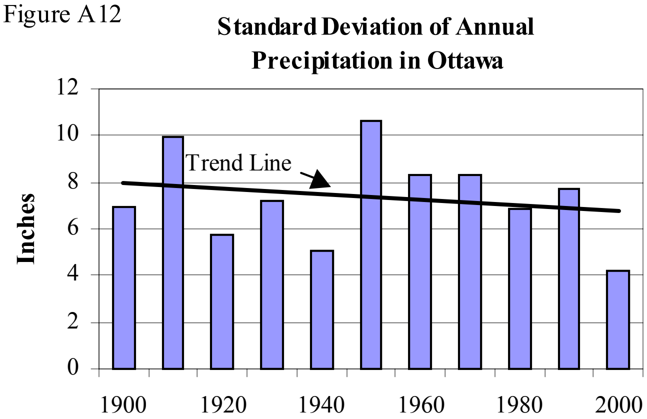


Figure A13

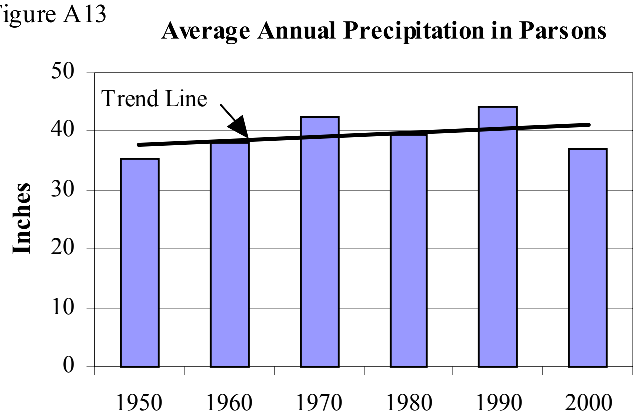
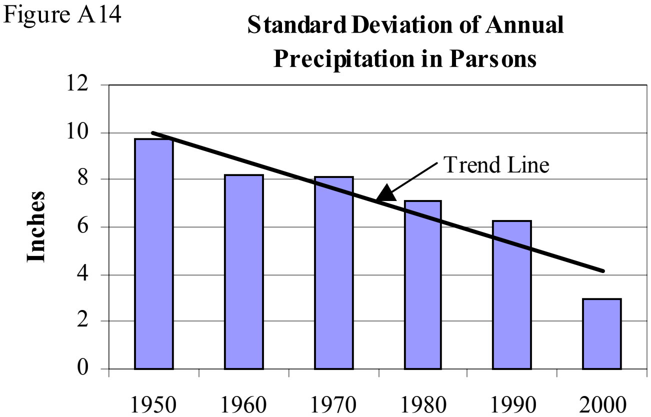


Figure A14



Appendix B

Table B1. Actual and Predicted Yields for Colby, KS

	Corn		Milo		Wheat	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	--	--	31.0	44.5	35.0	37.0
1971	--	--	32.0	28.4	33.0	36.2
1972	27.0	71.7	54.0	56.9	30.6	40.7
1973	54.0	101.5	42.0	84.2	37.7	55.9
1974	31.0	43.8	21.0	51.6	33.0	50.2
1975	25.0	137.3	36.0	99.9	31.0	14.4
1976	18.0	0.0	31.0	14.7	35.7	51.0
1977	45.0	106.7	53.0	67.6	35.8	28.2
1978	34.0	30.6	36.0	24.4	35.4	38.3
1979	66.0	120.0	53.0	85.9	44.2	27.9
1980	27.0	12.0	44.0	29.2	44.4	55.7
1981	0.0	70.8	57.0	16.4	12.0	47.7
1982	75.0	125.2	52.0	83.6	36.4	47.5
1983	38.0	9.5	40.0	15.0	44.5	38.3
1984	50.0	11.3	56.0	22.8	39.9	31.8
1985	70.0	83.9	59.0	72.1	58.5	36.5
1986	45.0	52.3	41.0	33.1	38.1	49.2
1987	66.0	66.0	60.0	51.4	37.4	22.9
1988	70.0	57.8	56.0	42.3	27.3	33.3
1989	40.0	87.4	34.0	64.2	28.4	31.9
1990	39.4	45.9	40.0	24.4	39.9	36.5
1991	47.0	56.1	43.0	41.4	31.3	31.8
1992	65.2	133.0	53.0	117.9	26.0	35.8
1993	72.9	164.4	68.0	137.9	40.4	37.9
1994	57.0	34.5	73.0	56.6	37.7	62.2
1995	26.0	103.6	44.0	52.2	37.0	39.9
1996	100.0	181.5	78.0	133.7	26.0	15.5
1997	71.0	49.5	65.0	68.0	33.0	42.3
1998	114.0	81.6	98.0	70.9	48.0	26.1
1999	113.0	71.8	99.0	78.1	43.0	12.9
2000	49.0	0.0	53.0	28.8	32.0	40.2
2001	54.0	39.1	69.0	38.5	43.0	15.7
Avg	53.0	71.6	52.2	57.4	36.1	36.6

Table B2. Actual and Predicted Yields for Tribune, KS

	Corn		Milo		Wheat	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	--	--	25.0	35.4	38.0	16.6
1971	--	--	16.0	20.1	31.0	15.9
1972	--	--	36.0	88.4	21.0	19.4
1973	--	--	30.0	65.7	25.9	28.1
1974	--	--	33.0	13.8	32.4	19.4
1975	--	--	25.0	17.5	24.8	0.6
1976	--	--	21.0	16.4	19.2	32.1
1977	--	--	32.0	25.8	19.1	33.5
1978	--	--	27.0	41.1	30.8	24.0
1979	--	--	32.0	24.9	28.9	52.6
1980	--	--	37.0	51.4	30.0	18.3
1981	--	--	30.0	18.3	17.0	24.7
1982	--	--	23.0	67.3	27.8	54.1
1983	--	--	21.0	45.3	38.6	30.3
1984	--	--	39.0	18.1	41.3	29.4
1985	--	--	37.0	21.9	48.1	26.0
1986	--	--	36.0	63.9	27.6	48.0
1987	--	--	36.0	48.6	36.0	23.9
1988	--	--	47.0	47.8	23.0	29.3
1989	--	--	40.0	59.2	28.4	28.6
1990	55.3	4.9	25.0	27.4	39.1	23.9
1991	45.5	71.7	72.0	77.3	32.4	33.1
1992	58.0	65.8	40.0	73.3	30.7	44.0
1993	52.5	44.0	45.0	36.3	42.3	31.1
1994	53.0	22.2	56.0	44.7	37.2	47.0
1995	49.0	56.2	42.0	43.9	25.0	19.3
1996	109.0	88.8	68.0	98.1	23.0	26.9
1997	73.0	74.0	62.0	92.1	39.0	36.0
1998	90.0	32.9	93.0	45.4	52.0	38.7
1999	94.0	51.4	68.0	56.8	45.0	15.0
2000	48.0	0.0	30.0	15.8	30.0	34.0
2001	51.0	21.7	--	--	32.0	0.0
Avg	64.9	44.5	39.5	45.2	31.8	28.2

Table B3. Actual and Predicted Yields for Garden City, KS

Year	Milo		Wheat	
	Actual	Predicted	Actual	Predicted
1970	33.0	43.2	32.0	25.9
1971	33.0	31.8	35.0	54.2
1972	48.0	100.0	35.6	39.4
1973	45.0	24.8	32.9	19.0
1974	30.0	12.4	32.3	31.6
1975	26.0	25.3	27.4	19.1
1976	23.0	9.9	24.6	42.6
1977	49.0	30.3	28.5	39.9
1978	41.0	27.2	32.5	21.6
1979	48.0	61.4	34.4	41.3
1980	38.0	12.0	32.2	9.9
1981	47.0	44.1	11.3	41.5
1982	46.0	81.1	33.7	43.7
1983	20.0	33.5	45.4	25.4
1984	34.0	5.0	33.1	33.3
1985	45.0	65.7	36.9	25.6
1986	49.0	47.8	25.5	48.0
1987	48.0	51.5	39.5	9.0
1988	41.0	20.2	28.0	47.5
1989	45.0	78.4	23.5	43.1
1990	57.0	14.9	47.7	28.6
1991	56.0	46.3	31.2	36.1
1992	70.0	82.5	35.2	48.4
1993	60.0	65.0	39.0	38.0
1994	63.0	60.2	38.0	56.9
1995	39.0	52.2	22.0	22.1
1996	70.0	85.2	24.0	44.4
1997	70.0	87.6	38.0	27.0
1998	71.0	59.6	49.0	52.7
1999	78.0	72.5	59.0	31.0
2000	59.0	16.4	36.0	54.1
2001	64.0	85.9	34.0	2.8
Avg	45.5	47.9	33.7	34.5

Table B4. Actual and Predicted Yields for Hays, KS

	Corn		Milo		Wheat	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	--	--	22.0	61.9	29.0	36.7
1971	--	--	33.0	21.7	28.0	35.2
1972	--	--	41.0	67.3	29.7	49.0
1973	--	--	46.0	87.5	36.6	48.4
1974	--	--	25.0	21.7	19.1	50.8
1975	--	--	28.0	43.8	26.7	33.9
1976	--	--	27.0	48.1	30.6	24.1
1977	--	--	47.0	51.2	31.8	21.9
1978	--	--	26.0	18.4	26.1	38.0
1979	--	--	51.0	24.9	32.9	30.0
1980	--	--	40.0	28.3	33.5	24.6
1981	--	--	51.0	44.5	18.8	49.4
1982	--	--	44.0	28.9	35.2	21.2
1983	--	--	15.0	0.7	37.8	53.2
1984	--	--	32.0	32.9	29.9	40.5
1985	--	--	52.0	59.9	37.3	35.6
1986	70.0	34.4	49.0	74.8	27.9	68.5
1987	48.0	45.2	66.0	53.9	35.8	4.8
1988	40.0	0.0	32.0	35.4	32.0	17.8
1989	36.0	27.4	18.0	66.2	12.0	48.3
1990	36.0	48.2	38.0	52.2	37.9	16.9
1991	35.0	0.0	36.0	12.6	28.7	45.2
1992	46.0	97.6	51.0	88.0	29.7	63.0
1993	50.0	177.6	53.0	131.1	35.1	14.0
1994	35.0	0.0	69.0	20.5	36.8	47.2
1995	31.0	33.1	46.0	0.0	21.0	37.0
1996	98.0	138.7	68.0	104.1	28.0	41.1
1997	66.0	72.2	69.0	92.4	39.0	40.5
1998	65.0	35.8	73.0	55.6	47.0	43.8
1999	95.0	70.5	77.0	84.2	48.0	27.0
2000	57.0	13.9	57.0	30.9	34.0	53.1
2001	--	--	61.	85.3	32.0	27.8
Avg	53.9	53.0	45.1	51.1	31.5	37.1

Table B5. Actual and Predicted Yields for Hutchinson, KS

	Corn		Milo		Wheat		Soybeans	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	--	--	32.0	78.0	33.0	42.2	--	--
1971	--	--	51.0	56.4	36.0	24.8	--	--
1972	--	--	45.0	77.2	36.3	57.5	--	--
1973	--	--	47.0	77.9	34.4	57.5	--	--
1974	--	--	44.0	71.3	26.7	34.7	--	--
1975	--	--	40.0	92.4	27.4	42.2	--	--
1976	--	--	33.0	61.5	28.2	55.2	--	--
1977	--	--	58.0	111.4	24.6	57.5	--	--
1978	--	--	35.0	70.6	29.9	35.1	--	--
1979	--	--	61.0	75.3	35.5	57.5	--	--
1980	--	--	47.0	51.6	25.6	22.8	--	--
1981	--	--	46.0	78.5	30.4	41.3	--	--
1982	--	--	51.0	82.9	33.5	49.0	--	--
1983	--	--	36.0	68.3	39.5	50.0	--	--
1984	--	--	29.0	8.1	31.6	39.9	14.3	0.0
1985	--	--	61.0	109.1	32.8	51.2	37.0	42.8
1986	78.0	144.3	79.0	111.4	37.7	57.5	33.0	54.0
1987	33.0	133.8	74.0	111.4	29.5	22.4	26.0	54.0
1988	50.0	55.7	56.0	61.1	34.2	10.5	21.0	19.8
1989	57.0	136.2	46.0	111.4	15.3	24.1	21.0	54.0
1990	34.5	0.0	58.0	57.9	37.0	40.8	17.0	18.3
1991	29.4	54.7	51.0	57.9	39.6	26.1	23.0	18.3
1992	55.0	95.3	76.0	107.0	25.8	57.5	33.0	41.8
1993	40.7	124.0	58.0	111.4	33.4	11.4	33.0	51.8
1994	53.0	59.0	53.0	60.1	35.4	55.4	15.0	19.3
1995	50.0	132.9	57.0	111.4	23.0	18.5	22.0	54.0
1996	45.0	42.9	76.0	90.2	33.0	35.1	35.0	33.8
1997	74.0	81.3	82.0	111.4	53.0	41.8	34.0	45.6
1998	51.0	29.3	--	--	44.0	56.4	26.0	24.5
1999	102.0	125.9	--	--	48.0	40.7	30.0	40.4
2000	86.0	26.0	--	--	39.0	48.1	20.0	16.5
2001	44.0	12.2	--	--	37.0	20.3	14.0	16.9
Avg	55.2	78.3	52.9	81.2	33.8	40.2	25.2	33.6

Table B6. Actual and Predicted Yields for Ottawa, KS

	Corn		Milo		Wheat		Soybeans	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	--	--	33.0	101.3	30.0	20.0	--	--
1971	--	--	85.0	96.2	38.0	38.1	--	--
1972	98.0	91.0	77.0	96.3	37.0	45.1	--	--
1973	69.0	42.9	57.0	119.5	32.0	36.1	--	--
1974	33.0	53.8	39.0	77.5	27.6	45.1	--	--
1975	46.0	60.4	47.0	99.8	29.1	17.3	--	--
1976	36.0	0.0	42.0	20.7	19.7	20.4	--	--
1977	80.0	149.2	69.0	153.8	24.1	35.9	--	--
1978	63.0	64.1	60.0	70.3	27.4	33.7	--	--
1979	93.0	64.7	82.0	85.6	44.3	26.6	--	--
1980	27.0	0.0	35.0	38.8	37.3	32.3	--	--
1981	103.0	167.4	78.0	158.0	27.0	45.1	--	--
1982	77.0	118.7	70.0	113.3	19.7	45.1	--	--
1983	30.0	39.8	42.0	36.8	36.8	45.1	--	--
1984	58.0	78.6	50.0	65.4	29.1	45.1	9.1	21.9
1985	95.0	86.4	80.0	116.1	30.7	45.1	28.0	44.1
1986	101.0	73.5	91.0	142.5	30.0	45.1	36.0	44.1
1987	79.0	94.0	78.0	101.3	33.0	30.2	31.0	39.0
1988	85.0	19.7	77.0	51.3	40.3	16.7	17.0	15.1
1989	84.0	79.3	79.0	113.9	35.3	45.1	32.0	44.1
1990	70.6	109.4	84.0	100.4	32.3	25.8	20.0	38.6
1991	39.5	1.6	45.0	32.0	39.0	26.6	16.0	5.9
1992	121.0	80.9	100.0	97.8	36.5	45.1	42.0	37.4
1993	61.4	193.7	59.0	200.2	25.1	29.7	25.0	44.1
1994	82.0	113.4	94.0	72.8	33.7	45.1	35.0	25.4
1995	68.0	141.2	57.0	130.3	26.0	17.6	28.0	44.1
1996	--	--	83.0	155.3	41.0	45.1	36.0	44.1
1997	--	--	91.0	115.8	49.0	30.0	37.0	44.1
1998	--	--	86.0	118.9	39.0	45.1	28.0	44.1
1999	--	--	73.0	122.3	34.0	6.9	26.0	44.1
2000	--	--	65.0	47.8	41.0	35.8	10.0	13.4
2001	--	--	71.0	97.4	55.0	23.8	29.0	37.2
Avg	70.8	80.1	68.1	98.4	33.8	34.0	27.0	35.0

Table B7. Actual and Predicted Yields for Parsons, KS.

	Corn		Milo		Wheat		Soybeans	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1970	--	--	34.0	92.1	33.0	17.5	--	--
1971	--	--	54.0	78.0	34.0	31.0	--	--
1972	51.0	35.7	49.0	79.3	39.0	45.1	--	--
1973	61.0	15.8	57.0	92.1	30.0	45.1	--	--
1974	27.0	67.6	34.0	92.1	23.2	45.1	--	--
1975	42.0	75.6	41.0	89.1	23.5	29.4	--	--
1976	63.0	114.4	54.0	92.1	29.3	26.6	--	--
1977	78.0	114.4	62.0	92.1	38.2	38.0	--	--
1978	46.0	31.3	44.0	58.0	24.2	42.4	--	--
1979	73.0	77.6	73.0	80.1	43.1	41.6	--	--
1980	32.0	2.8	22.0	43.8	37.9	19.6	--	--
1981	66.0	44.0	53.0	59.2	39.2	45.1	--	--
1982	58.0	82.7	57.0	92.1	28.8	45.1	--	--
1983	33.0	69.2	35.0	49.6	28.5	45.1	--	--
1984	55.0	20.7	47.0	23.8	32.2	45.1	12.3	0.0
1985	65.0	114.4	69.0	92.1	23.5	33.7	25.0	39.6
1986	81.0	34.1	70.0	92.1	24.2	45.1	21.0	27.7
1987	112.0	66.7	72.0	92.1	23.6	45.1	23.0	17.4
1988	68.0	55.0	83.0	63.5	35.6	27.4	19.0	16.6
1989	49.0	76.8	70.0	92.1	36.2	45.1	18.0	24.5
1990	43.5	77.4	69.0	92.1	23.4	23.6	14.0	3.3
1991	37.5	46.9	46.0	57.4	32.6	36.2	20.0	6.3
1992	70.0	114.4	97.0	92.1	43.0	45.1	23.0	44.1
1993	52.0	114.4	76.0	92.1	28.2	45.1	19.0	44.1
1994	53.0	114.4	88.0	66.2	34.5	45.1	32.0	14.0
1995	60.0	114.4	59.0	92.1	15.0	6.4	17.0	32.6
1996	--	--	73.0	92.1	27.0	39.6	22.0	28.8
1997	--	--	84.0	92.1	56.0	40.5	30.0	39.4
1998	--	--	85.0	92.1	38.0	45.1	18.0	40.8
1999	--	--	47.0	92.1	23.0	39.1	11.0	14.8
2000	--	--	84.0	92.1	40.0	37.3	9.0	19.4
2001	--	--	76.0	80.1	37.0	45.1	35.0	16.1
Avg	57.3	70.0	61.4	80.6	32.0	37.7	20.5	23.9