THE USE OF ANALYTICAL MODELS IN DETERMINING CROP ALLOCATIONS FOR KANSAS

by

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TABLE OF CONTENTS

LIST OF TABLES

(List of Tables Continued)

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The purpose of this study was two-fold: (1) The first part was concerned with measuring the relative influence of acreage and yield changes on crop production for Kansas. It is evident that the total production of any crop depends on the number of acres and the yield per acre. But frequently the question arises: Are changes in acreage or changes in yields more instrumental in causing variation in total production experienced from year to year? A least squares regression method was used to measure the relative effects of changes in total crop production due to acreage and due to yields. (2) The second part was to estimate the percentage of acres devoted to each of the major crops on the basis of maximizing returns. This was done by finding the total acres of cropland devoted to the major crops and then finding what percent each of the major crops shared in the total acreage. The actual percentages were computed first which were needed later for comparison with the estimated results.

Two methods were used for estimation: (a) The first method was the use of linear programming. With this method the year, 1961, was the only year used for estimating purposes. The data for previous years were used in setting up constraints and cost functions. (b) The second method employed was the use of the game theory method. Estimates were calculated for each year during a twenty-year period for each of the major crops. The estimates obtained by this method were then correlated with the actual use of cropland by the major crops for the same twenty-year period.

Data

The study was conducted on each of the type-of-farming areas in Kansas. It was approached in this manner for two reasons: (1) The type-of-farming areas were determined on physical, biological, and economic factors, these being the important factors determining the adaptation of various crops in different areas. The basis of classifying the counties of Kansas into areas was: (a) the percentage of farm land in different crops and pastures; (b) the kind and number of livestock per 100 acres of farm land; (c) the trends of the acreage of crops and numbers of livestock; (d) the number and percentage of farms of a given type; and (e) the acreage and percentage of farm land occupied by farms of a given type. Stratifying in this manner gave homogeneity within areas.[1] (2) The crop data for each county, which is published in The Biennial Reports by the State Board of Agriculture, have been compiled for the type-of-farming areas by the Economics Department of Kansas State University.[2] Kansas is thus divided into fifteen type-of-farming areas, numbering from the east to the west as shown in Fig. 1.

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[1]Leo M. Hoover, Kansas Agriculture After 100 Years, Kansas Agricultural Experiment Station Bulletin 392 (Manhattan: Kansas State University of Agriculture and Applied Science, August, 1957), p. 15.

[2]Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1941-60).

The major crops considered for the study were wheat, corn, oats, barley, and grain sorghum. The same crops were considered for each of the areas. In addition to the five crops mentioned, soybeans were included in estimating yield and acreage changes for Area 1 through Area 5. Data were gathered for a twenty-year period starting from 1941 to 1960. The data used were based on seeded acres and yields for all crops except grain sorghum. Actual seeded acres and yields have not been recorded for grain sorghum. It was desirable to use data on seeded acres and yields since this gave an actual measure of changes in the cropping system from year to year.

Assumptions

A similar study was done in Illinois in 1959 by Earl R. Swanson, Department of Agricultural Economics, University of Illinois, which is referred to from time to time throughout this study.[3] Swanson made one very basic assumption for his study. He assumed that farmers are reluctant to alter their cropping system to any large degree from year to year. A question arises whether or not this same assumption holds true for Kansas. Some of the findings would indicate that it does not hold true for Kansas, at least in the western part of the state.

It is understood that farmers collectively determine the use of the agricultural land in the state, realizing certain government acreage control programs. Each crop competes with its alternatives in the selection

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[3]Earl R. Swanson, Short-Run Acreage Adjustments in Illinois, Illinois Agricultural Experiment Station Volume 1, No. 2 (Urbana: University of Illinois, July, 1961), 24-32.

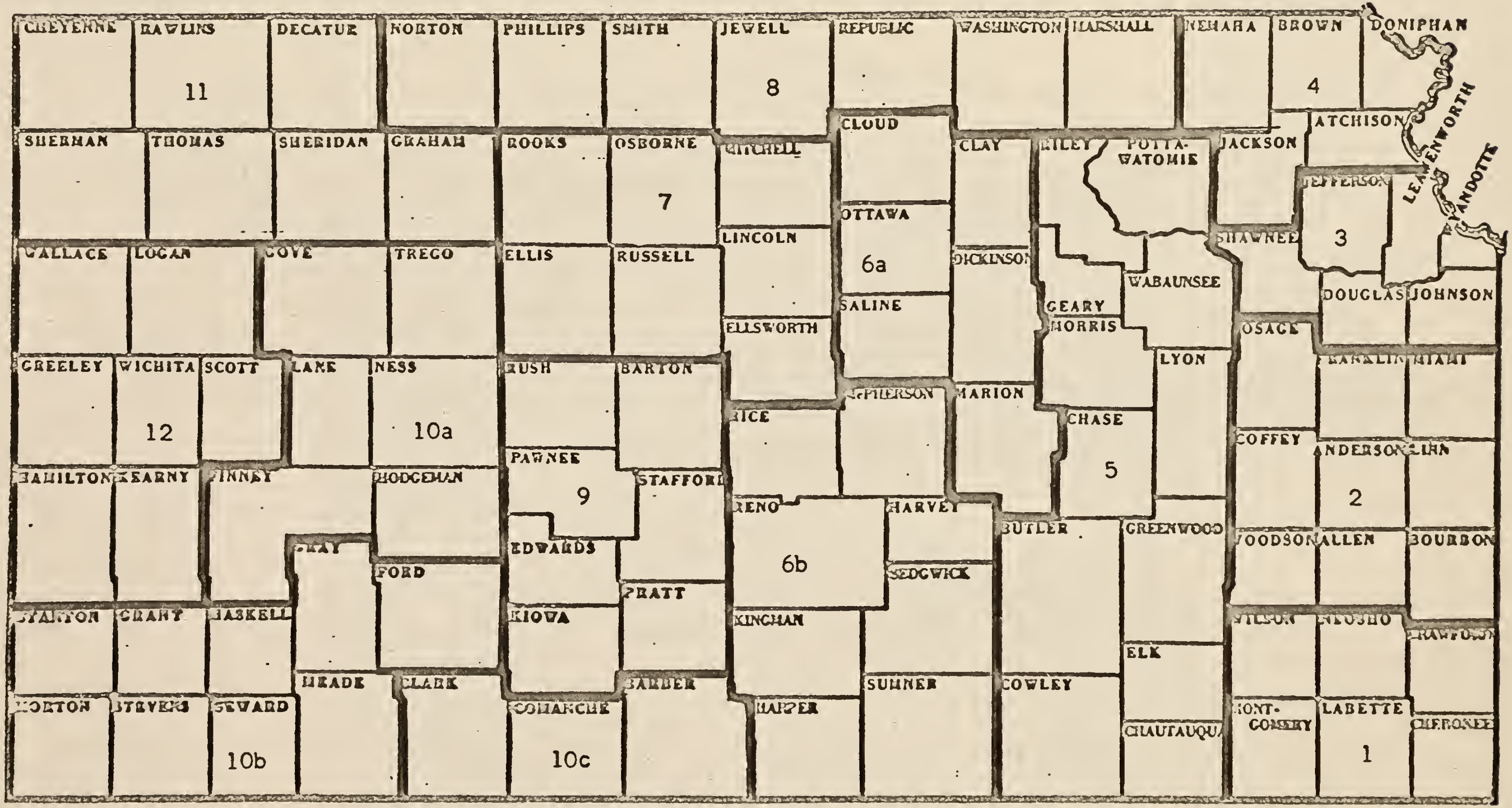

Fig. 1.--The Fifteen Types-of-Farming Areas in Kansas.

of a cropping system, and each year there is opportunity for farmers to revise crop-acreage plans in response to changes in expectations concerning prices and yields, government programs, and other considerations. For estimating crop allocations by the two methods explained earlier, it was assumed that farmers attempted to maximize profits under certain conditions or constraints. These conditions were assumed to be a known number of acres in each farmer's cropping system, the elasticity of demand for each crop, government control programs, and market prices.[4]

Problems

As already indicated, the Illinois study was based on the assumption that farmers are reluctant to make large changes in their cropping system once one is established. One measure of the willingness of farmers to adjust to changes under the conditions which cropping plans are developed, is the extent to which crop-acreage adjustments have been made in the past. As an indicator for this the percentage acreage adjustments, Table 2 in Chapter Two, were divided into those years in which planted acres increased from the previous year, and those years in which decreases occurred. Table 1 on the following page gives the results from the study in Illinois.[5] Here, also, the percentage acreage adjustments were divided into those years in which planted acres increased from the previous year,

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[4]The word "farmer" will be used interchangeably to refer to the farmers of an entire area or a single farmer within an area.

[5]Earl R. Swanson, Short-Run Acreage Adjustments in Illinois, Illinois Agricultural Experiment Station Volume 1, No. 2 (Urbana: University of Illinois, July, 1961), 24-32.

TABLE 1.--Acreage adjustments of principal Illinois crops expressed as average percentage increases and decreases from preceding year 1940-1959.[a]

Crop Reporting District	CORN		SOYBEANS		OATS	
	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.
Northwest	4.2(12)[b]	-2.1(7)	17.4(9)	-14.7(10)	2.5(9)	-3.3(10)
Northeast	4.3(10)	-2.4(9)	19.0(8)	-10.0(11)	2.5(8)	-4.9(11)
West	7.7(11)	-5.4(8)	9.7(11)	-10.3(8)	14.2(8)	-9.1(11)
Central	6.1(12)	-5.5(7)	15.5(9)	-9.0(10)	6.0(9)	-6.9(10)
East	4.7(12)	-4.9(7)	10.6(10)	-7.6(9)	5.8(7)	-6.8(12)
W-Southwest	8.8(12)	-8.2(7)	11.7(11)	-6.7(8)	26.3(6)	-13.3(13)
E-Southeast	9.1(12)	-10.4(7)	7.8(11)	-3.2(8)	20.4(9)	-19.5(9)
Southwest	12.4(10)	-8.2(9)	15.3(16)	-4.7(3)	29.4(6)	-15.6(13)
Southeast	7.5(13)	-10.0(6)	12.6(15)	-8.2(4)	51.7(6)	-22.4(13)
STATE	6.2(11)	-5.4(7)	9.2(11)	-5.6(8)	10.4(5)	-6.1(13)

Crop Reporting District	WHEAT		HAY		PLOWLAND PASTURE	
	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.
Northwest	12.3(9)	-14.1(10)	4.1(8)	-3.9(11)	2.0(6)	-4.2(13)
Northeast	17.4(11)	-14.2(8)	2.5(9)	-4.5(10)	5.4(6)	-5.3(13)
West	19.0(9)	-13.5(10)	17.7(8)	-12.0(11)	5.4(8)	-7.5(11)
Central	13.0(10)	-15.3(9)	11.6(8)	-8.8(11)	4.6(7)	-7.5(12)
East	25.1(12)	-19.2(7)	12.7(6)	-7.6(13)	6.4(6)	-7.6(13)
W-Southwest	10.7(12)	-17.4(7)	12.1(7)	-11.4(12)	6.3(4)	-7.8(15)
E-Southeast	14.7(14)	-18.8(5)	14.4(4)	-10.3(15)	3.0(3)	-6.2(16)
Southwest	6.9(9)	-9.1(10)	7.4(7)	-6.9(12)	6.7(8)	-8.4(11)
Southeast	11.8(13)	-15.4(6)	9.4(4)	-7.8(15)	7.4(5)	-7.3(14)
STATE	8.7(13)	-17.8(6)	7.1(7)	-5.7(12)	2.3(5)	-5.4(14)

[a]Data are based on planted acres of the grain crops, harvested acres of hay, and the land reported in plowland pasture irrespective of its use.

[b]Numbers in parentheses indicate the number of year-to-year increases or decreases entering the average percentage change presented. For the state as a whole, there was no change in the planted acres of corn from 1953 to 1954 and of oats from 1955 to 1956.

and those years in which decreases occurred. For example, for the northwest district, corn acreage increased over the previous years 12 times, but decreased only seven times. For the years in which increases occurred, the increase in planted corn was, on the average, 4.2 percent; for years in which decreases occurred, the average decrease was 2.1 percent. In general, the major crops show less tendency for pronounced year-to-year shifts in acreage. Thus, the results in Table 1 offer reasonable belief for making such an assumption for Illinois.

In Kansas, on the other hand, the year-to-year shifts between major crops were more pronounced. As an example, corn (planted) had an average percentage increase of 41.2 and an average percentage decrease of 20.3 percent. These percentages denote shifts in corn acreage for the whole state of Kansas and not for any one particular area. Some of the areas actually displayed larger percentage changes than the above figures. The changes in land use represent a pronounced difference between the two states. The major reason for these differences was apparently due to different climatic conditions.

The average yearly rainfall for Illinois is more abundant and more stable from year to year than that experienced in Kansas. This is particularly true for western Kansas where the highly variable weather conditions cause yields to fluctuate more than they do in the eastern part of the state and other more humid areas. The average annual precipitation for western Kansas ranges from 16 to 24 inches. The range for the eastern one-half of the state varies from 26 inches to 40 inches in the extreme southeast corner of Kansas.

There is a good reason for the distribution of annual precipitation. Practically the only source of moisture for precipitation in Kansas is the Gulf of Mexico. A map of the United States shows that Kansas lies just a little too far to the west to be under the major portion of the warm, moist, southwesterly flow of air from the Gulf. The southeastern section of Kansas is frequently favored by this flow of air from the Gulf and thus has the highest annual rainfall. Toward the western part of the state, this type of flow is less frequent, and consequently, there is less rain.[6] Historically, the high variability of rainfall has caused western Kansas at certain times to be known as the Great American Desert and the Dust Bowl. When poor yields coincide with poor prices and when this condition persists over a period of years, many farmers suffer acute financial distress.

The problem facing the farmer particularly in western Kansas seems to fall largely in the general area of uncertainty. It has become increasingly more important for this farmer to have a flexible cropping system with a combination of various crops. This has a tendency to reduce the number of years in which there would be a complete crop failure.[7] The importance of the degree of flexibility for the Kansas farmer will become evident in Chapter Two. The relative stability of a cropping system becomes important when one tries to estimate the percentage of each of the five major crops for each area in Kansas. The increase in flexibility of

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[6]L. Dean Bark, Rainfall Patterns in Kansas, Kansas Agricultural Experiment Station Reprint No. 9 (Manhattan: Kansas State University of Agriculture and Applied Science, May, 1961).

[7]Emery N. Castle, Adapting Western Kansas Farms to Uncertain Prices and Yields, Kansas Agricultural Experiment Station Technical Bulletin 75 (Manhattan: Kansas State University of Agriculture and Applied Science, February, 1954), 5-42.

land use in Kansas relative to Illinois makes the land use pattern more difficult to predict and thus it may be a major reason for Kansas estimates to be farther from the actual land use pattern than those for Illinois.

CHAPTER II

THE DEGREE OF YEAR-TO-YEAR ACREAGE ADJUSTMENTS

Table 2 shows the year-to-year changes in acreages devoted to different crops which can be interpreted as the willingness of farmers to make adjustments as changes in the conditions under which cropping plans are developed for Kansas occur. The percentage changes are shown for the 15 type-of-farming areas for Kansas. At the bottom of the chart are shown the average changes for the state which are computed from the total state acreage figures. Over the twenty-year period, 1941-1960, the percentage acreage adjustments are divided into those years in which planted acres increased from the previous year, and those years in which decreases occurred. For example, wheat in Area 5 had percentage increases after 10 years and decreases for 9 years over the twenty-year period. For the years in which increases occurred, the increase in planted wheat acres was, on the average, 11.4 percent; for years in which decreases occurred, the average decrease was 12.3 percent.

The average percentage changes in Table 2 obscure some substantial shifts in planted acres in individual years. The line graphs in Appendix II for each of the fifteen areas indicate the actual year-to-year shifts. In Fig. 2 through Fig. 6, a double vertical bar chart was used to compare the average increase to the average decrease for the twenty-year period

TABLE 2.--Acreage adjustments of principal Kansas crops expressed as average percentage increases and decreases from preceding year 1941-1960[a]

Crop Reporting Area	WHEAT		CORN		OATS	
	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.
1	13.9(8)[b]	45.2(11)	14.3(11)	20.8(8)	26.7(9)	26.5(10)
2	23.2(11)	19.3(8)	10.2(12)	15.1(7)	32.8(9)	27.1(10)
3	12.1(10)	15.2(9)	08.8(10)	08.4(9)	26.3(8)	22.5(11)
4	26.6(9)	13.3(10)	07.4(11)	08.6(8)	16.7(8)	16.8(11)
5	11.4(10)	12.3(9)	17.6(6)	08.9(13)	20.8(10)	26.1(9)
6a	06.9(10)	10.4(9)	21.5(10)	13.0(9)	24.4(9)	20.0(10)
6b	07.6(11)	12.0(8)	39.9(7)	19.4(12)	23.8(12)	36.3(7)
7	11.5(9)	10.5(10)	24.5(10)	28.3(9)	32.9(7)	21.0(12)
8	12.9(8)	10.2(11)	14.8(7)	11.0(12)	15.5(9)	21.9(10)
9	14.8(9)	11.8(10)	46.0(10)	38.3(9)	42.3(7)	25.5(12)
10a	31.2(9)	15.1(10)	06.3(8)	28.4(11)	29.0(9)	29.2(10)
10b	45.4(7)	11.3(12)	90.2(10)	31.4(9)	64.4(9)	42.3(10)
10c	18.4(9)	12.1(10)	77.8(8)	32.1(11)	65.5(9)	35.8(10)
11	11.5(9)	09.8(10)	43.4(6)	18.5(13)	26.3(9)	27.0(10)
12	49.1(10)	16.8(9)	94.9(7)	22.0(12)	65.3(10)	46.3(9)

TABLE 2 - Continued

Crop Reporting Area	BARLEY Inc.	BARLEY Dec.	SORGHUM Inc.	SORGHUM Dec.
1	185.4(6)	24.4(13)	75.7(8)	21.2(11)
2	147.6(7)	31.6(12)	42.9(9)	20.2(10)
3	110.4(8)	31.6(11)	47.1(13)	32.5(6)
4	80.5(11)	37.3(8)	81.0(11)	33.7(8)
5	119.7(8)	32.7(11)	34.8(9)	21.1(10)
6a	170.5(11)	53.2(8)	56.3(12)	32.1(7)
6b	99.7(9)	37.8(10)	43.1(12)	23.3(7)
7	62.8(10)	39.9(9)	78.5(11)	32.6(8)
8	52.7(11)	46.2(8)	80.0(10)	30.3(9)
9	55.6(10)	35.1(9)	75.8(10)	26.1(9)
10a	33.4(10)	30.1(9)	17.2(10)	44.3(9)
10b	96.9(7)	31.2(12)	79.0(10)	33.2(9)
10c	104.4(10)	43.8(9)	140.5(9)	34.9(10)
11	55.1(7)	25.3(12)	142.1(9)	37.9(10)
12	71.7(8)	31.1(11)	177.6(10)	48.9(9)

[a]Data are based on seeded acres for wheat, corn, oats, barley; harvested acres for grain sorghum.

[b]Numbers in parentheses indicate the number of year-to-year increases or decreases entering the average percentage change presented. For the state as a whole, there was no change in the seeded acres of wheat from 1945 to 1946, from 1958 to 1959; oats from 1953 to 1954, from 1955 to 1956.

for each of the crops considered. The frequency of the number of percentage increases and decreases is shown atop each set of bars for that particular area. Again, this obscures the actual shifts in planted acres for individual years. But the charts are convenient for making comparisons of average percent increases and decreases between areas. To indicate year-to-year shifts it may be well to look at a few individual years during the twenty-year period.

The war-time incentives made the Kansas 1942 crop production the second largest on record at that date, exceeded only by that of 1931. Although the acreage in crops declined about 1.4 percent in 1942, production was 21 percent higher than that of the previous year. Outstanding high yields were made possible by a combination of unusually favorable weather and war-time demands that called for maximum effort, insuring a market for practically everything that farmers could produce. Even though seeded acres of wheat were 15 percent below the 1941 period for Kansas, the wheat crop was the largest exceeded only by the 1931 crop. Area 1 had the largest decrease, 85.9 percent, in wheat acreage, but a considerable increase in the acreage of barley and corn as compared to that of the previous year. For the state, barley had a seeded acreage increase of 24.2 percent while corn increased 24.0 percent. The corn crop for that year was the largest since 1932, again reflecting the war-time incentives.[8]

Total agricultural production was down in 1945. There was a decrease in seeded acres of corn, oats, and barley as well as a decrease in harvested

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[8]Biennial Reports of the State Board of Agriculture (Kansas State Board of Agriculture, 1942).

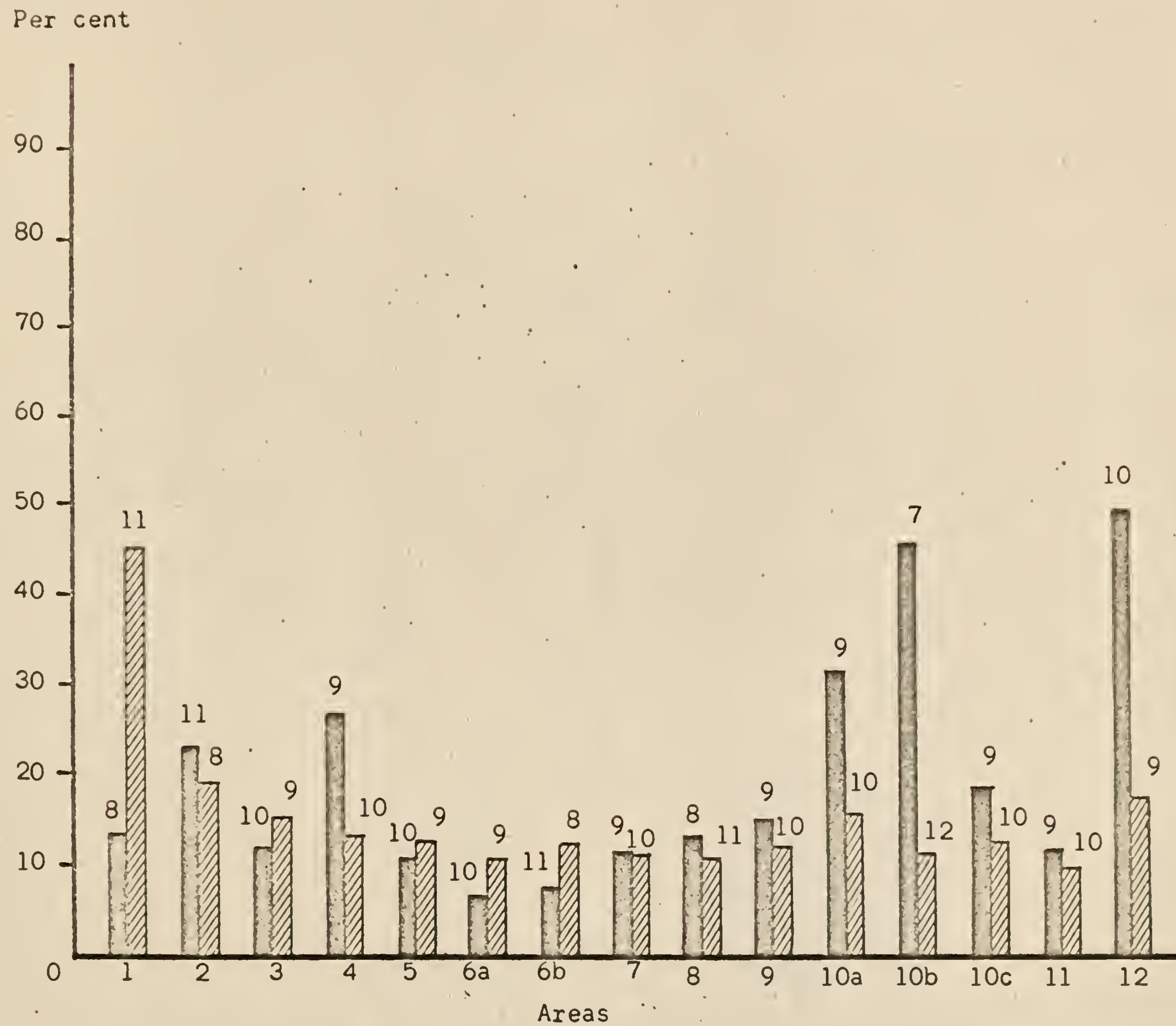

Fig. 2.-- Bar chart of acreage adjustments for wheat in Kansas expressed as average percentage increases and decreases from preceding year 1941 - 1960.

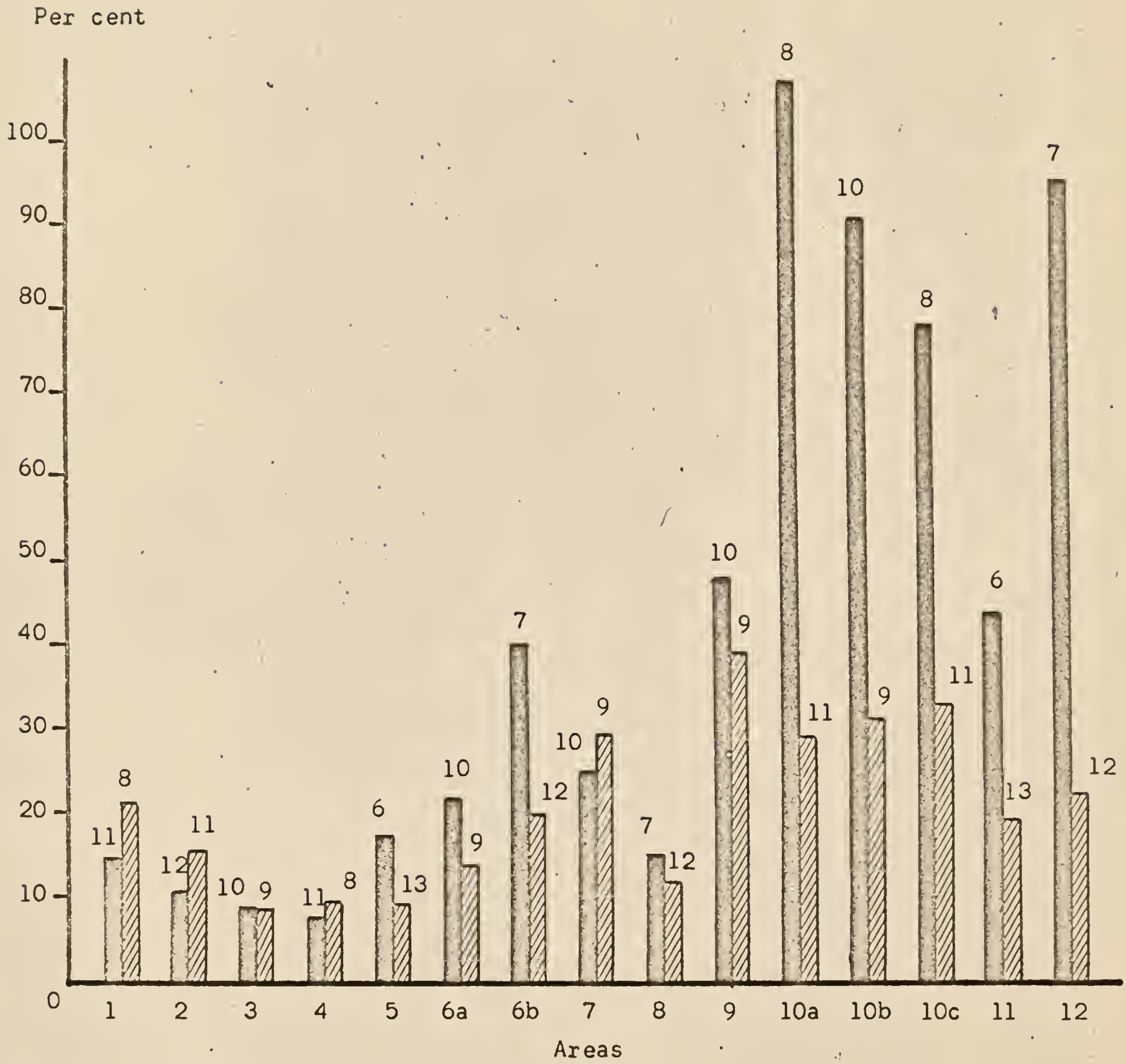

Fig. 3. Bar chart of acreage adjustments for corn in Kansas expressed as average percentage increases and decreases from preceding year 1941 - 1960.

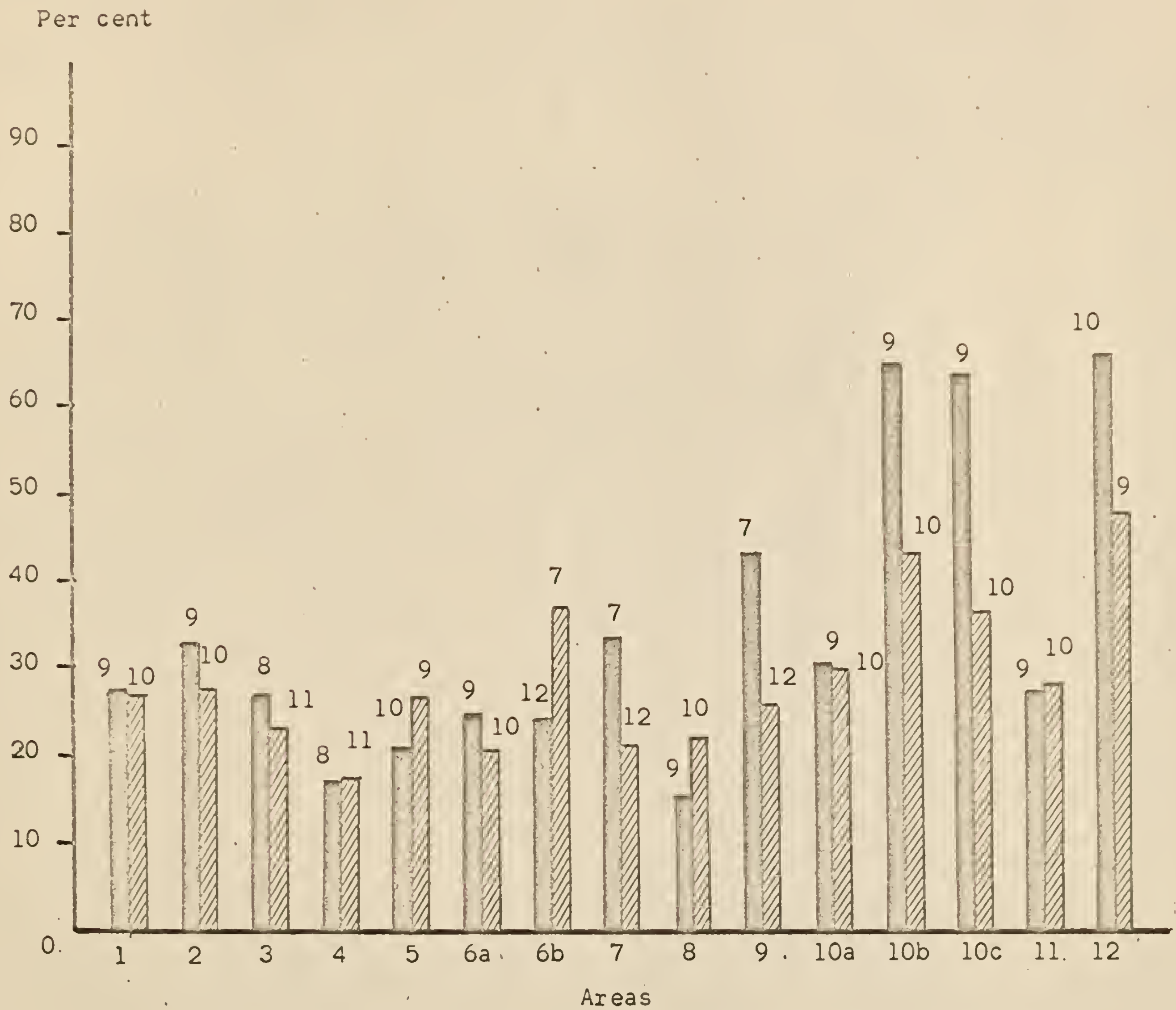

Fig. 4.--Bar chart of acreage adjustments for oats in Kansas expressed as average percentage increases and decreases from preceding year 1941 - 1960.

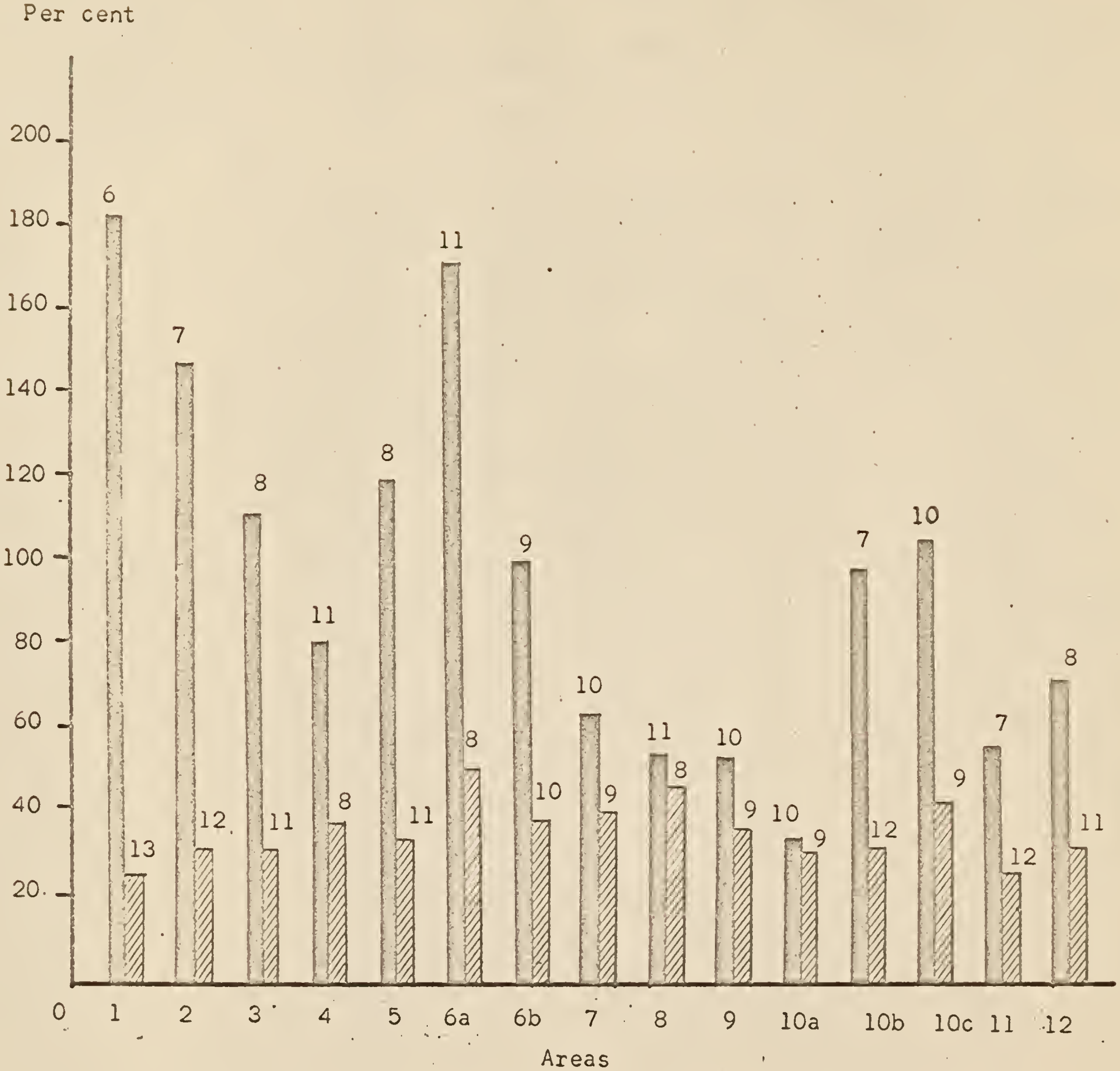

Fig. 5.--Bar chart of acreage adjustments for barley in Kansas expressed as average percentage increases and decreases from preceding year 1941 - 1960.

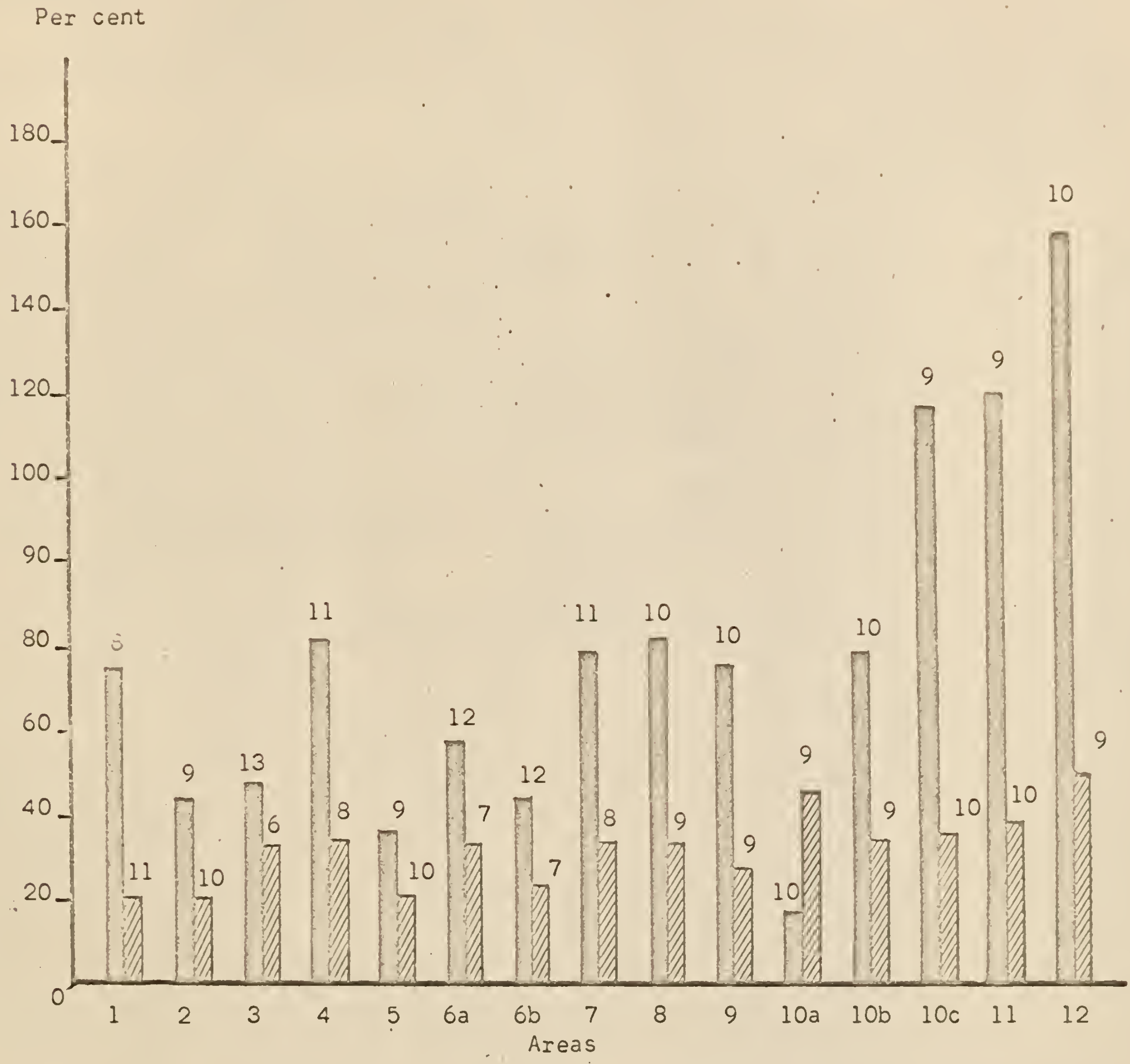

Fig. 6.--Bar chart of acreage adjustments for grain sorghum in Kansas expressed as average percentage increases and decreases from preceding year 1941 - 1960.

Notes: The numbers atop each bar indicate the frequency of increases and decreases for the twenty-year period.

The solid bars indicate increases and the hatched bars indicate decreases.

acres of grain sorghum. Barley had the largest percentage decrease, 57.8 percent, in seeded acres. Abnormal weather conditions at planting time played a large role in the cutback of seeded acres.[9]

From the years 1949 to 1952, the number of seeded acres of corn was increasing from year to year. The average increase in the corn acreage for this period was 3.1 percent. A high amount of moisture and cool growing seasons during this period made conditions excellent for bumper corn crops.[10] This period ended in 1953 when Kansas was faced with five years of hot, searing winds and a lack of moisture during the summer growing season.[11] For the state of Kansas the average decrease for corn during this period was 10.8 percent in seeded acres. Areas 1, 8, and 12 had the largest cutback in seeded acres of corn. During this drought period farmers were summer fallowing a higher number of acres of cropland, thus taking a larger number of acres of cropland out of production. The acreage of corn in 1956 reached an 83-year low for the state.[12] Farmers planted only 1,694,000 acres for all purposes, less than two thirds of the 10-year average and less than one fifth of the peak of more than 9 million acres reached in 1917.

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[9] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1945).

[10] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1949-52).

[11] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1953).

[12] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1956).

During this period there was an indication of a diverting of wheat and corn acres to sorghum crops. The reduction in wheat allotments accentuated this tendency further. The 1954 acreage of sorghums was Kansas' largest on record, due largely to heavy abandonment of wheat in the west central and southwestern part of the state. In 1957 sorghum was the Kansas "Crop of the Year," exceeding wheat in acreage and production for the first time in the state's history.[13] The percent increase in seeded acres for grain sorghum was 278.2 percent above that of 1956. Kansas farmers planted 8,166,000 acres of sorghum, one fourth more than in any previous year. On the other hand the wheat crop, totaling 100 million bushels, was the smallest since 1963.

During the years of 1958 to 1960 there was an increase in seeded acres of corn for each year during this period.[14] The average percent increase was 9.3 percent for Kansas. The growing season for corn during this period was favorable. The 1959 year was generally a good year for crop production, but a second stress was adding to the already uncertain condition of climate. Sharply rising expenses and declining farm prices caught many of the farmers in a cost-price squeeze. In the last few years of the 20-year period there appeared to be more acres going into soybeans where there was still a relatively good market. This was only true in those areas suitable to soybean production.

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[13] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1957).

[14] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1958-60).

In 1959, prices of crops averaged the lowest in 14 years with most products a little below a year earlier. Table 3 gives some indication of declining farm prices in crop production for the 1958 to 1960 period. This is compared with the 1952 to 1954 period, a period in which farm prices were relatively good. The largest percentage price drop was in corn, followed by barley and grain sorghum between the two periods. Wheat price had the smallest percentage decrease; 18.4 percent. This small decrease was due largely to the government acreage control programs and price supports for wheat. In 1959, soybean production was the second largest in history, totaling 9,114,000 bushels; 2 percent less than the 1958 record crop. Soybeans were planted on 447,000 acres with 434,000 acres cut for beans. A new high record in soybeans for the state was set in 1960 totaling 12,892,000 bushels. Many farmers who were unable to get their intended oats acreage seeded turned to soybeans and 594,000 acres were planted, of which 586,000 acres were harvested for beans. Oats seedlings were seriously delayed by snow cover during late February and most of March.[15]

After taking a close look at a few individual years, the pronounced year-to-year percentage shifts in acreages become apparent. This is indicated by Fig. 2 through 6. Wheat tended to be the most stable crop in the cropping system as shown by Fig. 2. Only in Areas 1 and 12 were there significant fluctuations in percentage changes in seeded acres of wheat. In Area 1, the bar chart shows a significant average percentage decrease of acres seeded to wheat. Most of this was due to the period between 1942 and 1945. The acreage seeded to wheat in 1943 was 214.4 percent less than the

[15] Biennial Reports of the State Board of Agriculture, (Kansas State Board of Agriculture, 1960).

TABLE 3.--Percent change in price from the 1952-54 period to the 1958-60 period for the five major crops grown in Kansas[a]

	WHEAT		CORN		OATS	
	52-54	58-60	52-54	58-60	52-54	58-60
	$2.09	$1.70	$1.76	$1.05	$1.03	$0.59
	2.04	1.75	1.61	1.04	0.83	0.65
	2.22	1.75	1.62	0.97	0.86	0.66
Total	$6.35	$5.20	$4.99	$3.06	$2.72	$1.90
Av.	$2.12	$1.73	$1.66	$1.02	$0.91	$0.63
Percent decrease		18.4%		38.6%		30.8%
	BARLEY		GRAIN SORGHUM		SOYBEANS	
	52-54	58-60	52-54	58-60	52-54	58-60
	$1.26	$0.74	$1.56	$0.95	$2.69	$1.85
	1.16	0.74	1.12	0.80	2.69	1.85
	1.03	0.70	1.21	0.73	2.69	1.85
Total	$3.45	$2.18	$3.89	$2.48	$8.07	$5.55
Av.	$1.15	$0.73	$1.30	$0.83	$2.69	$1.85
Percent decrease		36.5%		36.2%		31.2%

[a]*Biennial Reports of the State Board of Agriculture*, (Kansas State Board of Agriculture, 1952-54, 1958-60).

1942 acreage. A 214.4 percent change in wheat for Area 1 would not affect total acres of wheat for Kansas as would the same percent change in western Kansas. Wheat in Area 1 made up only around 33 percent of the total acreage devoted to the five crops whereas in Area 11 around 75 percent of the total acreage for the five crops was devoted to wheat. But it is not the absolute shift in acres, but the relative shift from year-to-year that is important in estimating procedures. In Fig. 3, corn appeared to be somewhat stable in Area 1 through Area 9. Areas 10-a through 12 showed to be very unstable as far as corn production is concerned. This was to be expected, and was due to dry weather conditions and a small number of acres devoted to corn in these areas. This is shown by the line graphs in the Appendix. Oats began to show unstable conditions from Area 6-b through Area 12. Again, this was due largely to a low number of acres devoted to oats for these areas. Barley seemed to be somewhat unstable in all areas in regard to percentage changes in acreage. This was due to a small production of barley in Kansas relative to wheat, corn, and grain sorghum. Grain sorghum showed to be the most unstable of the five major crops. This was probably due to two reasons: (1) The data collected for grain sorghum was for harvested acres and yields and not on seeded acres and yields. This would include abandoned acres of grain sorghum and would cause acreage shifts from year to year to be larger. It was necessary to use harvested acreage figures since data for seeded acres have not been compiled for grain sorghum. (2) A second reason for relatively great sorghum acreage fluctuations was that grain sorghum was used as a substitute for wheat in the cropping system under certain conditions. A situation in which this would occur could be a dry, hot fall during wheat-sowing time. This would cause a large percentage of abandoned acres of wheat to be devoted to grain sorghum the following spring. A situation such as this would not be unlikely for western Kansas. Substitution also arises between the grain sorghum and corn and grain sorghum and oats; the degree of these substitutions depends to a large degree on weather conditions during the seeding time. Since 1947, the yearly crop production totals showed an increase in grain sorghums. The increase has been mostly evident in the thirteen southwestern Kansas counties, and is probably due to the increased use of irrigation in this area. The increased use of irrigation could be listed as a third factor causing such a high average percentage increase in seeded acres as shown in Fig. 6 for Area 10-b to Area 12. Irrigation has increased considerably in western Kansas during the past several years, and it has been estimated that 14 percent of the cropland in these thirteen counties is irrigated. Six percent of all grain sorghum acres harvested and 15 percent of the total production in Kansas in 1957 was irrigated.[16]

When comparing the year-to-year acreage adjustment between Kansas and Illinois, the average state increase in Illinois for wheat was only 8.7 percent and an average decrease was 17.8 percent for the 1940 to 1959 period. During the 1941 to 1960 period for Kansas, the average percent increase in wheat acreage was 13.8 percent and an 11.6 percent average decrease. The percentage figures for Kansas were not too different from

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[16]Donald W. Grimes and Jack T. Musick, <u>How Plant Spacing, Fertility, and Irrigation Affect Grain Production in Southwestern Kansas</u>, Kansas Agricultural Experiment Station Bulletin 414 (Manhattan: Kansas State University of Agriculture and Applied Science, December, 1959), p. 3.

the Illinois figures. The noticeable difference was in area-to-area comparisons between the two states. The eastern part of Illinois seemed to fluctuate the most in acreage changes relative to other areas in Illinois. The average increase was 25.1 percent and an average decrease was 19.2 percent. Area 12 in Kansas had an average increase of 49.1 percent and an average decrease of 16.8 percent. In general those areas in Kansas that experienced large average percentage increases had low average percentage decreases. The same inverse relationship was true for those areas that had high average percentage decreases. This relationship was not true for all areas nor did it hold true for the five crops. But this does give some explanation why the state average percentage changes were fairly low when actually some of the individual areas had witnessed large shifts. As for oats, Illinois had a percentage increase for the state of 10.5 percent and an average decrease of 6.1 percent. Comparing this with Kansas, Kansas had an average percentage increase in oat acreage of 34.0 percent and a decrease of 28.3 percent. The changes of these magnitudes represent tremendous differences in the acreage adjustments between the two states. Taking corn as another example, Illinois had a percent increase of 6.2 as compared to 41.2 percent for Kansas; a percent decrease of 5.4 for Illinois as compared to 20.3 percent for Kansas.[17] The state averages for Kansas obscure the actual increases and decreases of the individual areas due to the inverse relationship between average year-to-year increases and average year-to-year decreases in individual areas. It was the acreage shifts within the type-of-farming areas that were estimated,

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[17]The percentages are from Tables 1 and 2.

and thus, the average percentage acreage shifts within these areas were of more importance than the acreage shifts for the state as a whole.

The percentage changes in Table 1 and Table 2 represent responses to many different dynamic factors in the setting in which farmers operate and decide on a cropping program. Such factors would be price-cost relationships, government programs, improved technology, etc. Although the historical average percentage changes in acres summarize a reaction to a mixture of events, weather conditions and price changes occupy the greater part of this mixture. After looking at a few individual years it becomes evident how abrupt changes in seasonal rainfall affect cropping systems for a Kansas farmer. History shows that the rainfall pattern for Kansas is cyclic in nature, i.e., the poor and good years tend to occur in cycles. A farmer may experience two to three years of dry, hot winds followed by several years of above average annual rainfall with a cool growing season. A period of below normal rainfall and above average temperatures may encourage a farmer to make an abrupt change in his cropping system. He will be encouraged to plant those crops that are able to stand a dry period. This would be especially true for western Kansas. Historical data tend to point this out. Also, the weather conditions at seeding time play a large role in affecting a farmer's cropping system. Cases were cited where actual decreases in seeded oat acres were due to a wet-cool planting period. These acres were usually used later for planting of sorghums or soybeans in the eastern part of the state. The cost-price squeeze in crop production caused a shift away from some crops to other crops which at the time seemed to offer a greater return as seen by an individual farmer. There was little way of estimating the relative importance of the cost-price squeeze causing a shift, but to only expect that it did have a great deal of importance. The same cost-price squeeze faced the Illinois farmer. The magnitude of the squeeze would be greater for a Kansas farmer in instances where poor yields coincided with poor prices and particularly when this condition persisted over a period of years. The cycles talked about are not predictable or of a regular duration, and it is difficult to establish statistically that such cycles occur. Farmers probably show a lagged response to a drought period. That is to say, farmers expect conditions for the forthcoming year to be similar to the present year, and thus base their cropping system for that year on the present conditions. The same would be for above normal conditions. They are unable to estimate when the shift from a drought period to a normal period will occur and there will be a tendency for them to respond during the second cropping season after the shift occurred. This cyclic tendency between good and bad years plus price changes have caused the Kansas farmer's cropping system to be somewhat more flexible than that for an Illinois farmer. The poor and good years reflect on total production of crops. A series of bad years will cut yields and may cause a diverting of acres away from one crop to a crop more adaptable to the prevailing conditions. Thus, the two variables, yield variability and acreage changes, have pronounced effect on the total production of crops. Their effects on crop production are discussed in the next chapter.

CHAPTER III

IMPORTANCE OF ACREAGE AND YIELD CHANGES IN YEAR-TO-YEAR PRODUCTION VARIATION

The objective of this chapter is to assess the relative stability of the land use on the cropping system.

Changes from one year to the next in total production of a crop are due to changes in total acres planted to that crop and changes in the yield per acre planted. A question often arises which of the two variables are more instrumental in causing variation in production normally experienced from year to year. The relative importance of these variables can be determined by least-squares regression.[18] It can be said that total production of a crop is a function of acres times yield. This can be expressed algebraically as follows:

$$P = A \times Y$$

where P is total production, A is acreage seeded, and Y is average yield per acre. The relationship can be expressed in a logarithmic form:

$$\log P = \log A + \log Y$$

When expressed as first differences of logarithms, to get changes from the preceding year, the equation becomes:

$$\Delta \log P = \Delta \log A + \Delta \log Y$$

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[18] S. M. Sackrin, "Measuring the Relative Influence of Acreage and Yield Changes on Crop Production," U. S. Agricultural Economics Research, Vol. IX, No. 4 (October, 1957), 136-39.

A least-squares regression was computed, with Δ log P as the dependent variable X_1, and Δ log A and Δ log Y as the independent variables X_2 and X_3, respectively. The only statistical coefficients required were b_{21} and b_{31}. Their sum will equal exactly 1.00. The coefficients may be interpreted as follows: on the average, for each 1 percent change in production from the preceding year, ____ percent is ascribable to X_2 (acreage changes) and ____ percent is ascribable to X_3 (yield changes). This follows because the coefficient b_{21} measures the change in X_2 associated with a one-unit change in X_1, while the coefficient b_{31} measures the change in X_3 associated with a one-unit change in X_1. As the data were expressed in first differences of logarithms, the unit change involved here was a one-percent change from the preceding year. This unit change was the exact sum of the changes in the two determining variables, hence the coefficients b_{21} and b_{31} represent the proportion that each comprises of the total.

Much of the computational labor consisted of obtaining the logarithms and computing the first differences. Below is an example to show the computational procedure in calculating b_{21} and b_{31}. The example illustrated is for Area 5 and the crop is corn. The data for this example for the twenty-year period is shown in Table 4.

The data was first expressed in terms of logarithms. The year-to-year changes in yields, production, and acres are shown in logarithms by subtraction. For an example, the production of corn in 1941 in Table 5 expressed in logarithms was 3.83283. For 1942 corn production was 3.54108. The difference found by subtraction was -0.29708 as shown in Table 6. The

TABLE 4.--Corn production records for area 5 from 1941 to 1960

Year	Production 10^{3a}	Acreage 10^{3a}	Yield
1941	6,805	610	11.2
1942	3,476	292	11.9
1943	3,578	288	12.4
1944	5,902	354	16.7
1945	6,345	422	15.0
1946	7,387	425	17.4
1947	9,460	507	18.7
1948	11,194	601	18.6
1949	9,805	636	15.4
1950	10,716	515	20.8
1951	5,402	571	9.5
1952	11,977	539	22.2
1953	11,778	589	20.0
1954	11,313	449	25.2
1955	8,820	427	20.7
1956	11,229	443	25.4
1957	9,809	438	22.4
1958	13,035	437	29.8
1959	10,809	454	23.8
1960	10,931	442	24.7

[a]The original data for production and acreage have been divided by 1,000 for ease of computation.

TABLE 5.--The data from Table 4 expressed in five-place logarithms

LOG P	LOG A	LOG Y	YEAR
3.83283	2.78533	1.04532	1941
3.54108	2.46538	1.06819	1942
3.55364	2.45939	1.08991	1943
3.77100	2.54900	1.22531	1944
3.80243	2.62531	1.16732	1945
3.86847	2.62839	1.23045	1946
3.97589	2.70501	1.27416	1947
4.04883	2.77887	1.28103	1948
3.99145	2.80346	1.17898	1949
4.03019	2.71181	1.31806	1950
3.73255	2.75664	0.94448	1951
4.07846	2.73159	1.34044	1952
4.07115	2.77012	1.31597	1953
4.05346	2.65225	1.41162	1954
3.94547	2.63043	1.36549	1955
4.05038	2.64640	1.43136	1956
3.99162	2.64147	1.35025	1957
4.11528	2.64048	1.47567	1958
4.03383	2.65706	1.35218	1959
4.03862	2.64542	1.38917	1960

TABLE 6.--The year-to-year changes expressed in logarithms.

LOG P (X_1)	LOG A (X_2)	LOG Y (X_3)	YEAR
-0.29708	-0.31995	0.02287	1941
0.01573	-0.00599	0.02172	1943
0.22501	0.08961	0.13540	1944
0.01832	0.07631	-0.05799	1945
0.06621	0.00308	0.06313	1946
0.12033	0.07662	0.04371	1947
0.08073	0.07386	0.00687	1948
-0.07746	0.02459	-0.10205	1949
0.04743	-0.09165	0.13908	1950
-0.32875	0.04483	-0.37358	1951
0.37091	-0.02505	0.39596	1952
0.01406	0.03853	-0.02447	1953
-0.02222	-0.11787	0.09565	1954
-0.06795	-0.02182	-0.04613	1955
0.08184	0.01597	0.06587	1956
-0.08604	-0.00493	-0.08111	1957
0.12443	-0.00099	0.12542	1958
-0.10691	0.01658	-0.12349	1959
0.02535	-0.01164	0.03699	1960

minus sign shows an actual decrease in production from 1941 to 1942. The same method was used in finding year-to-year changes for acres and for yields, the changes being expressed as logarithmic differences. After the logarithmic differences were calculated, square and cross-product terms were calculated. Table 7 gives the square and cross-product terms for the example cited above. From the information given in Table 7 the (b) values can be calculated.

The formula for b_{21} is:

$$b_{21} = \Sigma x_1 x_2 / \Sigma x_1^2 \text{ where } \Sigma x_1 x_2 = \Sigma X_1 X_2 - \bar{X}_2 \Sigma X_1$$

and

$$\Sigma x_1^2 = \Sigma X_1^2 - \bar{X}_1 \Sigma X_1$$

b_{21} computed for wheat in Area 5 is:

$$b_{21} = 0.10580 - 0.00150/0.46353$$

$$b_{21} = 0.225$$

The formula for b_{31} is:

$$b_{31} = \Sigma x_1 x_3 / \Sigma x_1^2 \text{ where } \Sigma x_1 x_3 = \Sigma X_1 X_3 - \bar{X}_3 \Sigma X_1$$

and

$$\Sigma x_1^2 = \Sigma X_1^2 - \bar{X}_1 \Sigma X_1$$

b_{31} computed for wheat in Area 5 is:

$$b_{31} = 0.35991 - 0.00046/0.46353$$

$$b_{31} = 0.775$$

TABLE 7.--The squares and cross-product terms from Table 6

X_1^2	X_1X_2	X_1X_3	YEAR
0			1941
0.08826	0.09505	-0.00679	1942
0.00025	-0.00009	0.00034	1943
0.05063	0.02016	0.03047	1944
0.00034	0.00140	-0.00106	1945
0.00438	0.00020	-0.00418	1946
0.01448	0.00922	0.00526	1947
0.00652	0.00596	0.00055	1948
0.00600	-0.00190	0.00790	1949
0,00225	-0.00435	0.00660	1950
0.10808	-0.01474	0.12281	1951
0.13757	-0.00929	0.14687	1952
0.00020	0.00054	-0.00034	1953
0.00049	0.00262	-0.00213	1954
0.00462	0.00148	0.00313	1955
0.00670	0.00131	0,00539	1956
0.00740	0.00042	0.00698	1957
0.01548	-0.00012	0.01561	1958
0.01143	-0.00177	0.01320	1959
0.00064	-0.00030	0.00094	1960
$\Sigma X_1^2 = 0.46572$	$\Sigma X_1X_2 = 0.10580$	$\Sigma X_1X_3 = 0.35991$	

$$b_{21} + b_{31} = 1$$

$$0.225 + 0.775 = 1$$

The coefficients, b_{21} and b_{31} were estimated for wheat, corn, oats, barley, and grain sorghums in each of the 15 different type-of-farming areas in Kansas. The b coefficients were also estimated for soybeans in Areas 1, 2, 3, 4, and 5 since soybeans as a crop are of some importance in these areas. Table 8 lists those coefficients for each of the areas. As a review, the method employed divides the average year-to-year changes in production into its two component parts--acreage and yield changes. As an example, consider corn in Area 4. This is in northeast Kansas including the counties of Nemaha, Brown, Doniphan, Jackson, and Atchison. On the average, over the 20-year period, a one-percent change in production from the previous year was composed of a 0.961 percent change in yield and a 0.039 percent change in seeded acres. In general, the contribution of acreage changes was relatively small for crops that were major crops in their respective areas. For wheat, on the other hand, the change in total production due to changes in acreage was relatively larger than that due to yields. Conversely, in western Kansas the changes in yields had a greater effect on changes in total production of wheat than changes in acreages. This was caused by unstable weather conditions and the importance of wheat in the cropping system. Weather conditions were more unstable in western Kansas as compared to eastern Kansas; thus causing year-to-year changes in yield to be larger in western Kansas. Also, for many of the areas in western Kansas wheat is a major crop, and in general, the

TABLE 8.--Average contribution of acreage and yield changes to a 1-percent change in crop production from preceding year, principal grain crops, Kansas, 1941-1960.

FARMING	WHEAT		CORN		OATS		BARLEY		GRAIN SORGHUM		SOYBEANS	
AREAS	Acreage	Yield	Acreage	Yield	Acreage	Yield	Acreage	Yield	Acreage	Yield	Acreage	Yield
1	.684	.316	.128	.872	.231	.769	.731	.269	.565	.435	.624	.376
2	.419	.581	.055	.945	.561	.439	.675	.325	.596	.404	.730	.270
3	.347	.563	.190	.810	.462	.538	.688	.312	.707	.293	.739	.271
4	.107	.893	.039	.961	.297	.703	.563	.437	.711	.289	.605	.395
5	.237	.763	.194	.806	.423	.577	.714	.286	.514	.486	.779	.221
6a	.123	.877	.203	.797	.218	.782	.899	.101	.710	.290		
6b	.095	.905	.301	.699	.530	.470	.851	.149	.441	.559		
7	.078	.922	.319	.681	.064	.936	.458	.542	.582	.418		
8	-.129	1.129	.061	.939	.044	.956	.502	.498	.509	.491		
9	.169	.831	.507	.493	.058	.942	.442	.558	.593	.407		
10a	.255	.745	.636	.364	.148	.852	.167	.833	.761	.239		
10b	.349	.651	.628	.372	.217	.783	.186	.814	.727	.273		
10c	.232	.768	.576	.424	.172	.828	.265	.735	.658	.342		
11	.072	.928	.347	.653	.127	.873	.123	.877	.687	.313		
12	.272	.728	.638	.362	.149	.851	.006	.994	.761	.239		

contribution of acreage changes would be small relative to yield changes. For wheat the areas showing the greatest importance of acreage shifts were Areas 1, 2, and 3. In these areas wheat was less important in relation to other crops in the cropping system.

For the state as a whole there was a general trend for acreage changes to be larger in the areas where a particular crop was less well adapted to that area. An example of this would be the acreage changes for wheat and corn. In western Kansas acreage changes were lower relative to eastern Kansas for wheat, wheat being the dominant crop in western Kansas. The opposite held true for corn. Acreage changes for corn were higher in western Kansas than in eastern Kansas where eastern Kansas produced most of the corn raised in Kansas. Barley followed the same general pattern as wheat for the state. There seemed to be no general pattern for grain sorghum. One area may have had a higher percent acreage change while a neighboring area may have had a low acreage change. For an example, Area 4 had a percent acreage change of 0.407 percent, Area 5 had a 0.514 percent change, and Area 6 again had a 0.710 percent acreage change.

For the state as a whole, year-to-year changes in yield seemed to be substantially more influential than changes in planted acres in determining production changes. The remaining chapters will be devoted to actual estimating yearly acreage cropping systems.

CHAPTER IV

PREDICTION OF 1961 CROP PLANTINGS BY THE USE OF LINEAR PROGRAMMING

The objective of this chapter was to determine the optimum land use or the optimum cropping pattern for the individual type of farming areas, and to ascertain the difference between the actual and the estimated crop plantings.

A simple linear programming model was used to estimate the crop plantings for each of the 15 areas in Kansas for 1961, based on information available at the end of the 1960 crop season. The theoretical analysis based upon maximizing behavior was developed by James M. Henderson as a part of the research program of the Harvard Economic Research Project.[19] It was assumed that the objective of the farmers was the maximization of returns above direct costs. Upper and lower limits on adjustment from 1960 planted acres were assumed to reflect the average behavior of farmers since 1941. The upper and lower limits for individual crops were obtained from the figures reported in Table 2. Wheat acreage allotments for 1961 were also considered. It was assumed that farmers would seed the total wheat allotment for each area, or the maximum limit, which will be

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[19]James M. Henderson, "The Utilization of Agricultural Land: A Theoretical and Empirical Inquiry," The Review of Economics and Statistics, XLI (August, 1959), 242.

explained more fully later, whichever was the smaller. The total acres in the five crops--wheat, corn, oats, barley, and grain sorghum--were assumed to be the same in 1961 as in 1960.

The model assumes that each individual farmer within an area is a separate decision-making unit and that all domestic crop land is distributed among a number of farmers. Each farmer is assumed to hold a given number of acres of cropland of a given type within an area, but different farmers may hold cropland of different types among areas. It is the decision of the farmer to select at the beginning of each year how much of his land to devote to the cultivation of each of (i) alternative crops. The decisions of the farmers are assumed to be independent. Since there are far too many farmers to treat each as a separate decision-making unit in an empirical analysis, some degree of aggregation becomes a necessity. Each of the 15 type-of-farming areas in Kansas was treated as a single decision-making unit, assuming a high degree of homogeneity within areas. Thus, each area was treated as one individual farmer.

The m^{th} area's land utilization pattern is given by a set of values for the acreages for each of the (i) crops, which are assumed to be grown separately. The choice of land utilization patterns was limited by the fact that an area cannot devote more land than it possessed to the cultivation of crops. The constraint could be written as:

$$(1) \quad \sum_{m=1}^{15} \sum_{i=1}^{5} (x_{im} \overset{<}{-} a_m) \quad (i = 1, \ldots\ldots\ldots, 5) \quad (m = 1, \ldots\ldots\ldots, 15)$$

where x_{im} is the number of acres devoted to the i^{th} crop and a_m is the total number of acres devoted to the five crops in the previous year for the m^{th} area.

The land utilization decisions for any area are conditioned by a number of economic, technical, institutional, and sociological factors. Factors such as costs, prices, and yields are quantifiable, but factors such as knowledge, and uncertainty are not easily identifiable and hardly possible to be quantifiable. The factors that cannot be easily measured can be reflected in an area's reluctance to make large changes in an established land utilization pattern.[20] Within an area it was assumed a reluctance to shift a large proportion of the acreage to the crop which promised the largest return since a number of benefits can be derived from diversity. Diversity means the ability to practice advantageous crop rotation and labor distribution.

From these assumptions the crop allocation patterns were not assumed to be computed anew for each crop year. Deviations from the 1960 cropping system in terms of the 1961 plantings were determined from historical data since 1941 on acreage changes. From this an inequality can be written indicating the maximum and minimum limits which indicate a desire for diversity and a reluctance to depart from an established pattern:

$$(2) \quad (1 - \beta_{im}, \text{min.})\, X^{*}_{im} \leq x_{im} \leq (1 + \beta_{im}, \text{max.})\, X^{*}_{im}$$

$$(i = 1, \ldots\ldots, 5)\ (m = 1, \ldots\ldots, 15)$$

where x^{*}_{im} is the acreage which the m^{th} area devoted to the i^{th} crop in the year 1960, and β_{im}, min. and β_{im}, max. are respectively the minimum and

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[20] For the purpose of this analysis, it was assumed there would be only moderate changes in the cropping system within each area from year to year. This assumption may be somewhat in violation with some of the conclusions reached earlier.

maximum proportions by which there is willingness on the part of producers to deviate from an established cropping pattern. The β coefficients were assumed to be constant for the determination of an area's 1961 land utilization pattern.

There was no precise method for calculating the β coefficients. However, the coefficients have to meet certain conditions. One condition is that the maximum potential increase for one of the crops could not be greater than the sum of the maximum potential decreases for the remaining crops. This can be shown by the relation:

$$(3)\ \beta_{im},\ \text{max.}\ x^*_{im} \leq \sum_{k \neq i}^{5} \beta_{km},\ \text{min.}\ x^*_{km}\ (i = 1, \ldots\ldots, 5)$$

If this condition were met it would be impossible to meet the conditions set forth in (2).

Each of the maximum potential acreage declines must also be obtainable. Therefore,

$$(4)\ \beta_{im},\ \text{min.}\ x^*_{im} \leq \sum_{k \neq i}^{5} \beta_{km},\ \text{max.}\ x^*_{km}\ (i = 1, \ldots\ldots\ 5)$$

It would be impossible for the two conditions above to describe the behavior of an individual area, but boundaries can at least be estimated for feasible β coefficient values. Thus, there was no direct method for estimating the β coefficients. This estimation was approached indirectly' by focusing on actual year-to-year acreage changes for each crop over the last twenty years. These year-to-year changes were stratified by sign, i.e., year-to-year increases and decreases. A general assumption can be implied as a guide in estimating the   coefficients.

Generally, a farmer who devotes a high percentage of his total crop acreage to one particular crop will assign a lower value to β_{im}, max. than a farmer who is more diversified in his cropping system. This will generally hold true for all cases and for all crops. If both farmers used the same value for β_{im}, max., this would imply that the first farmer was willing to make a greater proportional reduction of his acreage devoted to other crops than the second farmer. This can easily be seen by an example. If the more specialized farmer devoted 60 acres of his total acreage to 100 acres to wheat, a β_{im}, max. coefficient of 0.2 would imply that he would be willing to shift as high as 12 acres from other crops to the i^{th} crop. This would mean a 30 percent decrease in the base acreage for the other crops. If the more diversified farmer only devoted 20 acres of the same total acreage to wheat, the same coefficient would imply that he would be willing to shift a maximum of 4 acres over to wheat. This would represent only 5 percent of his base year acreage for the other crops.

The same type of argument can be used for estimating values for β_{im}, min. for each of the crops. Again, the same β_{im}, min. value would imply that the more specialized farmer would be willing to increase his plantings of other crops by a much higher proportion than the more diversified farmer.

This reasoning can be broadened to encompass an entire area which was needed for our purpose. Some areas were more specialized in a particular crop over other areas and thus the β coefficients can be adjusted accordingly. For instance, wheat was a major crop in western Kansas whereas the cropping system in the eastern portion of the state was more diversified relative to that in western Kansas.

Government control programs were considered to impose certain restrictions on a farmer's cropping system. Such a restriction placed a maximum limit upon the acreage that can be devoted to certain crops. Wheat was the only crop of the five major crops considered to be under such a restriction for this model. Thus for wheat two upper limits exist--one limit set by the government and the other limit set by condition (2). Obviously, both cannot hold unless by chance they happen to be equal. In the case of two upper limits for wheat the smaller of the two limits was assumed to be effective. An acreage allotment can force a farmer to consider a smaller increase than he would in the absence of the allotment, but it was assumed he would always be free to consider a smaller increase than the allotment allowed. Again, if this type of an argument was true for an individual farmer, it would be true for an entire area if that area was assumed to be homogeneous in nature, i.e., each farmer acting in the same way.

Acreage allotments are sometimes intended to reduce the acreages devoted to a crop below the levels of the preceding year, i.e., $\bar{a}_{im} < x^*_{im}$, for some (m). The restriction may be so severe that the allotments are less than the minimum acreages given by (2). In this case, the maximum limit equals the acreage allotment, and it was convenient to define the minimum limit as:

$$(5) \quad \bar{a}_{im} - 1 \leq x_{im} \quad \text{if } a_{im} \leq (1 - \beta_{im}, \text{min.})\, X^*_{im}$$

The estimates of the β coefficients for the 15 areas are shown in Table 9.

Before estimating the optimum cropping system under given constraints for 1961, the per-acre costs had to be considered. Only direct costs needed

TABLE 9.--Estimates of the β coefficients

AREA	WHEAT		CORN		OATS		BARLEY		GRAIN SORGHUM	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	0.139	0.283	0.077	0.208	0.267	0.265	0.960	0.249	0.520	0.212
2	0.194	0.193	0.102	0.151	0.192	0.271	1.009	0.316	0.429	0.202
3	0.121	0.101	0.088	0.084	0.168	0.225	0.599	0.316	0.398	0.325
4	0.266	0.133	0.074	0.086	0.167	0.168	0.565	0.373	0.467	0.337
5	0.114	0.123	0.176	0.089	0.161	0.261	0.844	0.327	0.348	0.211
6a	0.069	0.104	0.136	0.130	0.244	0.200	0.617	0.532	0.563	0.321
6b	0.076	0.120	0.399	0.194	0.171	0.363	0.515	0.378	0.343	0.233
7	0.107	0.105	0.245	0.283	0.329	0.210	0.481	0.399	0.455	0.326
8	0.129	0.102	0.148	0.110	0.155	0.219	0.344	0.462	0.307	0.303
9	0.089	0.086	0.309	0.383	0.423	0.255	0.473	0.351	0.423	0.261
10a	0.104	0.095	0.760	0.284	0.222	0.292	0.334	0.301	0.369	0.399
10b	0.088	0.058	0.920	0.314	0.453	0.423	0.969	0.312	0.186	0.284
10c	0.076	0.075	0.535	0.679	0.453	0.358	0.805	0.438	0.544	0.300
11	0.085	0.098	0.202	0.185	0.263	0.230	0.551	0.253	0.367	0.379
12	0.121	0.091	0.380	0.220	0.412	0.325	0.717	0.311	0.271	0.419

to be considered since the planning was short run in nature. The direct costs included such costs as planting, cultivating, fertilizing, irrigating, and harvesting. Such costs as capital ownership, rent, and taxes were considered incurred regardless of the type of cropping system, and thus, were not relevant for the planning of a cropping system. The best estimate of market prices for the 1961 period was assumed to be the given prices for the 1960 crops. Yields were also estimated from the data on past yields.

Each crop was assumed to be produced independent of the other four crops. It was also assumed that the per acre variable costs were constant. A total cost function then will be additive and can be written as:

$$(6) \quad C_{im} = \sum_{i=1}^{5} c_{im} x_{im}$$

where each crop was defined by its maximum and minimum constraints. The term, C_{im} denotes constant per acre costs for the i^{th} crop and x_{im} is the estimated acreage devoted to the i^{th} crop for area m.

A total per acre revenue function can also be written assuming given prices, yields, and estimated acreage allotments:

$$(7) \quad U_{im} = \sum_{i=1}^{5} (p_{im} y_{im}) \, x_{im}$$

where p_{im} is expected price for the i^{th} crop expressed in dollars per bushel and y_{im} is the expected yield for the i^{th} crop expressed in bushels per acre.[21]

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[21]For grain sorghum price is expressed in dollars per hundredweight and yield in hundred pounds per acre.

From equations (6) and (7) an equation for expected net returns can be written. Net returns will be denoted by N_i. Thus, the objective function will be to maximize net returns.

$$(8) \quad N_{im} = \sum_{i=1}^{5} Z_{im}x_{im}$$

where $Z_{im} = P_{im}y_{im} - C_{im}$ is the expected per-acre return from the i^{th} crop and for area m.

It was thus assumed that a given area will select a land utilization pattern which maximizes (8) subject to the following constraints:

$$(9) \quad \sum_{i=1}^{5} x_{im} - a_m,$$

$$(10) \quad x_{im} \leq a_{im}, \text{ max. } (i=1, \ldots\ldots, 5),$$

$$(11) \quad -x_{im} \leq -a_{im}, \text{ min. } (i=1, \ldots\ldots, 5),$$

and

$$(12) \quad x_{im} \geq 0 \ (i=1, \ldots\ldots, 5),$$

where a_{im}, max. is the maximum acreage defined by equation (2) or by government acreage allotments--whichever was the smaller. For this study government acreage allotments applied only to wheat. The lower limit a_{im}, min. is defined by (2) or (5). Both sides of (11) have been multiplied through by a minus one to change the direction of the inequality. This was done to formulate the general case of the linear programming problem. The constraints (12) are a mathematical statement which makes it impossible for an area to have negative acreages devoted to any one crop.

Information concerning the variable costs was very hard to obtain. This was approached by considering the different methods used in seed-bed preparation for each of the five crops and for each area. As one would believe, seedbed preparation for a particular crop will not vary to a great degree from area to area. But some degree of differentiation was believed to exist between the eastern and western portion of the state. A few examples will show the differences in seedbed preparation between the two areas. The illustrations will also show costs for such factors as cost of seed, cost of harvesting, and cost of fertilizing.

The average 1961 yield for wheat was estimated at 17.3 bushels per acre for western Kansas and 24.4 bushels per acre for the eastern portion of the state. It was assumed that fertilizer was applied to the soil for the growing of wheat in eastern Kansas. This would cause direct costs to be higher for eastern Kansas since the application of fertilizer was not assumed for the western portion of the state. Information on different rates of application of fertilizer and amount of seed planted per acre was obtained from Agricultural Experiment Station bulletins. The cost of gasoline, oil, seed, fertilizer, and labor was obtained from Agricultural Prices, 1960, and was assumed to be the same throughout the state. The estimated tractor hours and estimated gas and oil per acre were taken from Agricultural Experiment Station bulletins.[22]

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[22]Income Advantage to the Specialized Grain Producing Firm from Flexible Compared with Inflexible Use of Resources, Agricultural Experiment Station Bulletin 87 (Manhattan: Kansas State University of Agriculture and Applied Science, September, 1956).

What it Costs to Use Farm Machinery, Agricultural Experiment Station Bulletin 417 (Manhattan: Kansas State University of Agriculture and Applied Science, April, 1960).

TABLE 10.--Direct cost data for wheat in eastern Kansas

OPERATION	TRACTOR HOURS Acre	MAN HOURS Acre	GAS PER ACRE Gal.	GAS PER ACRE $	OIL PER ACRE Gal.	OIL PER ACRE $	LABOR COST PER ACRE $	SEED PER ACRE Pks.	SEED PER ACRE $	FERT. PER ACRE Lbs.	FERT. PER ACRE $	HAULING COST PER ACRE $
Seedbed												
Plow	.61	.61	1.85	0.32	.046	0.05	0.70					
Disc (2)	.64	.64	1.80	0.28	.04	0.02	0.79					
Harrow	.12	.12	.31	0.05	.01	0.01	0.14					
Packer	.23	.23	.60	0.10	.018	0.02	0.26					
Planting												
Drill	.16	.16	.45	0.08	.025	0.03	0.18					
Harvesting												
Combining	.27	.54	1.34	0.23	.06	0.07	0.63					
Hauling												1.64
Seed								5	2.75			
Fertilizer										30,P 40,N	7.50	
SUM				1.06		0.20	2.70		2.75		7.50	1.64

TOTAL DIRECT COST/ACRE = $15.85

TABLE 11.--Direct cost data for wheat on fallow for western Kansas

OPERATION	TRACTOR HOURS Acre	MAN HOURS Acre	GAS PER ACRE Gal.	GAS PER ACRE $	OIL PER ACRE Gal.	OIL PER ACRE $	LABOR COST PER ACRE $	SEED PER ACRE Pks.	SEED PER ACRE $	FERT. PER ACRE lbs.	FERT. PER ACRE $	HAULING COST PER ACRE $
Seedbed												
Oneway	.31	.31	1.10	0.19	.028	0.03	0.35					
Rodweeder	.16	.16	.55	0.09	.02	0.02	0.18					
Duchfoot	.23	.23	.60	0.10	.018	0.02	0.26					
Springtooth	.23	.23	.60	0.10	.018	0.02	0.26					
Packer	.23	.23	.60	0.10	.018	0.02	0.26					
Planting												
Drill	.16	.16	.45	0.08	.025	0.03	0.18					
Harvesting												
Combining	.27	.54	1.34	0.23	.06	0.07	0.63					
Hauling												1.04
Seed								3.5	2.48			
Fertilizer												
SUM				0.89		0.21	2.12		2.48			1.04

TOTAL DIRECT COST/ACRE = $6.74

For wheat, direct variable cost in western Kansas was estimated at $6.74 per acre, and for eastern Kansas the direct variable cost was estimated at $15.85. This same method was used to estimate the direct per acre costs for the remaining four crops for both eastern and western Kansas. The following table gives the direct variable cost of each of the crops broken down for eastern and western Kansas.

TABLE 12.--The direct variable costs on a per acre basis for each of the five crops for both eastern and western Kansas[a]

DIRECT PER ACRE COST	AREA	CROP				
		WHEAT	CORN	OATS	BARLEY	GRAIN SORGHUM
	Eastern Kansas	$15.85	$14.63[b]	$15.70	$ 5.28	$8.28
	Western Kansas	$ 6.74	$36.74[c]	$ 5.51	$13.48	$5.39

[a]The areas included in western Kansas were 6b, 7, 9, 10a, 10b, 10c, 11, and 12. The areas included in Eastern Kansas were 1, 2, 3, 4, 5, 6a, and 8.

[b]For corn, areas 6b, 7, 9, 10c, and 11 are included in the per acre cost estimate given for eastern Kansas.

[c]It was assumed that the majority of the corn raised in areas 10a, 10b, and 12 was irrigated.

Once the β coefficients and direct per acre costs had been estimated, the allocation of crop land among the five crops was determined. The cropping system for the year 1961 was estimated by this procedure. This was done for each of the 15 areas in Kansas. Market prices and yields of the five crops were assumed to be the same in 1961 as in 1960 for each area.

The following are explanatory notes for each of the columns for the tables given in the appendix:

Crop - An asterisk following the name of a crop is assumed to be influenced by government allotments within a cropping system.

c_{im} - Costs are stated in dollars per acre.

p_{im} - Expected prices for wheat, corn, oats, and barley are stated in dollars per bushel. Prices for grain sorghum are in dollars per hundred pounds weight.

y_{im} - Expected yields are stated in bushels per acre for wheat, corn, oats, and barley. Grain sorghum is stated in hundred pounds per acre.

x_{im} - Expected returns are in dollars per acre.

$x_{im} = p_{im}y_{im} - c_{im}$.

x^*_{im} - Base acreages for 1960 have been coded by 10^3. The over-all acreage limit (a_{im}) is the sum of the base acreages.

a_{im}, max. - The maximum limits are also coded by 10^3 and are in acres. Those followed by a single asterisk are acreage allotments. All other maxima were computed from the coefficients in Table 9.

a_{im}, min. - The minimum limits are coded by 10^3 and are in acres. All minima were computed from the coefficients in Table 9.

x_{im} - The acreage estimates are the solution for the 1961 cropping system, and are coded by 10^3.

Table 13 shows the estimated percent of acres devoted to each crop within an area for 1961. The estimates were compared with the actual percentages. The actual solution for the 1961 cropping system for a particular area is shown in the appendix.

The estimated percent of land devoted to wheat tended to be lower than the actual. Wheat was assumed for estimation purposes to be influenced by government allotments. It was noted that farmers tend to over seed in wheat from year to year, and thus would cause the actual percent of land allocated to wheat to be higher than the corresponding estimate for the same area.

The solutions for each area in Table 13 also give information on the relative pressures for increases and decreases for each crop. It will be recalled that the assumed limits on individual crop acreage adjustments are based on historical average shifts with the exception of wheat. These limits on adjustment are subject to constraints (4) and (5) and total acreage. Excluding wheat, one of the remaining four crops will have an expected planting somewhere between its upper and lower limit after adjustment. This can readily be seen by referring to the appendix. The return above variable cost (Table 12) for this "floating" crop gives an indication of the increase in income that would be received from an additional acre of crop land under the conditions that the individual crop adjustment limits and the government control program for wheat remain effective. What is meant by a floating crop is that amount of crop land (acres) that remains for the i^{th} crop after picking the upper and lower limits of those crops offering the highest and lowest constant returns to scale, respectively. The floating crop is necessary to meet the condition of a fixed amount of crop land, and

TABLE 13.--Percent estimates of acreages for the five crops for 1961

AREA	WHEAT		CORN		OATS		BARLEY		GRAIN SORGHUM	
	Est.	Actual	Est.	Actual	Est.	Actual	Est.	Actual	Est.	Actual
1	38.5	48.9	31.8	20.1	06.1	13.8	05.3	08.9	18.2	08.3
2	24.1	38.9	42.6	31.4	04.9	09.6	02.7	05.1	25.7	15.0
3	27.3	35.8	43.6	39.7	05.1	08.4	01.3	01.7	22.7	14.4
4	19.8	26.2	53.9	47.8	07.1	11.2	00.6	00.7	18.7	14.1
5	37.5	43.9	23.4	16.2	04.6	09.1	04.6	07.7	30.0	23.1
6a	52.2	59.3	13.4	09.3	04.9	09.6	04.6	08.2	24.9	13.6
6b	06.7	67.9	02.0	02.2	01.8	04.6	05.9	09.6	23.5	15.7
7	78.7	82.2	01.3	01.5	00.8	01.7	02.2	03.4	17.1	11.3
8	45.3	51.9	18.5	16.9	01.8	03.5	02.0	03.5	32.4	24.1
9	77.7	82.3	00.5	00.7	00.3	00.6	02.5	03.7	19.0	12.6
10a	70.2	77.2	01.1	01.0	00.2	00.3	03.1	04.6	25.3	16.8
10b	65.6	72.6	01.1	01.2	00.1	00.2	02.1	03.7	31.2	22.3
10c	84.4	81.9	01.6	00.5	00.8	01.9	04.2	07.2	09.1	08.5
11	06.7	71.7	05.8	03.6	00.3	00.5	07.5	10.5	20.8	13.7
12	60.8	68.2	01.1	01.1	00.1	00.2	03.8	05.3	34.2	25.2

also the assumption of total utilization of crop land among the (i) crops. For most of the areas grain sorghum was neither at the upper nor at the lower limit of adjustment.

CHAPTER V

GAME THEORY METHOD OF ESTIMATING CROP ALLOCATION

The objective of this chapter is to determine the cropping pattern for each of the type-of-farming areas by employing a game theoretic model. This model was used to determine acreage allocations for each year during the 20-year period under study as compared to the linear programming model in the previous chapter which considered only the year 1961. The use of the theory of games is receiving more emphasis lately as an important tool in agricultural research. Both linear programming and game theory have much in common and both can be used on problems dealing with the allocation of resources to meet desired objectives.

The Model

The traditional game theory approach to determine acreage allocation for an individual farmer is to develop a one-person game model. This approach does not, however, seem adequate to explain many factors that enter in the explanation of optimal crop allocation.

Each year an individual farmer is faced with the decision of the allocation of crop land among competing crops. This decision is not only a function of expected yields but also a function of expected prices at time of harvest. But expected prices are a function of total production.

Total production of each crop in turn is a function of the aggregate cropping patterns of all other individual farmers and their average yield for the season. Thus, there exists a competitive game between the individual farmer and the rest of the group. A zero-sum game theory applies the idea of a purely competitive situation.

A two-person zero-sum game theory model, as illustrated by Dresher, is applicable to this problem for the reason that it seems to provide fairly close estimates of the actual crop allocation coefficients.[23] It can be argued that the zero-sum game model as applied here is not a replica of the real world. This causes no significant problem since the objective in outlining the logic of the model is to estimate crop allocation coefficients. So, the problem then becomes one of finding a workable model. The degree of workability of any model can be determined by the correlation of the model outputs with results from the real world. Thus, the test of any good model is its usefulness.

The game theory model has a wide range of applicability. Its use as a problem solving tool extends from economics to military as well as to politics.[24] The model is adaptable to several kinds of problems in agriculture, particularly those dealing with the crop and/or livestock selection problems on either an individual farm, area or regional, as well as national basis. When the model is applied to an individual farm situation, it can be used as a two-person zero-sum game model. In this situation the individual is considered in competition with a combination of all the forces (the rest of the farms, weather, etc.) that determine market prices.

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[23]Melvin Dresher, Games of Strategy: Theory and Applications (New York: Prentice-Hall, Inc., 1961), p. 2.

[24]Ibid., p. 2.

The use of the zero-sum game model in an agricultural problem was first demonstrated by Moglewer.[25] He analyzed the optimum allocation of major United States crops using the 1948-1958 data. Two players were considered, a Blue player and a Red player. The Blue player was considered the individual farmer in competition with a Red player. The Red player consisted of all the forces that determine market prices for agricultural products. This hypothetical combination of forces includes all the other farmers, buyers of grain, as well as nature. The key force necessary in order to obtain a zero-sum game is the inclusion of grain buyers. This assures that the two players have opposing objectives.[26]

In this chapter steps used by Moglewer are followed and an example is given in an area programming sense. The Blue player will again be the individual farmer, but the Red player will consist of all farmers within a particular area plus the forces mentioned above that inscribe a defined area.

Kansas is divided into fifteen type-of-farming areas. The Moglewer method is used to estimate the percent of cropland devoted to each of the major crops in Kansas within each area. Results for each of the areas for Kansas are shown in the appendix. The estimates given in the tables are the strategies for the Red player. The emphasis was placed on finding the solution for the Red player since the objective was to estimate the percent of cropland devoted to each of the major crops within an area. This will become more evident in the following pages.

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[25]Sidney A. Moglewer, "A Game Theory Model for Agricultural Crop Selection," <u>Econometrica</u>, Vol. 30 No. 2 (April, 1962), pp. 253-266.

[26]<u>Ibid</u>., p. 256.

The model presented differs from the usual linear programming models because it does consider and incorporate the elasticities of demand for the products under consideration. Thus, the effects of government crop controls and legislation are indirectly inherent in the model. Their past influence is reflected in the price and production statistics used to derive the demand elasticity curves for each of the major crops considered. The model is functionally dependent upon statistical demand elasticity curves; and over-production of a crop lowers its price and the extent of the decrease in the price depends on the elasticity of demand for that crop. This is an important feature of the model, and its usefulness can be visualized particularly in analyses of aggregative problems and relationships that are important to both the industry and individual producers.

The functional dependence of the model on the elasticities of demand represents a decisive improvement over the usual programming techniques, particularly those employed in the studies of agricultural adjustments where the immediate solution for the few farmers may not be the best for farming as a whole. Some of the adjustments may produce adverse price or income effects if a large number of farmers make them.

The method shows promise in describing more accurately the output-price interdependence under given or changing demand and output conditions. It reflects the demand elasticities and price patterns resulting from the economic pressures that are imposed upon producers in case of an over-production and on consumers in case of underproduction.

Algebraic Illustration

The payoff function to an individual producer (the Blue player) can be expressed as:

$$(1) \quad M = \sum_{i=1}^{n} Y_i L p_i \quad (i = 1, \ldots. n)$$

where:

Y_i is the actual yield of the i^{th} crop per acre;

L is the individual producer's total crop acreage;

x_i is the fraction of the individual producer's acreage devoted to the i^{th} crop;

P_i is the price received for the i^{th} crop; and

n is the number of crops considered.

Prices of the individual crops, in most instances, depend on the demand curves which express the functional relationship between price and production of individual crops as well as other factors affecting the determination of price.

A theoretical demand curve can be formulated to express the relationship between price and production of individual crops which reflect many of the factors that go into determining price.[27] In our model it is assumed that the law of demand for a particular commodity in a particular market is specified in the following terms: elasticity of demand is constant for all amounts of the commodity. Using the definition for

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[27] William L. Crum and Joseph A. Schumpter, Rudimentary Mathematics for Economists and Statisticians. (New York: McGraw-Hill Book Co. Inc., 1946), pp. 145-147.

elasticity a demand elasticity curve can be formulated. The definition for elasticity is a percent change in quantity divided by a percent change in price. In mathematical terms this can be expressed as follows:

$$= \frac{\Delta q}{q} \div \frac{\Delta p}{p}$$

The derivative form can be obtained by using the limit idea, i.e., letting p approach zero and finding the limit of

$$\frac{\Delta q}{q} \div \frac{\Delta p}{p} \text{ to be } \frac{p}{q} \cdot \frac{dq}{dp}$$

From the assumption of constant elasticity and the definition of elasticity an equation for constant elasticity can be written:

$$(2) \quad \frac{p_i}{q_i} \cdot \frac{dq_i}{dp_i} = a_i$$

where "a" is a supposedly known constant. Integration of (2) by separating the variables

$$\frac{1}{q_i} \cdot \frac{dq_i}{dp_i} = \frac{a_i}{p_i}$$

gives $\log q_i = a_i \log p_i + k_i$

and if the constant "k" is replaced by $\log c_i$, the equation then becomes:

$$-a_i \log p_i + \log q_i = \log c_i$$

From the principles of logarithms, and letting a_i equal $\mathcal{E}_i$, the general solution is:

(3) $P_i^{-\mathcal{E}_i} q_i = c_i$

where:

$\mathcal{E}_i$ is the elasticity coefficient of the i^{th} crop;

q_i is the total production;

c_i is the demand constant.

The total production q_i, which is dependent on area's (Red's) crop allocation, can be expressed in the following form:

(4) $q_i = \bar{Y}_i y_i \bar{L}$

where:

$\bar{Y}_i$ is the average yield for the area's (Red's) i^{th} crop;

$\bar{L}$ is the total crop acreage for the area; and

y_i is the fraction of the area's (Red's) total acreage devoted to the i^{th} crop.

By substituting equations (3) and (4) into equation (1) one gets the following payoff function of the allocation for the individual producer (the Blue player):

(5) $M = \sum_{i=1}^{n} Y_i L x_i \left(\frac{y_i}{\frac{c_i}{\bar{Y}_i \bar{L}}} \right)^{\frac{1}{\mathcal{E}_i}}$

where P_i is defined by the demand equation (2) as:

(6) $P_i = \left(\frac{q_i}{c_i}\right)^{\frac{1}{\mathcal{E}_i}}$ and helps to explain the right side of equation (4).

Let $K_i = \left(\frac{c_i}{\bar{Y}_i \bar{L}}\right)$ Then the payoff function (4) becomes

(7) $M = \sum_{i=1}^{n} Y_i L x_i \left(\frac{y_i}{K_i}\right)^{\frac{1}{\mathcal{E}_i}}$

This equation (6) which is convex in y_i for all x_i can be solved. However, for the solution to be meaningful other conditions must also be met. In addition to the negative elasticity of demand the

(8) $\sum_{i=1}^{n} x_i = 1$, and $\sum_{i=1}^{n} y_i = 1$, where all the x_i's and y_i's ≥ 0

in first and second derivatives.[28]

The above conditions specify that the fraction of cropland devoted to each of the crops cannot be negative. Each fraction of the crop must either equal or be greater than zero and all the fractions together must add to one (100% of cropland).

From the theory for continuous games with the convex payoff function, the value of the game can be found by

(9) $V = \min_{y} \max_{x} M(x,y)$

where V is the value of the game and x and y represent the sets $(x_1 \ldots x_i)$ and $(y_1 \ldots y_i)$ respectively. According to the theory the area's (all farmers) optimal strategy is unique and that there is only one set

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[28]Moglewer, op. cit., pp. 258-259 and Dresher, op. cit., Chapter 8.

$(y_1^* \ldots y_i^*)$ which represents optimum allocation of crops for the area (Red).

The main interest in the presented model is to find the optimum set denoted by y_i^*'s. Once the estimated y_i^*'s are obtained, the objectives of optimum allocation of crops, considering the resources and market conditions for the area, is achieved.

If the objective centers on the strategy the individual producer (farmer) would select, given the y_i^*'s, then the sets $(x_1 \ldots, x_a)$ along with estimated probabilities of success can also be derived.[29]

An illustrated example, where the estimated y_i^*'s for the area, as well as the individual producer's strategies, are derived, along with the step-by-step arithmetic procedure, follows.

An Illustrative Example

An illustrative example of the model, which has been discussed above, will now be presented. For computational simplicity hypothetical values have been chosen and the model is limited to two crops and an area of 100 acres of cropland.

The following hypothetical values are assumed:

$Y_1 = \bar{Y}_1 = 5$ bushels per acre (Crop I)

$Y_2 = \bar{Y}_2 = 10$ bushels per acre (Crop II)

$\bar{L} = 100$ acres

$\mathcal{E}_1 = \mathcal{E}_2 = -1$, e.g., equal elasticities of demand for the two crops of minus unity are assumed.

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[29] Moglewer, op. cit., p. 260.

$c_1 = 600$ and $c_2 = 400$. These figures represent demand constants and are defined as in equation (2) above.

The payoff function in this example is:

$$(10) \quad M = \sum_{i=1}^{2} Y_1 L x_i \left(\frac{y_i}{k_i}\right)^{\frac{1}{\mathcal{E}_i}} \quad (i = 1,2)$$

$$K_1 = \frac{c_1}{Y_1 L} = \frac{600}{500} = 1.2$$

$$K_2 = \frac{c_2}{\bar{Y}_2 \bar{L}} = \frac{400}{1000} = 0.4$$

The payoff function broken down for the two crops is:

$$(11) \quad H - Y_1 L x_1 (y_1/k_1)^{1/\mathcal{E}_1} + Y_2 L x_2 (y_2/k_2)^{1/\mathcal{E}_2} \quad \text{or}$$

$$M = 5Lx_1(y_1/k_1)^{-1} + 10Lx_2(y_2/k_1)^{-1} \quad \text{or}$$

$$H = 5(600/500)Lx_1(1/y_1) + 10(400/1000)Lx_2(1/y_2)$$

$$(12) \quad V = \min_{y} \max_{x} [5(600/500)Lx_1(1/y_1) + 10(400/1000)Lx_2(1/y_2)] \quad \text{and}$$

$$(13) \quad V = \min \max [5(600/500)L(1/y_2) \text{ or } 10(400/1000)L(1/y_2)] \quad \text{which}$$

occurs when:

$$5(600/500)1/y_1 = 10(400/1000)1/y_2$$

$$6/y_1 = 4/y_2$$

Since $y_1 + y_2 = 1$ is a condition that must be met, then $y_1 = 1 - y_2$; thus,

$$6y_2 = 4y_1 \quad \text{or}$$

$$6y_2 = 4(1 - y_2) \quad \text{or}$$

$$y_2 = 0.4 \text{ and } y_1 = 0.6$$

From the above calculations, 60 percent of the total acreage is allocated to Crop I and 40 percent to Crop II. In essence, using the above model, gross returns on a per acre basis are equated. This is in line with the minimax expectation. The justification for using gross income criterion is that it does explain reasonably well changes in acreage allocation. This objective may be stated somewhat different to that achieved through linear programming. The objective function of a linear programming problem may be to maximize net returns or to minimize costs. The objective of the model used in this paper is dependent on the elasticity of demand along with the demand constants (c_1 and c_2) which play an important part in the allocation of acreage between the two crops. The product prices, in the model, depend on the total production as well as on the individual demand schedules.

Any changes in the relative elasticities among the crops change the crop allocation as well. For example, if in the above case the elasticity of demand for Crop I were changed from -1 to -0.5 and that of Crop II remained the same, then instead of 80 percent of crop acreage devoted to the Crop I, 72 percent would be devoted and subsequently the acreage of Crop II would decrease from 40 percent to 28 percent.

A similar effect would be obtained by holding the elasticities of demand constant and changing the demand constant. This type of change would correspond to a shift in the demand schedule. In the above example, for the same number of acres shifted from Crop I to Crop II, as was the case when $\mathcal{E}_1$ decreased from -1.0 to -0.5, the demand constant (c_2) would have to decrease from 400 to 230.

On the other hand, an increase in yields of any one of the crops would have the effect of shifting the acreage toward the relatively higher yielding crop, even though the demand constant would remain the same. For example, the per acre yield for Crop I doubled, increase from 5 to 10, then the new situation would call for 75 acres devoted to Crop I and only 25 acres to Crop II. The price of Crop I, as a result of the production exceeding the demand constant ($q_i > c_1$) would decrease by 1.80, from 2.00 to 0.80.

The check for determining the equality of per acre returns between crops can be made in the following way:

(14) $V_1 = Y_1(c_1/Y_1L)1/y_1$ and $V_2 = Y_2(c_2/Y_2L)1/y_2$

$V_1 = 5(600/500)1/0.6$

$V_1 = 6/0.6$ or $V_1 = 10$

$V_2 = 10(400/1000)1/0.4$

$V_2 = 4/0.4$ or $V_2 = 10$

Thus, $V_1 = V_2$ or the per acre returns from Crop I are the same as those from Crop II. Also, as one would expect, a decrease in the elasticity of demand of any one of the crops, other things remaining unchanged, would lower the per acre returns of all the crops. In the above example, a decrease in $\mathcal{E}_1$ from -1.0 to -0.5 increases the per acre returns (V_1 and V_2) from 10 to 14.

Similarly, a decrease in the demand constant in any one of the crops, with other offsetting effects absent, will decrease the per acre returns. As the demand constant for Crop II (c_2) decreases from 400 to 230, other things being the same, the per acre returns (V_1 and V_2) decrease from 10 to 8.3.

Individual Producer's Strategy

Given the optimum strategy for the area (y_1^* and y_2^*) what would be the best cropland allocation for the individual producer? Generally, he does not have control over sufficiently large fraction of the acreage and the market to affect the price. While he has several alternative ways of using the land, the producer's decision will not have any effect on the per acre returns to the area. His cropland allocation could well follow the pattern determined for the area, particularly if the yield expectations are the same.

Following the model, however, the individual's "best" strategy can be computed algebraically. Since the area's optimum strategy is not an end point of the interval (e.g., y_1^*'s are not 0 or 1) but is mixed (e.g., $0 < y_1^*$'s < 1), then the individual producer has a pure strategy. He should select one of the two crops and plant all of his acreage to the one crop.[30] The selection can be made at random or by determining the probabilities of success for either of the two crops. The latter course of action requires a set of equations which help determine the probabilities (a_1's).

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[30] Dresher, *op. cit.*, p. 119.

For the above example two probabilities are needed (a_1 and a_2), one for each crop. They can be obtained by solving the following equations.

$$(15) \quad a_1 \frac{\partial M}{\partial y_1} \quad x_1 = 1 + a_2 \frac{\partial M}{\partial y_1} \quad x_2 = 1 = 0 \text{ and}$$

$$(16) \quad a_1 + a_2 = 1, \text{ where } a_i \geq 0.$$

In the example given, where the area's acreage is allocated at 60 percent to Crop I and 40 percent to Crop II, a_1 is 0.86 and a_2 is 0.14. Thus, for the individual producer Crop I provides the maximum probability of success. Any change in basic conditions such as yields, demand elasticities, land use by different crops would also change the a_i's and therefore the probabilities of success.

An Actual Example

The same procedure used in the simplified illustration was also used to find the set ($*Y_1$, $*Y_2$, $*Y_3$, $*Y_4$, $*Y_5$) for each of the 15 areas in Kansas. Area 5 has been used in this study for illustrative purposes. This was done for each year during the 20-year period, but the year 1960 is shown in detail below. The demand elasticities used for the calculations were not estimated, but were taken from work already done in this area by Moglewer and Schultz.[31] The demand elasticity for grain sorghums has not been estimated, and the demand elasticity for feed grains was used instead. The demand elasticities and computed demand constants for each crop are shown in Table 14. The price used in calculating the demand constants was a deflated price obtained by dividing an average price for each crop by an

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[31]Sidney Moglewer, loc. cit. Henry Schultz, The Theory and Measurement of Demand (Chicago: The University of Chicago Press, 1958), pp. 461-482.

average Consumers Price Index.[32] The price was averaged over a five-year period, from 1956-1960. The Consumers Price Index used was an average over the same five-year period. This was not desirable from the standpoint of obtaining accurate estimates, but was desirable in shortening the computational procedure. More will be said about this problem at the end of the chapter.

TABLE 14.--Least squares elasticity of demand (period 1941-1960, Area 5)

CROP	COMPUTED ELASTICITY	DEMAND CONSTANT	RECIPROCAL OF COMPUTED ELASTICITY
Wheat	-0.54	$14.07 \cdot 10^6$	-1.85
Corn	-0.38	$6.07 \cdot 10^6$	-2.63
Oats	-0.20	$3.25 \cdot 10^6$	-5.00
Barley	-0.39	$1.75 \cdot 10^6$	-2.53
Grain sorghum	-1.30	$4.25 \cdot 10^6$	-0.77

An example of the application of the model to data for the 1960 crop year for Area 5 will now be presented.

Let the following values apply:

$Y_1 - \bar{Y}_1$ = 24.7 bushels/acre (1960 wheat yield),

$Y_2 = Y_2$ = 43.5 bushels/acre (1960 corn yield),

$Y_3 = \bar{Y}_3$ = 28.1 bushels/acre (1960 oats yield),

$Y_4 = \bar{Y}_4$ = 13.7 bushels/acre (1960 barley yield),

32 Kenneth R. Bennett and Frank H, Pearson, Statistical Methods (New York: John Wiley & Sons, Inc., 1942), pp. 55-75.

$Y_5 = \bar{Y}_5 = 47.2$ hundred pounds/acre (1960 grain sorghum yield),

$\bar{L} = 1{,}136{,}800$ acres (1960 acreage)

$c_1 = 14.07 \times 10^6$, $c_2 = 6.07 \times 10^6$, $c_3 = 3.25 \times 10^6$,

$c_4 = 1.75 \times 10^6$, $c_5 = 4.25 \times 10^6$.

$K_1 = c_1/\bar{Y}_1\bar{L} = 0.416$, $K_2 = c_2/\bar{Y}_2\bar{L} = 0.102$, $K_3 = c_3/\bar{Y}_3\bar{L} = 0.084$,

$K_4 = c_4/\bar{Y}_4\bar{L} = 0.093$, $K_5 = c_5/\bar{Y}_5\bar{L} = 0.066$,

(17) $M = 4.8911\ Lx_1y_1^{-1.85} + 0.1020\ Lx_2y_2^{-2.63} + 0.0001\ Lx_3y_3^{-5.00}$

$+ 0.0281\ Lx_4y_4^{-2.56} + 6.0358\ Lx_5y_5^{-0.77}$,

(18) $v = \min_y \max_x (4.8911\ Lx_1y_1^{-1.85} + 0.1020\ Lx_2y_2^{-2.63} +$

$0.0001\ Lx_3y_3^{-5.00} + 0.0281\ Lx_4y_4^{-2.56} +$

$6.0358\ Lx_5y_5^{-0.77})$,

and

(19) $v = \min \max (4.8911\ Ly_1^{-1.85}$ or $0.1020\ Ly_2^{-2.63}$ or

$0.0001\ Ly_3^{-5.00}$ or $0.0281\ Ly_4^{-2.56}$ or

$6.0358\ Ly_5^{-0.77})$,

which occurs when:

TABLE 15.--Crop statistics for wheat (Area 5)

YEAR	ACREAGE	PRODUCTION	YIELD	PRICE
1941	610,000	6,805,000	11.2	0.97
1942	292,000	3,475,600	11.9	1.07
1943	287,800	3,577,700	12.4	1.37
1944	354,400	5,901,600	16.7	1.45
1945	422,400	6,345,000	15.0	1.51
1946	425,100	7,386,700	17.4	1.86
1947	506,900	9,459,600	18.7	2.27
1948	601,100	11,193,800	18.6	2.01
1949	636,000	9.804,900	15.4	1.84
1950	514,900	10,716,200	20.8	2.01
1951	570,500	5,401,700	9.5	2.13
1952	539,000	11,977,100	22.2	2.12
1953	588,900	11,778,000	20.0	2.04
1954	449,300	11,313,400	25.2	2.18
1955	426,700	8,819,700	20.7	2.02
1956	442,500	11,228,700	25.4	2.00
1957	438,000	9,809,000	22.4	1.94
1958	437,000	13,035,000	29.8	1.71
1959	454,000	10,809,000	23.8	1.74
1960	442,000	10,931,000	24.7	1.76

TABLE 16.--Crop statistics for corn (Area 5)

YEAR	ACREAGE	PRODUCTION	YIELD	PRICE
1941	329,600	8,115,800	23.4	0.10
1942	451,700	13,651,400	29.4	0.82
1943	501,300	12,337,700	24.4	1.14
1944	496,500	15,114,300	29.4	1.03
1945	465,000	11,890,900	25.3	1.23
1946	468,300	8,756,800	17.4	1.34
1947	354,700	6,151,000	18.5	2.18
1948	318,100	10,760,300	33.1	1.36
1949	353,800	10,384,100	30.2	1.19
1950	366,700	13,925,900	37.0	1.35
1951	350,000	7,401,700	21.5	1.73
1952	349,400	6,368,500	17.4	1.62
1953	264,900	6,070,300	21.5	1.45
1954	250,500	3,466,600	10.2	1.59
1955	179,900	2,632,300	13.7	1.39
1956	173,900	3,315,200	15.7	1.39
1957	164,700	5,129,000	27.5	1.15
1958	233,000	9,745,550	41.9	1.05
1959	229,500	9,230,300	41.6	1.04
1960	225,500	9,736,200	43.5	0.97

TABLE 17.--Crop statistics for oats (Area 5)

YEAR	ACREAGE	PRODUCTION	YIELD	PRICE
1941	254,170	5,068,800	20.8	0.36
1942	273,380	6,292,500	23.3	0.43
1943	294,760	6,888,400	23.2	0.69
1944	257,090	3,477,300	13.0	0.76
1945	177,890	2,333,420	11.1	0.71
1946	201,630	5,382,480	27.0	0.80
1947	237,110	6,729,170	27.4	1.02
1948	231,900	2,909,420	14.6	0.80
1949	130,800	2,326,720	18.5	0.64
1950	213,000	3,464,640	15.8	0.78
1951	168,700	1,765,890	11.0	0.93
1952	143,600	2,934,400	20.4	0.94
1953	178,900	3,752,400	21.0	0.75
1954	171,700	4,599,600	27.3	0.73
1955	206,100	4,753,900	25.7	0.62
1956	216,800	4,086,200	20.1	0.72
1957	227,300	5,065,600	25.0	0.59
1958	90,700	1,775,900	20.0	0.59
1959	130,800	2,186,000	15.8	0.65
1960	70,900	1,910,800	28.1	0.66

TABLE 18.--Crop statistics for barley (Area 5)

YEAR	ACREAGE	PRODUCTION	YIELD	PRICE
1941	57,140	782,400	13.7	0.43
1942	81,300	1,212,400	15.4	0.57
1943	56,200	716,700	14.6	1.00
1944	27,500	298,040	10.2	1.10
1945	12,190	178,070	14.3	10.2
1946	9,040	186,360	20.6	1.33
1947	14,300	261,380	18.4	1.51
1948	12,360	210,100	19.2	1.31
1949	10,830	193,750	17.9	0.95
1950	31,950	596,510	17.1	1.10
1951	15,580	69,900	5.7	1.26
1952	4,630	105,670	20.0	1.32
1953	8,220	163,820	19.0	1.14
1954	38,400	991,370	24.8	1.05
1955	115,680	1,661,360	18.8	0.90
1956	110,700	1,827,700	18.0	0.93
1957	115,500	2,197,400	21.5	0.85
1958	85,000	2,198,100	25.7	0.78
1959	94,300	2,053,600	20.8	0.78
1960	77,800	1,277,700	13.7	0.76

TABLE 19.--Crop statistics for grain sorghums (Area 5)

YEAR	ACREAGE	PRODUCTION	YIELD	PRICE
1941	206,590	3,930,200	19.3	0.53
1942	205,840	4,137,900	20.1	0.64
1943	113,590	1,727,800	17.0	1.13
1944	209,820	4,703,140	22.8	0.90
1945	145,650	2,660,210	17.3	1.19
1946	114,080	1,544,390	15.6	1.27
1947	89,640	1,212,970	13.3	1.98
1948	142,520	3,369,900	23.9	1.12
1949	113,440	2,409,620	21.3	0.88
1950	124,640	3,178,580	25.3	1.08
1951	94,780	1,803,780	16.9	1.47
1952	115,300	1,941,200	17.0	1.59
1953	132,600	2,699,200	20.0	1.18
1954	111,300	1,705,400	13.9	1.32
1955	133,400	1,603,200	11.6	1.09
1956	113,400	1,693,600	11.8	1.22
1957	152,600	4,631,400	26.4	0.87
1958	268,500	9,589,700	35.7	0.96
1959	268,500	11,565,500	39.3	0.81
1960	320,600	15,445,500	47.2	0.76

$$(20)\quad 4.8911\, y_1^{-1.85} = 0.1020\, y_2^{-2.63} = 0.0001\, y_3^{-5.00} =$$

$$0.0281\, y_4^{-2.56} = 6.0358\, y_5^{-0.77} .$$

The solution for the set ($*y_1$, $*y_2$, $*y_3$, $*y_4$, $*y_5$) is:

$*y_1 = 0.487$, $*y_2 = 0.149$, $*y_3 = 0.103$, $*y_4 = 0.088$, and

$*y_5 = 0.172$.

In the appendix for Chapter V, there is a tabular comparison of the value of (y) for each of the five crops and for each of the 15 areas derived both from the actual crop statistics and from the game theory solution.

The results from the use of this model are not as close to the actual percentage crop allocation as one might have expected. Most of this was due to a too simplified assumption indicating that the demand constants (c_1) would be the same for each of the five crops throughout the twenty-year period. An average deflated price was also used for the entire state for each crop during the twenty-year study. These two conditions prevented the set ($*y_1$, $*y_2$, $*y_3$, $*y_4$, $*y_5$) from being under the dynamic movement of total production and market prices from year to year.

The results do reflect the relative importance of crops by different areas. For example, from the appendix for Chapter V, the estimates show wheat as a leading crop in western Kansas and corn in northeastern Kansas. The tables in the appendix also reveal that the range of year-to-year fluctuations in percent of acres allocated to each crop is greater for the actual than for estimated crop allocations. This is due largely to the exogenous factors such as a wet, cold period during sowing time which may prevent farm operators from completing their plans, and consequently affect the allocation of crops apart from the elasticity and demand constants. There is a tendency for substitution to take place to alter the original cropping plans. There are other reasons for substitutions to take place, but weather conditions seem to be the dominant factor for large changes in a Kansas farmer's cropping system.

In summary the main objective of this chapter was to demonstrate the usefulness and applicability of a modified game theory model in agricultural economics research. Within the general research area, this technique can be adapted to problems dealing with selection of enterprises on an individual farm, area and national level. However, the main applicability and usefulness of the method appears to be in analyzing aggregative problems and relationships important to individuals as well as industry. In this context the method has an advantage, when compared with the usual linear programming procedures, because it does take into account the elasticities of demand of products under consideration. For this reason the method can be well suited in analyzing problems dealing with the agricultural adjustments, particularly those problems that necessitate relatively extensive changes in the output mix.

While the model has some of the same limitations inherent in other models, usually traced to the degree of abstraction and deviation from the real world, the assumption of a zero-sum game, particularly with respect to the individual producer may be questioned. This point still requires further research and development. Undoubtedly more satisfactory results could be obtained from a non-zero-sum game model which would contain the elements of both competition and cooperation. However, the above described model comes close in its portrayal of actual situations and its limitations do not necessarily preclude the model's usefulness as a tool for evaluations of allocations on area basis.

CHAPTER VI

CONCLUSION

The study was undertaken to determine the relative influence of acreage and yield changes on crop production; and the usefulness and limitations of analytical models in determining crop allocations for Kansas. The objectives of the study were:

1) To determine the relative role of yield and acreage changes in relation to total production of a particular crop from year-to-year.

2) To assess the relative stability of the land use on the cropping system.

3) To determine the optimum land use or the optimum cropping pattern for the individual type of farming areas, and to ascertain the differences between the actual and the estimated crop plantings.

4) To determine the cropping pattern for each of the type-of-farming areas by employing a game theoretic model.

The main theme that carried throughout the study was: "Is it so that farmers are reluctant to alter their cropping pattern from year to year in Kansas?" This question developed out of a similar study done for Illinois. One of the assumptions and conclusions of the Illinois study was that farmers were reluctant to change their cropping pattern from year to year, i.e., a very low variability over a twenty-year period for acreage changes for each of the major crops in Illinois.

One might conclude from the study done for Kansas that the assumption of reluctancy could not be applied to the cropping patterns of a Kansas farmer. This belief was based mainly on the wide difference in the natural elements between Kansas and Illinois. For Kansas, farmers must adopt flexible cropping patterns to compete successfully with the natural elements and government programs. The degree of flexibility would vary within the state of Kansas due mainly to varying weather conditions within the state.

It may be well to point out that the study was only concerned with actual changes in the cropping patterns for Kansas and not desired cropping patterns. A different conclusion would have probably been reached if the study was concerned with desired cropping patterns.

The data used were based on seeded acres and yields for all crops except grain sorghum since this gave an actual measure of changes in the cropping system from year to year. Actual seeded acres and yields have not been recorded for grain sorghum.

The answer to the question posed became evident with the use of statistical methods. A sample period of twenty years, from 1941 to 1960, was used for the study. The data were obtained from The Biennial Reports of the Kansas State Board of Agriculture.

One measure of the willingness of farmers to adjust to changes under the conditions which cropping plans are developed, is the extent to which crop-acreage adjustments have been made in the past. As an indicator for this the percentage acreage adjustments were divided into those years in which planted acres increased from the previous year, and those years in which decreases occurred. A simple average was used for both the increases and the decreases as an indicator of the magnitude of the adjustments. The magnitude appeared to be quite high for Kansas relative to Illinois.

A least squares regression was used to determine the relative role of the variables, yield and acres, on total production of each crop. In general, acreage variability appeared higher relative to yield variability for eastern Kansas, whereas yield variability played a larger role in western Kansas. This tendency was not true for all areas and for all crops from eastern to western Kansas. But it did seem to have some validity for the more dominant crops in each of the areas.

The use of a linear programming model and a game theoretic model for estimating acres devoted to each of the major crops did not give very good results. This substantiated the degree of flexibility in a farmer's cropping pattern further.

It would be reasonable to conclude that the conclusion of the Illinois study can not be applied to Kansas. Also, the use of Kansas agricultural data for the use in theoretic models imposes limitations mainly due to the high degree of flexibility in a farmer's cropping pattern.

APPENDIX

Appendix
(pertaining to Chapter II)

Fig. 7.--Total acres devoted to the five major crops for Area 1, cropping years 1940-1960, inclusive.

Fig. 8.--Total acres devoted to the five major crops for Area 2, cropping years 1940-1960, inclusive.

Fig. 9.--Total acres devoted to the five major crops for Area 3, cropping years 1940-1960, inclusive.

Fig. 10.--Total acres devoted to the five major crops for Area 4, cropping years 1940-1960, inclusive.

Fig. 11.--Total acres devoted to the five major crops for Area 5, cropping years 1940-1960, inclusive.

Fig. 12.--Total acres devoted to the five major crops for Area 6a, cropping years 1940-1960, inclusive.

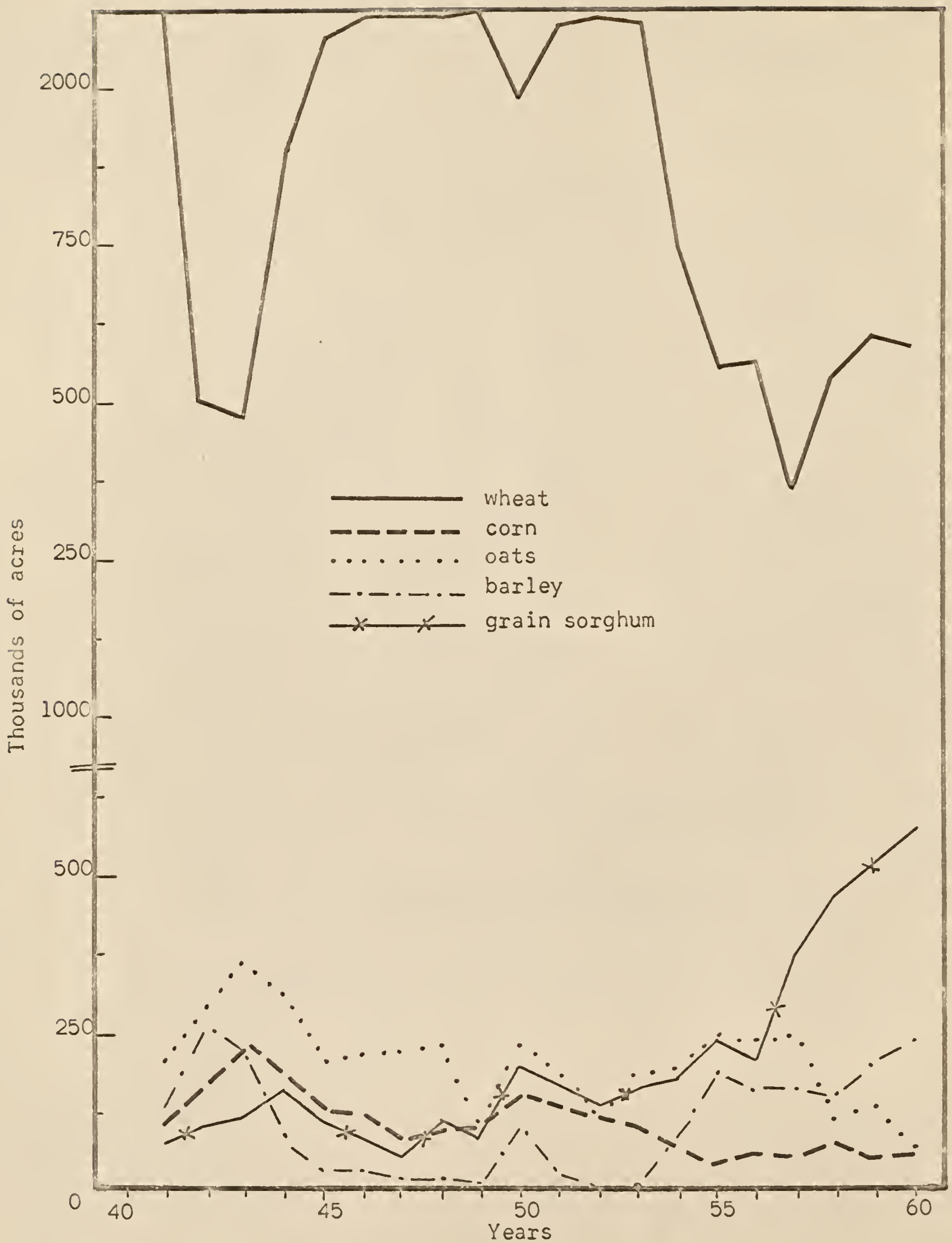

Fig. 13.--Total acres devoted to the five major crops for Area 6b, cropping years 1940-1960, inclusive.

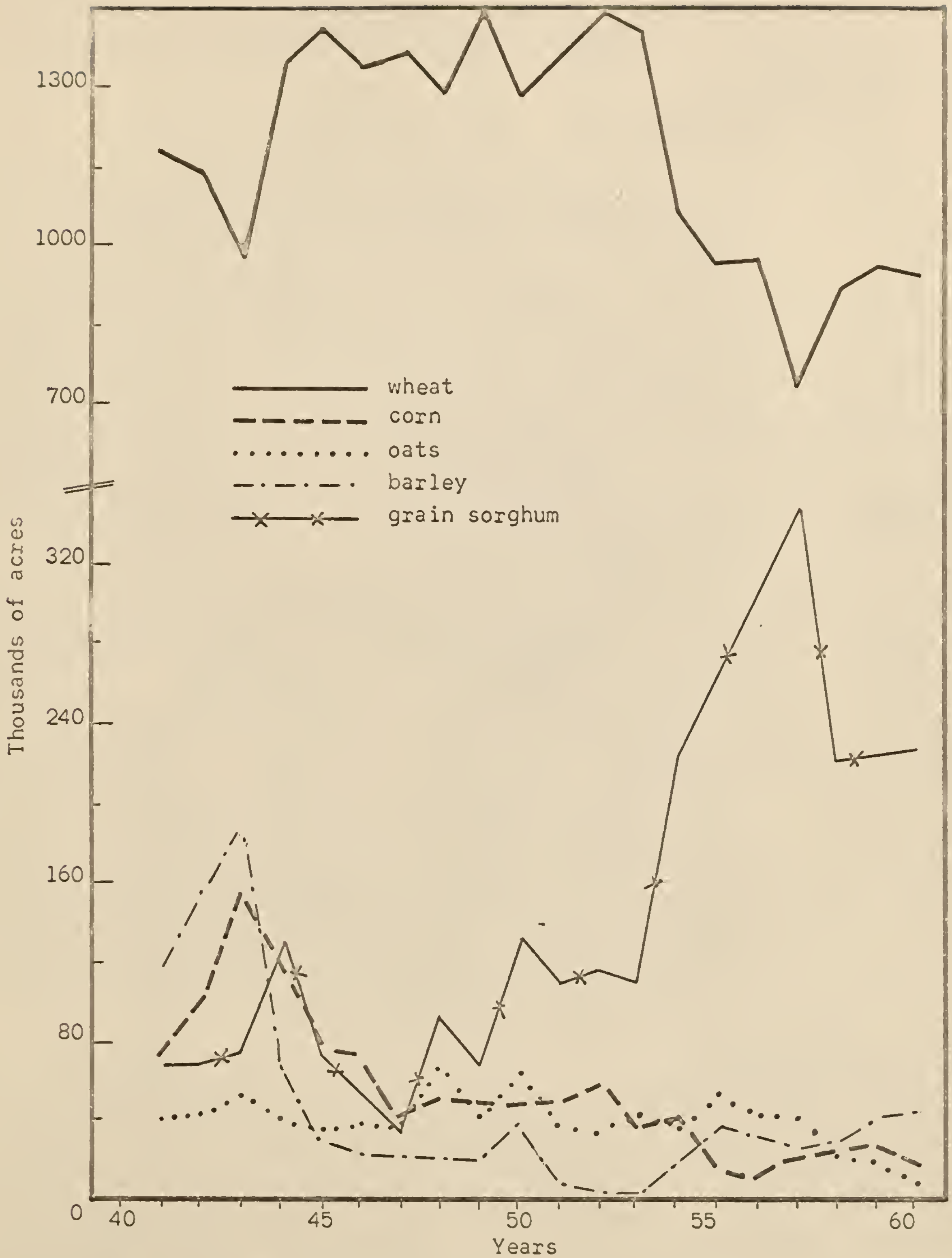

Fig. 14.--Total acres devoted to the five major crops for Area 7, cropping years 1940-1960, inclusive.

Fig. 15.--Total acres devoted to the five major crops for Area 8, cropping years 1940-1960, inclusive.

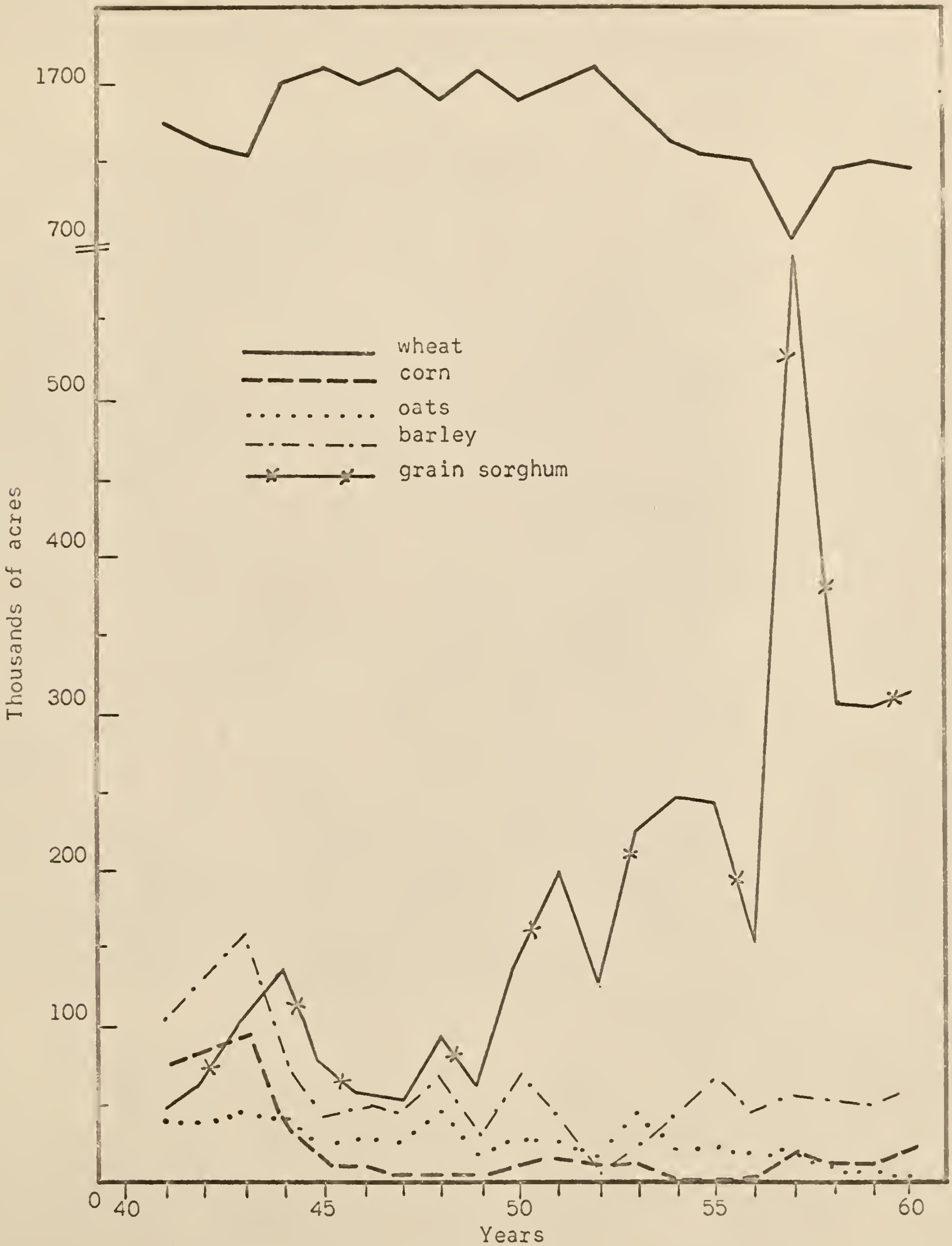

Fig. 16.--Total acres devoted to the five major crops for Area 9, cropping years 1940-1960, inclusive.

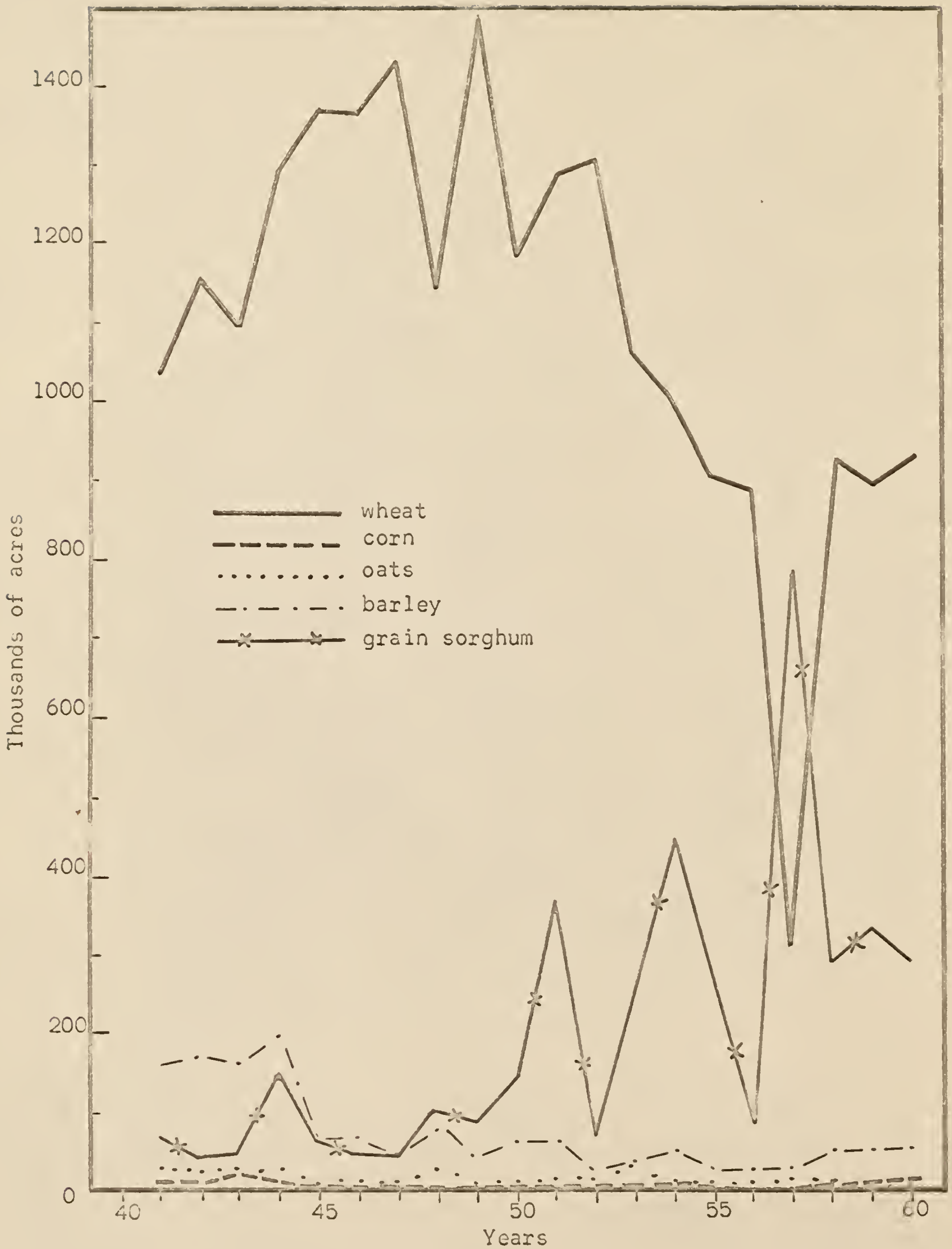

Fig. 17.--Total acres devoted to the five major crops for Area 10a, cropping years 1940-1960, inclusive.

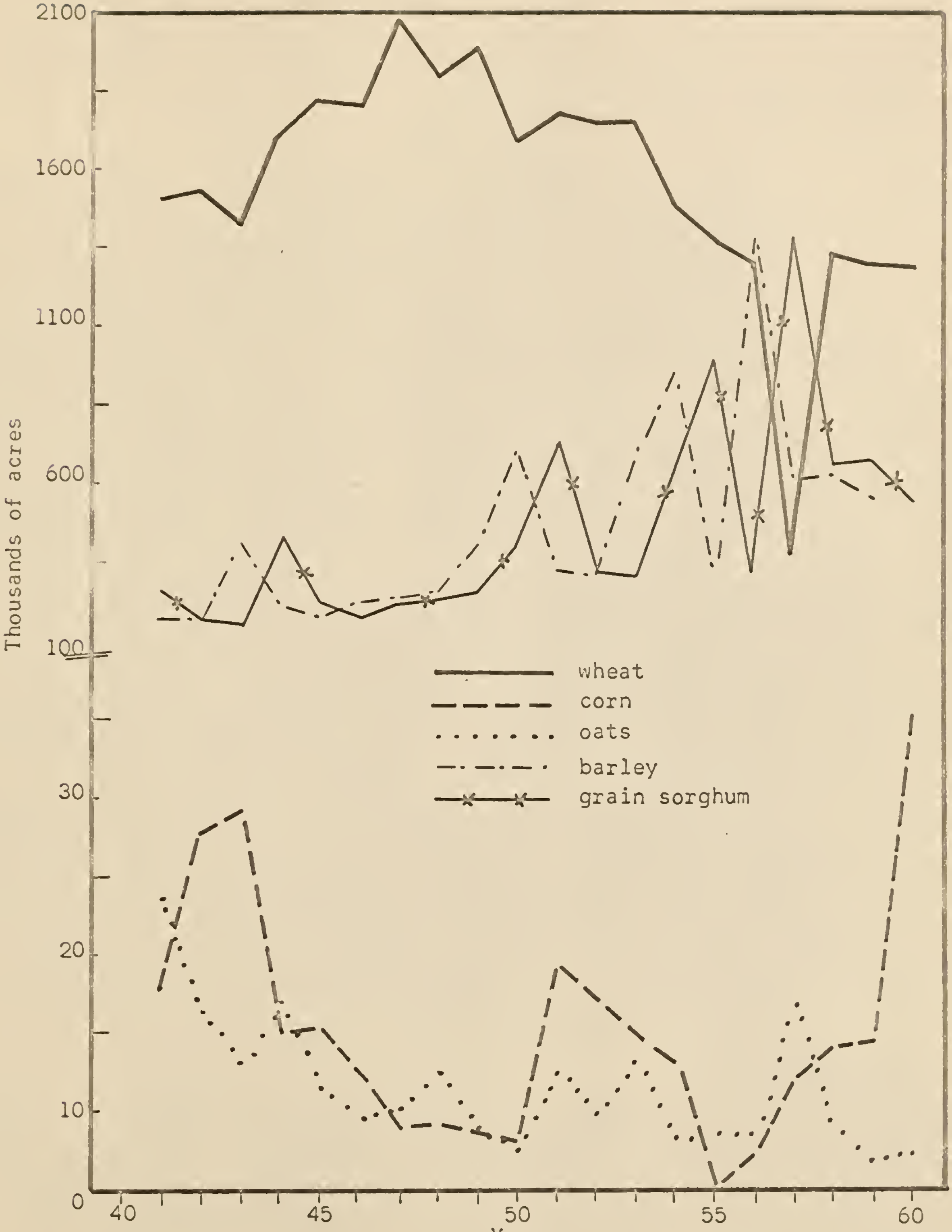

Fig. 18.--Total acres devoted to the five major crops for Area 10b, cropping years 1940-1960, inclusive.

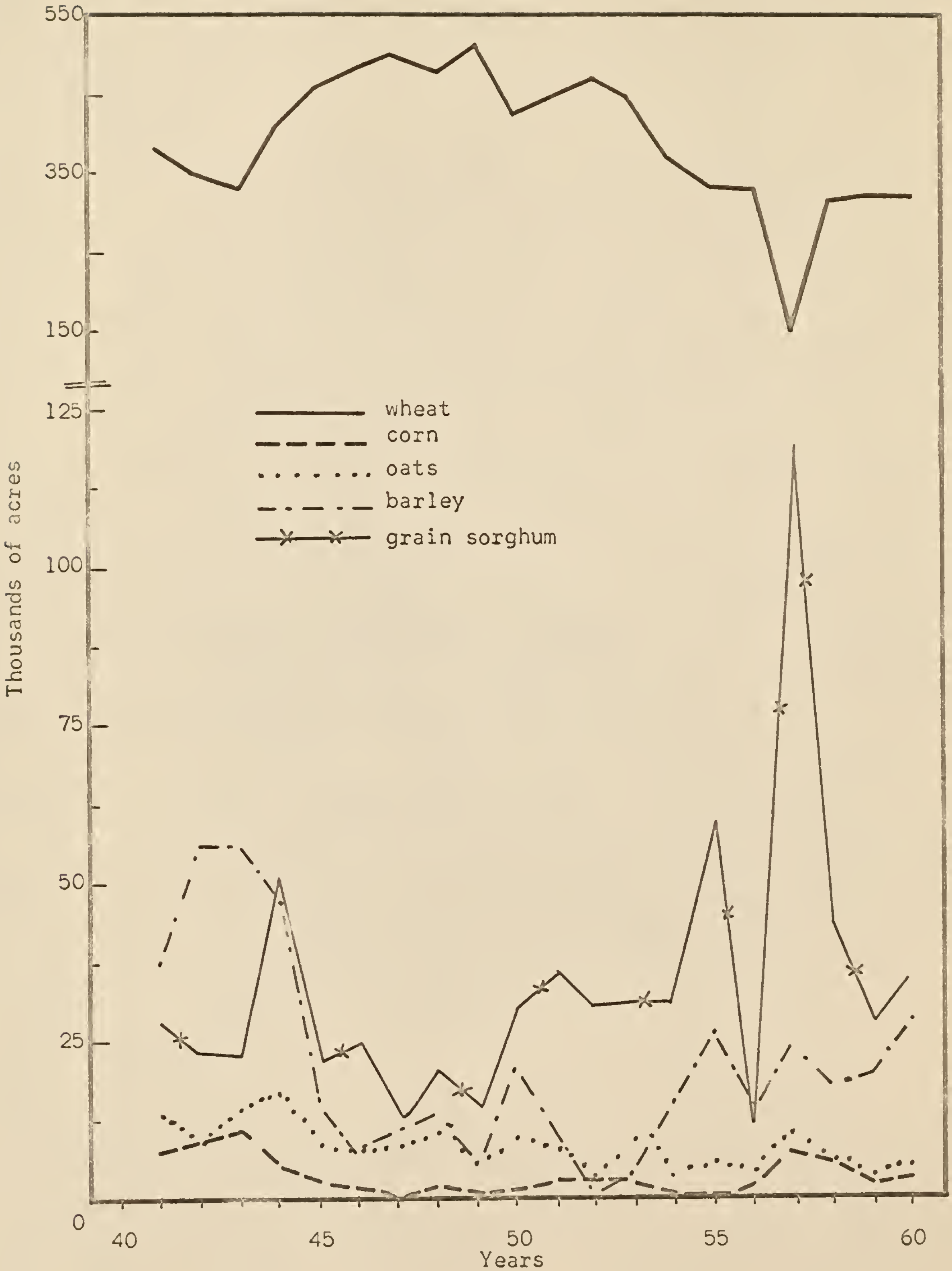

Fig. 19.--Total acres devoted to the five major crops for Area 10c, cropping years 1940-1960, inclusive.

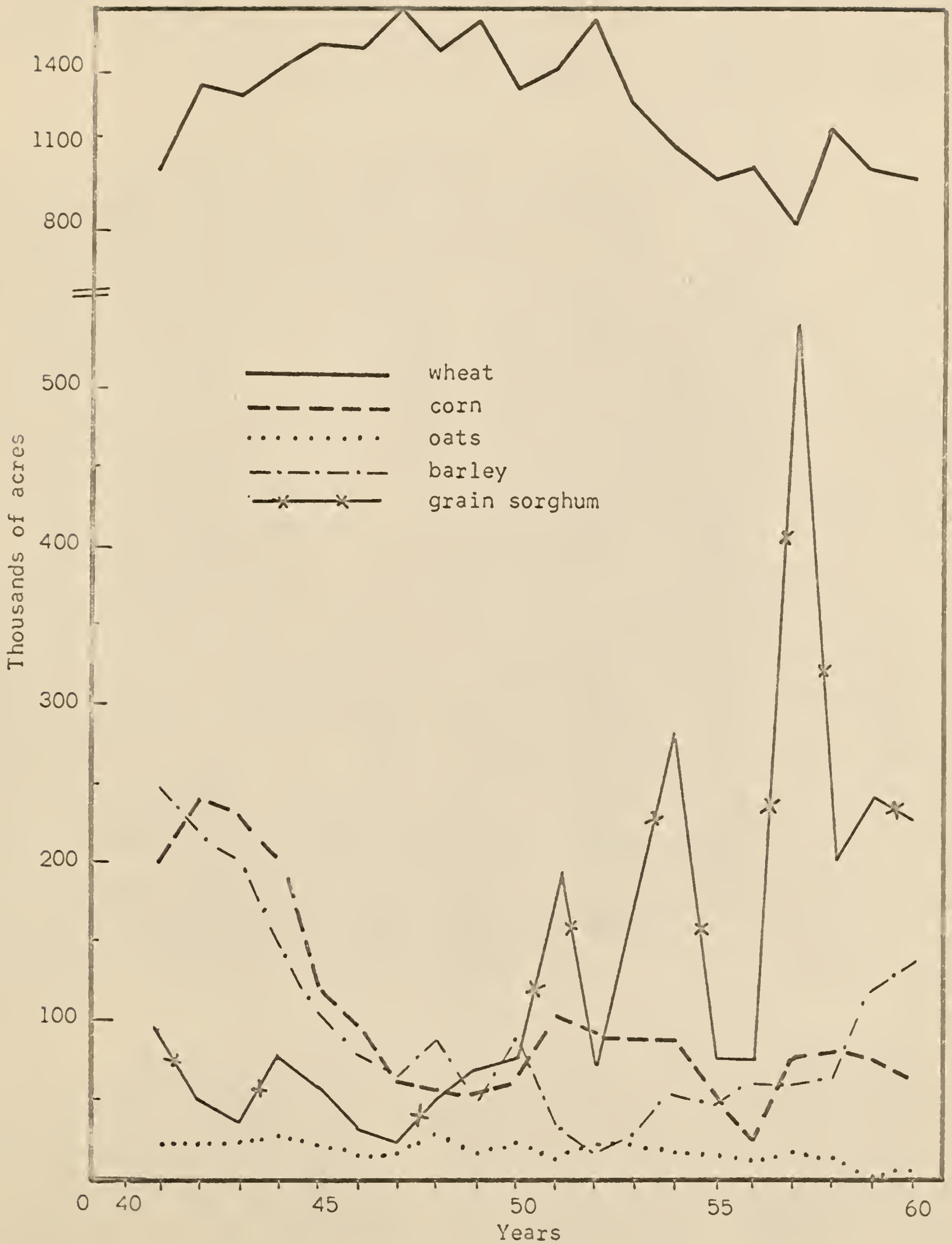

Fig. 20.--Total acres devoted to the five major crops for Area 11, cropping years 1940-1960, inclusive.

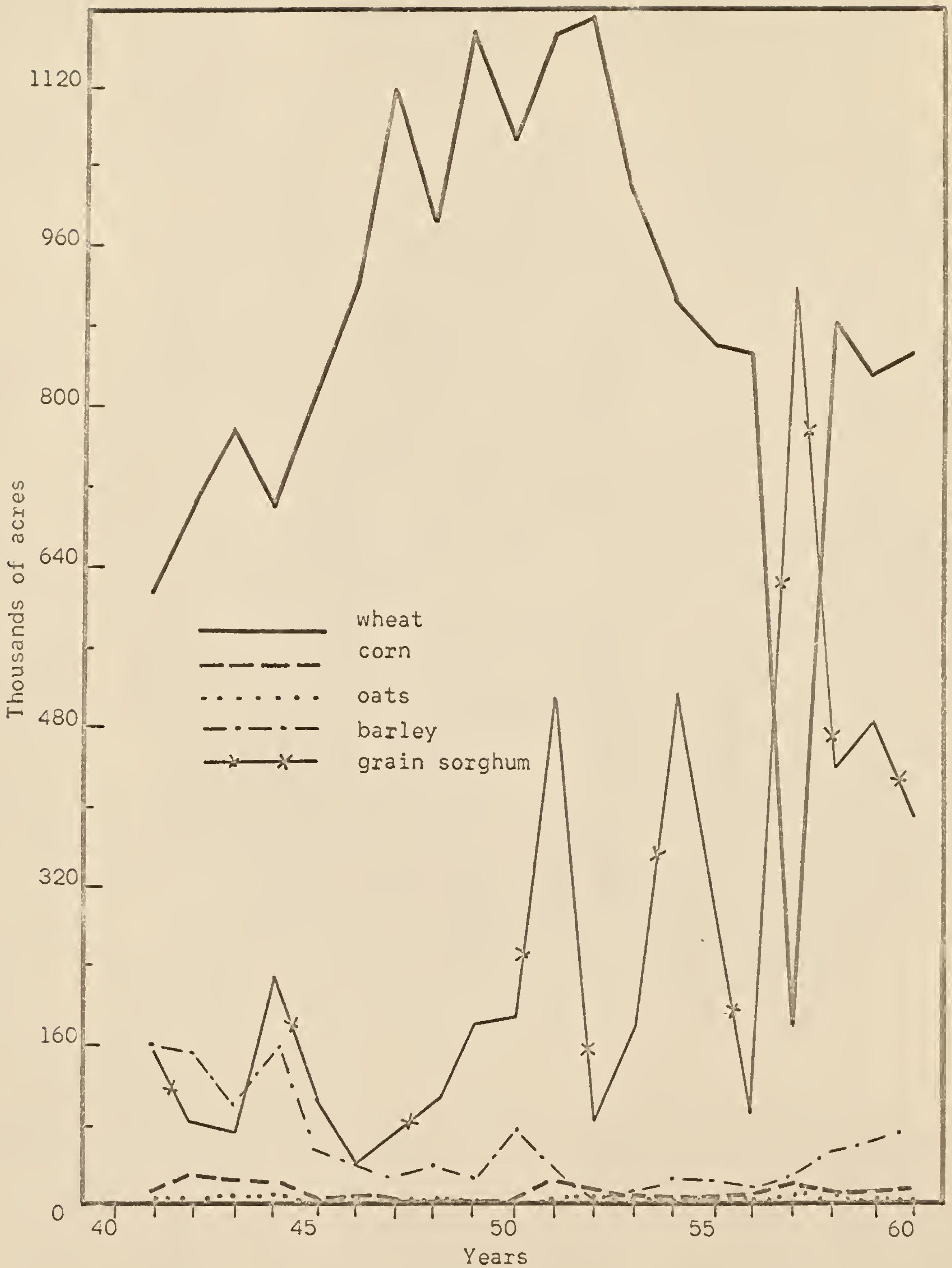

Fig. 21.--Total acres devoted to the five major crops for Area 12, cropping years 1940-1960, inclusive.

Appendix
(pertaining to Chapter IV)

TABLE 20.--The solution basis for linear programming problem (Area 1)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	23.8	40.79	288	328	206	277
Corn	14.63	0.99	31.9	16.95	213	229	169	229
Oats	15.70	0.65	21.6	-1.66	60	76	44	44
Barley	13.48	0.74	21.5	2.43	50	98	38	38
Grain sorghum	8.28	0.76	31.7	15.81	108	164	85	131
				a_{im} = 719				

TABLE 21.--The solution basis for linear programming problem (Area 2)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	26.3	46.74	254	303	205	210
Corn	14.63	0.96	38.6	22.43	338	372	287	372
Oats	15.70	0.66	23.7	-0.06	59	70	43	43
Barley	13.48	0.75	23.1	3,85	35	70	24	24
Grain sorghum	8.28	0.76	35.5	18.70	127	267	149	224
				a_{im} = 873				

* In Tables 20-34, acres allotted to wheat are government allotments.

TABLE 22.--The solution basis for linear programming problem (Area 3)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	27.5	49.60	159	178	143	144
Corn	14.63	0.96	43.7	27.32	211	230	193	230
Oats	15.70	0.67	25.8	1.59	35	41	27	27
Barley	13.48	0.77	21.3	2.92	10	16	7	7
Grain sorghum	8.28	0.76	41.9	23.56	113	158	76	120
			a_{im} = 528					

TABLE 23.--The solution basis for linear programming problem (Area 4)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	25.7	45.32	156	197	135	143
Corn	14.63	0.97	38.3	22.52	362	389	331	389
Oats	15.70	0.67	26.4	1.99	61	71	51	51
Barley	13.48	0.79	20.7	2.87	6	9	4	4
Grain sorghum	8.28	0.77	39.3	21.98	137	201	91	135
			a_{im} = 722					

TABLE 24.--The solution basis for linear programming problem (Area 5)

CROP	C_{im}	P_{im}	Y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	25.3	44.36	442	492	388	427
Corn	14.63	0.97	34.0	18.35	226	266	206	266
Oats	15.70	0.66	21.8	1.31	71	82	52	52
Barley	13.48	0.76	19.9	1.64	78	144	52	52
Grain sorghum	8.28	0.76	32.1	16.12	321	433	253	341
			a_{im} = 1,138					

TABLE 25.--The solution basis for linear programming problem (Area 6a)

CROP	C_{im}	P_{im}	Y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	22.3	37.22	729	779	653	721
Corn	14.63	1.06	27.3	14.31	163	185	142	185
Oats	15.70	0.66	21.9	1.25	85	106	68	68
Barley	13.48	0.71	18.7	-0.20	135	218	63	63
Grain sorghum	8.28	0.72	26.2	10.58	268	419	182	343
			a_{im} = 1,380					

TABLE 26.--The solution basis for linear programming problem (Area 6b)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	21.6	44.67	1,592	1,713	1,400	1,695
Corn	14.63	1.06	25.4	10.77	64	90	52	52
Oats	5.51	0.66	16.7	5.51	72	84	46	46
Barley	5.28	0.71	18.3	7.71	243	368	151	151
Grain sorghum	5.39	0.72	27.9	14.70	570	766	437	597
				a_{im} = 2,541				

TABLE 27.--The solution basis for linear programming problem (Area 7)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	16.1	31.58	956	1,058	856	995
Corn	14.63	0.98	23.7	8.60	23	29	16	16
Oats	5.51	0.65	17.3	5.74	13	17	10	10
Barley	5.28	0.71	14.0	4.66	46	68	28	28
Grain sorghum	5.39	0.71	24.9	12.29	227	330	153	216
				a_{im} = 1,265				

TABLE 28.--The solution basis for linear programming problem (Area 8)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	15.85	2.38	19.8	31.27	649	733	583	663
Corn	14.63	0.94	25.8	9.62	303	348	270	270
Oats	15.70	0.66	21.2	-1.71	34	39	27	27
Barley	13.48	0.72	16.0	-1.96	53	71	29	29
Grain sorghum	8.28	0.71	27.6	11.32	423	553	295	473
				a_{im} = 1,462				

TABLE 29.--The solution basis for linear programming problem (Area 9)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	15.5	30.15	1,198	1,305	1,095	1,237
Corn	14.63	1.06	23.4	10.17	13	17	8	8
Oats	5.51	0.66	13.8	3.60	7	10	5	5
Barley	5.28	0.71	13.5	4.31	62	91	40	40
Grain sorghum	5.39	0.72	24.8	12.47	312	443	231	302
				a_{im} = 1,592				

TABLE 30.--The solution basis for linear programming problem (Area 10a)

CROP	C_{im}	P_{im}	Y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	15.9	31.10	912	1,007	825	906
Corn	36.74	0.99	33.1	-3.97	19	33	14	14
Oats	5.51	0.69	11.9	2.70	4	5	3	3
Barley	5.28	0.67	16.1	5.51	57	76	40	40
Grain sorghum	5.39	0.71	27.8	14.35	298	408	179	327
				a_{im} = 1,290				

TABLE 31.--The solution basis for linear programming problem (Area 10b)

CROP	C_{im}	P_{im}	Y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	17.5	34.91	1,297	1,411	1,222	1,277
Corn	36.74	1.00	41.6	4.86	30	57	21	21
Oats	5.51	0.70	10.2	1.63	2	3	1	1
Barley	5.28	0.68	13.0	3.56	59	76	40	40
Grain sorghum	5.39	0.73	29.4	16.07	559	663	400	608
				a_{im} = 1,947				

TABLE 32.--The solution basis for linear programming problem (Area 10c)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	18.2	36.58	313	337	290	325
Corn	14.63	1.06	22.5	9.22	4	6	3	6
Oats	5.51	0.68	11.6	2.38	5	7	3	3
Barley	5.28	0.70	14.2	4.66	28	51	16	16
Grain sorghum	5.39	0.73	17.4	7.31	35	54	25	35
				a_{im} = 385				

TABLE 33.--The solution basis for linear programming problem (Area 11)

CROP	C_{im}	P_{im}	y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	21.6	44.67	963	1,045	869	921
Corn	14.63	0.97	25.8	10.40	67	81	55	81
Oats	5.51	0.63	14.9	3.88	5	6	4	4
Barley	5.28	0.67	19.3	7.65	140	217	105	105
Grain sorghum	5.39	0.71	21.1	9.59	227	411	141	291
				a_{im} = 1,402				

TABLE 34.--The solution basis for linear programming problem (Area 12)

CROP	C_{im}	P_{im}	Y_{im}	Z_{im}	X^*_{im}	a_{im} max.	a_{im} min.	X_{im}
*Wheat	6.74	2.38	19.4	39.43	853	956	775	814
Corn	36.74	0.97	42.6	4.58	19	26	15	15
Oats	5.51	0.69	11.1	2.15	2	3	1	1
Barley	5.28	0.67	14.7	4.57	74	127	51	51
Grain sorghum	5.39	0.71	26.4	13.35	391	497	227	458

$a_{im} = 1,339$

Appendix
(pertaining to Chapter V)

TABLE 35.--Comparison of theoretical and actual crop allocation for wheat

	Area 1		Area 2		Area 3		Area 4		Area 5	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.357	.443	.268	.396	.432	.446	.321	.377	.419	.551
1942	.065	.471	.082	.441	.234	.457	.242	.346	.224	.565
1943	.184	.419	.099	.391	.198	.436	.185	.328	.229	.551
1944	.277	.416	.147	.328	.232	.354	.208	.314	.282	.482
1945	.399	.374	.239	.299	.338	.336	.230	.301	.345	.485
1946	.378	.431	.191	.346	.280	.392	.202	.325	.349	.505
1947	.418	.459	.230	.317	.334	.340	.242	.246	.421	.502
1948	.463	.351	.303	.331	.391	.372	.275	.314	.460	.496
1949	.483	.464	.356	.351	.453	.339	.321	.315	.511	.528
1950	.412	.460	.273	.346	.357	.379	.270	.331	.412	.490
1951	.472	.357	.275	.318	.374	.358	.294	.293	.476	.494
1952	.483	.378	.255	.305	.340	.363	.227	.313	.468	.463
1953	.526	.410	.303	.305	.358	.327	.263	.275	.502	.487
1954	.425	.269	.250	.193	.302	.301	.220	.299	.440	.420
1955	.377	.428	.245	.317	.287	.327	.206	.242	.402	.463
1956	.390	.399	.270	.342	.306	.333	.224	.216	.419	.440
1957	.423	.445	.296	.344	.308	.368	.217	.277	.398	.495
1958	.340	.426	.283	.319	.321	.348	.244	.288	.392	.468
1959	.389	.460	.284	.352	.305	.376	.226	.308	.385	.475
1960	.400	.433	.291	.344	.301	.401	.216	.371	.388	.487

TABLE 35.--Continued

	Area 1		Area 2		Area 3		Area 4		Area 5	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.755	.723	.809	.780	.794	.771	.489	.638	.848	.723
1942	.553	.722	.642	.776	.753	.738	.387	.553	.807	.713
1943	.539	.737	.611	.792	.675	.777	.331	.548	.764	.739
1944	.632	.697	.718	.751	.787	.747	.394	.638	.855	.680
1945	.706	.671	.809	.760	.861	.834	.424	.567	.921	.790
1946	.720	.718	.825	.761	.875	.792	.435	.561	.927	.743
1947	.753	.697	.853	.784	.911	.779	.529	.535	.934	.735
1948	.744	.719	.827	.742	.830	.768	.491	.564	.884	.747
1949	.782	.753	.878	.798	.891	.858	.561	.647	.938	.730
1950	.655	.651	.742	.679	.817	.772	.495	.555	.864	.735
1951	.703	.697	.807	.726	.864	.802	.560	.596	.856	.747
1952	.696	.672	.859	.724	.867	.745	.543	.532	.915	.682
1953	.731	.702	.830	.760	.873	.834	.555	.567	.839	.855
1954	.648	.668	.763	.751	.766	.789	.473	.530	.806	.764
1955	.643	.617	.685	.782	.844	.827	.518	.467	.783	.841
1956	.639	.600	.703	.722	.859	.799	.550	.466	.846	.813
1957	.567	.709	.622	.763	.627	.890	.413	.590	.514	.886
1958	.595	.669	.667	.690	.752	.719	.488	.519	.755	.667
1959	.550	.676	.634	.709	.751	.796	.454	.537	.764	.781
1960	.528	.696	.626	.701	.755	.733	.444	.536	.752	.674

TABLE 35.--Concluded

	Area 10a		Area 10b		Area 10c		Area 11		Area 12	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.792	.709	.788	.661	.810	.803	.648	.821	.653	.773
1942	.815	.639	.807	.565	.780	.766	.700	.757	.729	.697
1943	.805	.732	.828	.690	.763	.837	.710	.784	.781	.711
1944	.765	.652	.743	.532	.776	.779	.717	.821	.623	.771
1945	.899	.671	.856	.586	.903	.803	.819	.780	.826	.653
1946	.913	.705	.886	.635	.915	.798	.855	.777	.917	.737
1947	.926	.616	.887	.524	.934	.775	.896	.767	.912	.592
1948	.844	.699	.870	.549	.914	.789	.856	.811	.869	.661
1949	.907	.716	.868	.603	.950	.807	.883	.859	.846	.733
1950	.841	.684	.786	.692	.870	.749	.830	.736	.797	.656
1951	.740	.811	.688	.725	.887	.768	.792	.848	.673	.857
1952	.914	.621	.823	.567	.924	.755	.878	.757	.905	.607
1953	.774	.858	.832	.799	.901	.840	.792	.812	.832	.790
1954	.659	.762	.667	.749	.876	.859	.702	.820	.619	.804
1955	.735	.771	.579	.764	.783	.857	.830	.762	.748	.776
1956	.883	.762	.780	.708	.905	.846	.850	.769	.873	.828
1957	.270	.847	.201	.736	.488	.879	.538	.829	.159	.815
1958	.722	.584	.651	.493	.812	.761	.756	.746	.632	.544
1959	.694	.679	.647	.550	.849	.831	.693	.794	.594	.543
1960	.706	.538	.665	.461	.812	.756	.687	.730	.637	.496

TABLE 36.--Comparison of theoretical and actual crop allocation for corn

	Area 1		Area 2		Area 3		Area 4		Area 5	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.294	.270	.337	.307	.320	.331	.460	.416	.226	.172
1942	.422	.220	.464	.289	.454	.334	.524	.439	.346	.160
1943	.397	.255	.501	.309	.505	.340	.594	.459	.398	.181
1944	.345	.225	.501	.273	.548	.329	.600	.414	.394	.158
1945	.303	.227	.506	.304	.479	.413	.580	.489	.380	.173
1946	.348	.345	.517	.407	.452	.397	.570	.461	.384	.236
1947	.237	.277	.428	.411	.434	.432	.604	.554	.295	.233
1948	.256	.195	.395	.302	.413	.347	.531	.422	.244	.157
1949	.298	.223	.433	.307	.409	.355	.534	.448	.284	.165
1950	.302	.229	.432	.308	.428	.365	.532	.421	.293	.152
1951	.293	.196	.472	.315	.455	.407	.553	.503	.292	.168
1952	.360	.342	.516	.386	.491	.392	.580	.466	.303	.244
1953	.249	.330	.390	.412	.436	.442	.560	.489	.226	.214
1954	.257	.552	.364	.635	.429	.510	.551	.487	.245	.343
1955	.180	.275	.253	.391	.368	.451	.570	.566	.169	.284
1956	.218	.288	.276	.337	.362	.391	.517	.562	.164	.269
1957	.153	.275	.282	.340	.347	.379	.454	.497	.150	.196
1958	.291	.221	.362	.294	.389	.356	.428	.439	.209	.159
1959	.274	.201	.343	.270	.372	.310	.497	.397	.195	.147
1960	.296	.226	.387	.286	.400	.319	.501	.380	.199	.149

TABLE 36.--Continued

	Area 6a		Area 6b		Area 7		Area 8		Area 9	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.072	.106	.038	.025	.051	.025	.286	.189	.043	.005
1942	.149	.089	.073	.023	.066	.020	.364	.173	.052	.005
1943	.179	.087	.098	.026	.107	.022	.447	.195	.055	.006
1944	.167	.069	.069	.023	.070	.014	.423	.124	.019	.004
1945	.151	.076	.050	.024	.048	.018	.436	.181	.005	.005
1946	.150	.103	.048	.041	.047	.030	.430	.201	.006	.008
1947	.118	.130	.030	.028	.026	.028	.372	.286	.004	.006
1948	.102	.070	.038	.021	.033	.025	.345	.165	.004	.004
1949	.116	.073	.038	.020	.030	.015	.325	.154	.004	.004
1950	.152	.057	.056	.018	.031	.013	.331	.142	.007	.003
1951	.161	.071	.052	.020	.033	.014	.343	.172	.010	.003
1952	.166	.116	.045	.034	.038	.023	.361	.193	.007	.006
1953	.125	.091	.038	.027	.025	.017	.334	.210	.008	.004
1954	.153	.158	.031	.063	.030	.037	.322	.211	.003	.011
1955	.119	.192	.018	.035	.016	.041	.303	.394	.002	.006
1956	.110	.184	.026	.051	.012	.042	.246	.342	.002	.008
1957	.100	.107	.025	.026	.020	.018	.181	.207	.007	.004
1958	.116	.077	.032	.021	.023	.016	.183	.154	.005	.004
1959	.121	.083	.023	.021	.025	.017	.228	.174	.005	.004
1960	.118	.068	.025	.019	.019	.016	.207	.148	.008	.003

TABLE 36.--Concluded

	Area 10a		Area 10b		Area 10c		Area 11		Area 12	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.010	.006	.007	.009	.016	.013	.123	.048	.015	.028
1942	.010	.006	.012	.009	.021	.014	.134	.049	.027	.030
1943	.016	.009	.014	.015	.024	.018	.135	.070	.026	.033
1944	.011	.004	.004	.006	.011	.012	.112	.032	.020	.016
1945	.005	.006	.005	.010	.006	.013	.071	.052	.009	.033
1946	.004	.008	.004	.014	.004	.017	.061	.069	.008	.039
1947	.002	.007	.002	.011	.002	.015	.038	.061	.005	.029
1948	.002	.004	.002	.007	.004	.009	.037	.051	.004	.021
1949	.002	.004	.001	.007	.004	.009	.033	.034	.002	.017
1950	.002	.004	.001	.005	.005	.007	.044	.043	.003	.015
1951	.004	.003	.006	.005	.007	.009	.061	.034	.012	.011
1952	.004	.007	.006	.013	.006	.015	.055	.056	.010	.029
1953	.005	.006	.005	.011	.005	.015	.060	.055	.008	.023
1954	.004	.008	.004	.011	.002	.020	.062	.057	.006	.020
1955	.001	.008	.001	.008	.002	.011	.048	.129	.008	.027
1956	.001	.007	.002	.014	.006	.021	.024	.060	.011	.017
1957	.006	.004	.004	.005	.025	.012	.050	.044	.017	.013
1958	.003	.004	.005	.004	.015	.010	.055	.038	.010	.012
1959	.004	.003	.005	.004	.009	.010	.052	.039	.009	.012
1960	.015	.004	.016	.004	.010	.009	.047	.044	.014	.012

TABLE 37.--Comparison of theoretical and actual crop allocation for oats

	Area 1		Area 2		Area 3		Area 4		Area 5	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.278	.158	.277	.146	.202	.126	.196	.136	.174	.103
1942	.411	.158	.326	.140	.248	.123	.216	.124	.210	.103
1943	.365	.191	.307	.166	.256	.134	.210	.134	.234	.105
1944	.283	.200	.229	.232	.179	.205	.175	.187	.204	.161
1945	.211	.282	.161	.303	.156	.191	.177	.153	.145	.190
1946	.205	.116	.216	.123	.241	.102	.219	.112	.166	.097
1947	.295	.112	.274	.149	.212	.146	.148	.154	.197	.098
1948	.227	.359	.212	.208	.174	.156	.182	.155	.178	.153
1949	.164	.179	.153	.180	.124	.147	.137	.154	.105	.130
1950	.213	.152	.216	.181	.189	.152	.181	.147	.170	.150
1951	.174	.268	.203	.236	.157	.158	.148	.158	.141	.181
1952	.110	.163	.157	.186	.148	.152	.184	.146	.125	.128
1953	.164	.121	.192	.145	.170	.144	.166	.153	.152	.123
1954	.210	.961	.205	.095	.180	.101	.186	.109	.168	.107
1955	.212	.137	.200	.110	.191	.097	.171	.108	.194	.110
1956	.198	.157	.204	.139	.181	.142	.186	.173	.205	.137
1957	.250	.160	.198	.141	.164	.117	.169	.115	.207	.115
1958	.113	.177	.055	.211	.078	.171	.141	.152	.081	.140
1959	.133	.151	.121	.171	.095	.167	.117	.174	.111	.158
1960	.084	.138	.068	.139	.065	.113	.084	.119	.062	.103

TABLE 37.--Continued

	Area 6a		Area 6b		Area 7		Area 8		Area 9	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.099	.073	.077	.048	.028	.014	.084	.029	.023	.005
1942	.157	.072	.129	.049	.030	.017	.099	.037	.022	.006
1943	.189	.070	.147	.041	.038	.017	.106	.029	.027	.008
1944	.136	.121	.118	.048	.025	.017	.093	.039	.020	.005
1945	.102	.157	.080	.063	.023	.021	.090	.044	.013	.005
1946	.100	.078	.084	.041	.026	.017	.099	.035	.013	.006
1947	.108	.071	.086	.037	.025	.013	.073	.034	.013	.004
1948	.110	.084	.085	.078	.044	.015	.107	.035	.025	.007
1949	.076	.085	.044	.049	.026	.014	.070	.040	.009	.005
1950	.116	.178	.086	.125	.041	.048	.098	.064	.015	.023
1951	.087	.121	.065	.076	.023	.023	.056	.047	.013	.008
1952	.083	.100	.044	.053	.020	.025	.060	.058	.009	.008
1953	.081	.100	.067	.067	.026	.031	,051	.065	.022	.015
1954	.100	.081	.085	.052	.027	.016	.056	.032	.012	.006
1955	.140	.115	.108	.072	.046	.030	.071	.061	.014	.009
1956	.153	.136	.108	.086	.039	.061	.067	.123	.013	.017
1957	.151	.079	.112	.057	.036	.015	.051	.031	.014	.006
1958	.080	.111	.044	.070	.019	.024	.049	.046	.009	.011
1959	.097	.108	.051	.063	.015	.027	.042	.051	.006	.009
1960	.061	.068	.028	.052	.010	.015	.023	.027	.004	,006

TABLE 37.--Concluded

	Area 10a		Area 10b		Area 10c		Area 11		Area 12	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.020	.003	.009	.001	.029	.033	.014	.004	.004	.001
1942	.018	.005	.006	.002	.022	.050	.013	.005	.004	.002
1943	.017	.006	.004	.004	.033	.058	.014	.004	.004	.002
1944	.016	.002	.005	.001	.033	.031	.015	.004	.006	.001
1945	.010	.003	.004	.001	.016	.038	.012	.004	.002	.001
1946	.011	.004	.002	.003	.014	.038	.012	.004	.001	.002
1947	.009	,002	.002	.001	.017	.033	.011	.003	.002	.001
1948	.018	.004	.003	.001	.019	.039	.019	.005	.004	.001
1949	.009	.002	.002	.001	.009	.044	.011	.003	.002	.001
1950	.009	.002	.001	.013	.020	.137	.016	.015	.002	.004
1951	.010	.003	.003	.001	.015	.119	.009	.004	.002	.001
1952	.013	.007	.002	.003	.006	.042	.014	.008	.004	.002
1953	.022	.009	.004	.005	.020	.059	.015	.008	.003	.003
1954	.010	.004	.001	.002	.010	.045	.013	.007	.001	.001
1955	.009	.007	.001	.002	.013	.093	.014	.011	.001	.003
1956	.011	.002	.002	.009	.014	.067	.011	.035	.001	.010
1957	.012	.004	.007	.002	.033	.042	.012	.004	.004	.001
1958	.009	.007	.002	.002	.017	.039	.009	.007	.002	.002
1959	.003	.005	.001	.002	.012	.038	.003	.009	.002	.001
1960	.003	.003	.001	.001	.014	.047	.004	.004	.001	.001

TABLE 38.--Comparison of theoretical and actual crop allocation for barley

	Area 1		Area 2		Area 3		Area 4		Area 5	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.026	.102	.025	.087	.015	.035	.002	.008	.039	.069
1942	.025	.125	.025	.076	.025	.033	.004	.009	.062	.069
1943	.015	.120	.016	.087	.021	.034	.002	.009	.045	.071
1944	.008	.123	.009	.098	.009	.046	.002	.012	.022	.087
1945	.007	.099	.004	.071	.004	.037	.001	.008	.010	.071
1946	.005	.081	.002	.067	.002	.035	.000	.007	.007	.061
1947	.008	.102	.004	.073	.003	.034	.000	.007	.012	.067
1948	.007	.069	.004	.070	.003	.032	.001	.008	.009	.063
1949	.011	.096	.005	.077	.003	.034	.000	.008	.009	.066
1950	.028	.095	.015	.075	.008	.033	.000	.008	.026	.071
1951	.026	.160	.012	.114	.004	.050	.000	.015	.013	.108
1952	.006	.086	.007	.066	.003	.031	.000	.008	.004	.064
1953	.010	.081	.011	.069	.003	.032	.000	.008	.007	.066
1954	.876	.066	.059	.048	.018	.027	.001	.007	.038	.057
1955	.172	.101	.139	.067	.038	.029	.002	.006	.109	.067
1956	.140	.101	.106	.072	.054	.032	.007	.007	.105	.071
1957	.135	.094	.080	.073	.048	.033	.013	.007	.106	.066
1958	.117	.099	.067	.072	.036	.035	.015	.008	.077	.062
1959	.085	.092	.056	.070	.033	.036	.013	.009	.080	.065
1960	.070	.097	.039	.078	.020	.053	.008	.014	.068	.088

TABLE 38.--Continued

	Area 6a		Area 6b		Area 7		Area 8		Area 9	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.047	.041	.047	.053	.080	.016	.102	.012	.061	.020
1942	.098	.057	.112	.062	.105	.025	.125	.022	.080	.029
1943	.055	.047	.093	.061	.128	.024	.089	.015	.092	.037
1944	.016	.054	.033	.058	.041	.023	.044	,022	.040	,020
1945	.006	.047	.015	.054	.020	.020	.017	.018	.022	.019
1946	.004	.041	.011	.051	.016	.016	.010	.015	.026	.022
1947	.004	.041	.009	.050	.014	.016	.011	.013	.023	.018
1948	.005	.044	.009	.052	.031	.017	.021	.014	.036	.022
1949	.003	.040	.008	.053	.012	.017	.014	.014	.016	.022
1950	.014	.066	.038	.067	.025	.040	.020	.024	.037	.057
1951	.004	.071	.012	.089	.008	.032	.006	.030	.020	.054
1952	.001	.051	.002	.049	.004	.023	.002	.018	.005	.027
1953	.001	.048	.003	.060	.005	.023	.003	.017	.012	.028
1954	.015	.040	.043	.050	.014	.017	.008	.014	.032	.021
1955	.054	.055	.082	.076	.034	.027	.020	.019	.043	.037
1956	.045	.053	.070	.073	.029	.041	.022	.025	.033	.042
1957	.052	.043	.075	.054	.024	.015	.016	.013	.042	.022
1958	.049	.042	.064	.048	.026	.019	.023	.015	,034	.021
1959	.075	.039	.083	.048	.034	.018	.029	.013	.032	.022
1960	.098	.068	.096	.060	.036	.024	.036	.021	.039	.027

TABLE 38.--Concluded

	Area 10a		Area 10b		Area 10c		Area 11		Area 12	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.123	.018	.063	.009	.080	.033	.060	.036	.170	.025
1942	.126	.041	.086	.021	.125	.050	.029	.061	.153	.059
1943	.121	.039	.058	.021	.127	.058	.021	.043	.110	.036
1944	.119	.019	.062	.009	.083	.031	.044	.051	.134	.026
1945	.044	.023	.025	.011	.031	.038	.036	.039	.062	.029
1946	.041	.027	.015	.014	.017	.038	.021	.043	.036	.036
1947	.030	.018	.013	.009	.021	.033	.016	.039	.025	.020
1948	.060	.023	.016	.011	.023	.039	.033	.041	.032	.027
1949	.026	.017	.008	.009	.009	.044	.043	.038	.020	.020
1950	.045	.087	.026	.067	.042	.137	.052	.114	.057	.143
1951	.036	.031	.019	.016	.020	.119	.117	.059	.021	.039
1952	.016	.035	.012	.018	.003	.042	.043	.054	.010	.039
1953	.023	.028	.010	.027	.009	.059	.116	.053	.010	.043
1954	.030	.023	.021	.018	.038	.045	.186	.049	.022	.035
1955	.023	.033	.012	.021	.063	.093	.066	.052	.022	.049
1956	.024	.058	.010	.027	.040	.067	.064	.116	.020	.068
1957	.028	.018	.025	.011	.074	.042	.360	.036	.024	.022
1958	.035	.020	.020	.011	.046	.039	.137	.037	.044	.023
1959	.037	.019	.017	.010	.055	.038	.169	.036	.046	.019
1960	.045	.020	.031	.010	.073	.047	.162	.037	.055	.022

TABLE 39.--Comparison of theoretical and actual crop allocation for grain sorghum

	Area 1		Area 2		Area 3		Area 4		Area 5	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.045	.027	.093	.063	.031	.063	.021	.062	.142	.105
1942	.077	.023	.103	.055	.029	.053	.015	.082	.158	.103
1943	.038	.015	.077	.047	.020	.056	.009	.070	.094	.092
1944	.087	.036	.114	.069	.032	.067	.016	.073	.167	.111
1945	.080	.018	.090	.023	.026	.023	.012	.047	.119	.081
1946	.064	.027	.075	.056	.025	.074	.009	.094	.094	.100
1947	.042	.050	.063	.051	.017	.048	.005	.039	.075	.100
1948	.047	.025	.086	.090	.019	.091	.011	.102	.109	.130
1949	.044	.039	.053	.085	.011	.075	.007	.076	.091	.111
1950	.045	.063	.064	.091	.018	.073	.017	.093	.100	.137
1951	.035	.019	.038	.017	.010	.028	.005	.030	.079	.049
1952	.041	.033	.065	.057	.018	.061	.009	.067	.100	.101
1953	.051	.058	.104	.070	.033	.056	.011	.076	.113	.110
1954	.032	.018	.122	.030	.071	.060	.042	.098	.109	.073
1955	.059	.058	.163	.115	.116	.097	.051	.077	.126	.075
1956	.054	.055	.144	.111	.097	.102	.067	.042	.107	.083
1957	.039	.026	.144	.102	.133	.104	.148	.103	.139	.128
1958	.139	.076	.233	.104	.176	.090	.171	.112	.241	.172
1959	.119	.096	.196	.138	.195	.111	.147	.113	.229	.154
1960	.150	.105	.215	.153	.214	.114	.190	.116	.283	.172

TABLE 39.--Continued

	Area 6a		Area 6b		Area 7		Area 8		Area 9	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.027	.057	.029	.094	.047	.173	.039	.145	.026	.248
1942	.043	.060	.044	.090	.046	.200	.025	.215	.039	.247
1943	.038	.058	.051	.080	.052	.159	.027	.212	.062	.160
1944	.049	.058	.062	.121	.077	.199	.047	.177	.066	.291
1945	.035	.049	.046	.099	.048	.107	.034	.189	.039	.180
1946	.026	.060	.032	.107	.036	.144	.026	.188	.028	.222
1947	.017	.061	.022	.101	.024	.165	.015	.131	.026	.237
1948	.038	.083	.041	.107	.062	.175	.036	.222	.051	.221
1949	.024	.048	.033	.080	.041	.097	.030	.144	.033	.188
1950	.063	.048	.078	.112	.086	.127	.056	.215	.077	.182
1951	.045	.040	.064	.089	.072	.129	.035	.155	.101	.187
1952	.054	.061	.050	.139	.071	.183	.034	.198	.064	.277
1953	.062	.060	.062	.086	.071	.095	.057	.142	.119	.098
1954	.084	.054	.078	.085	.163	.141	.141	.213	.147	.198
1955	.044	.021	.107	.035	.060	.075	.088	.059	.158	.106
1956	.053	.027	.093	.068	.061	.056	.115	.044	.106	.120
1957	.130	.063	.166	.101	.293	.062	.339	.158	.423	.083
1958	.160	.101	.193	,171	.180	.221	.257	.266	.197	.297
1959	.157	.100	.209	.159	.175	.143	.247	.225	.193	.185
1960	.195	.101	.225	.167	.180	.213	.290	.268	.197	.289

TABLE 39.--Concluded.

	Area 10a		Area 10b		Area 10c		Area 11		Area 12	
	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.	Act.	Est.
1941	.055	.265	.133	.320	.065	.137	.060	.092	.158	.173
1942	.031	.309	.089	.403	.052	.160	.029	.129	.087	.212
1943	.041	.214	,096	.274	.053	.075	.021	.098	.079	.217
1944	.089	.323	.186	.452	,097	.172	.044	.092	.212	.186
1945	.042	.296	.110	.393	.044	.137	.036	.125	.101	.284
1946	.031	.256	.093	.334	.050	.138	.021	.107	.038	.187
1947	.033	.357	.096	.456	.026	.170	.016	.130	.056	.358
1948	.076	.270	.109	.432	.040	.151	.033	.092	.091	.290
1949	.056	.260	.121	.380	.028	.131	.043	.066	.130	.230
1950	.103	.205	.186	.222	.063	.053	.052	.092	.141	.181
1951	.210	.151	.284	.251	.071	.094	.117	.056	.292	.092
1952	.053	.329	.157	.399	.061	.175	.043	.124	.071	.328
1953	.176	.098	.149	.158	.065	.065	.116	.072	.147	.142
1954	.297	.201	.307	.220	.074	.065	.186	.068	.352	.140
1955	.232	.180	.407	.205	.139	.022	.066	.046	.221	.146
1956	.081	.150	.206	.245	.035	.038	.064	.019	.095	.077
1957	.684	.128	.763	.246	.380	.054	.360	.088	.796	.149
1958	.231	.386	.322	.490	.110	.171	.137	.172	.312	.419
1959	.262	.294	.330	.435	.075	.105	.169	.123	.349	.424
1960	.231	.436	.287	.525	.091	.175	.162	.185	.293	.470

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THE USE OF ANALYTICAL MODELS IN DETERMINING CROP ALLOCATIONS FOR KANSAS

by

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AN ABSTRACT OF A MASTER'S THESIS

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This study was undertaken to determine the relative influence of acreage and yield changes on crop production; and the usefulness and limitations of analytical models in determining crop allocations for Kansas. The objectives of the study were:

1) To determine the relative role of yield and acreage changes in relation to total production of a particular crop from year to year.

2) To assess the relative stability of the land use on the cropping system.

3) To determine the optimum land use or the optimum cropping pattern for the individual type of farming areas, and to ascertain the differences between the actual and the estimated crop plantings.

4) To determine the cropping pattern for each of the type-of-farming areas by employing a game theoretic model.

The main theme that carried throughout the study was: "Is it so that farmers are reluctant to alter their cropping pattern from year to year in Kansas?" This question developed out of a similar study done for Illinois. One of the assumptions and conclusions of the Illinois study was that farmers were reluctant to change their cropping pattern from year to year, i.e., a very low variability over a twenty-year period for acreage changes for each of the major crops in Illinois.

It was believed by the author of this study that the conclusion for an Illinois farmer's cropping pattern could not be applied to the cropping patterns of a Kansas farmer. This belief was based mainly on the wide difference in the natural elements between Kansas and Illinois. For Kansas, farmers must adopt flexible cropping patterns to compete successfully with the natural elements and government programs. The degree of flexibility would vary within the state of Kansas due mainly to varying weather conditions within the state.

It may be well to point out that the author was only concerned with actual changes in the cropping patterns for Kansas and not desired cropping patterns. A different conclusion would have probably been reached if the study was concerned with desired cropping patterns.

The data used were based on seeded acres and yields for all crops except grain sorghum since this gave an actual measure of changes in the cropping system from year to year. Actual seeded acres and yields have not been recorded for grain sorghum.

The answer to the question posed became evident with the use of statistical methods. A sample period of twenty years, from 1941 to 1960, was used for the study. The data were obtained from The Biennial Reports of the Kansas State Board of Agriculture.

One measure of the willingness of farmers to adjust to changes under the conditions which cropping plans are developed, is the extent to which crop-acreage adjustments have been made in the past. As an indicator for this the percentage acreage adjustments were divided into those years in which planted acres increased from the previous year, and those years in which decreases occurred. A simple average was used for both the increases and the decreases as an indicator of the magnitude of the adjustments. The magnitude appeared to be quite high for Kansas relative to Illinois.

A least squares regression was used to determine the relative role of the variables, yield and acres, on total production of each crop. In general, acreage variability appeared higher relative to yield variability for eastern Kansas, whereas yield variability played a larger role in western Kansas. This tendency was not true for all areas and for all crops from eastern to western Kansas. But it did seem to have some validity for the more dominant crops in each of the areas.

The use of a linear programming model and a game theoretic model for estimating acres devoted to each of the major crops did not give very good results. This substantiated the degree of flexibility in a farmer's cropping pattern further.

It would be reasonable to conclude that the conclusion of the Illinois study can not be applied to Kansas. Also the use of Kansas agricultural data for the use in theoretic models imposes limitations mainly due to the high degree of flexibility in a farmer's cropping pattern.