KAMAL AHMED EL-GANZOURY


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CHANGES IN UNITED STATES COTTON YIELDS, 1939-1959 -- THE INFLUENCES OF WEATHER, TECHNOLOGY AND ECONOMIC FACTORS

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

Kamal Ahmed El-Ganzoury

1967

This is to certify that the

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CHANGES IN UNITED STATES COTTON YIELDS,
1939-1959--THE INFLUENCES OF WEATHER,
TECHNOLOGY AND ECONOMIC FACTORS

presented by

Kamal Ahmed El-Ganzoury

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Lawrence W. Witt
Major professor

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ABSTRACT

CHANGES IN UNITED STATES COTTON YIELDS, 1939-1959--THE INFLUENCES OF WEATHER, TECHNOLOGY AND ECONOMIC FACTORS

by
Kamal Ahmed El-Ganzoury

The main objective was to analyze the relative importance of factors related to past changes (1939-1959) in cotton yields. The factors considered were: (1) pounds of fertilizer nutrients per acre of cotton, (2) man-hours of labor per acre of cotton, (3) number of tractors per 1000 acres of harvested cropland, (4) dollars spent on gas and oil per acre of harvested cropland, (5) proportion of cotton acreage irrigated, (6) size of the cotton enterprise, (7) relative changes in cotton acreage, (8) percentage of total harvested cropland in cotton, (9) value of land and buildings per acre, (10) price of cotton for previous season, (11) monthly total rainfall, (12) monthly average temperature, (13) squared monthly total rainfall, (14) squared monthly average temperature, (15) monthly rainfall and temperature interaction, (16) successive month rainfall interaction, (17) shifts in location of production among counties, and (18) shifts in location of production among states.

Regression techniques employing a quadratic function of time to represent monthly weather data were the tools

for the analyses. A combination of time series and cross-sectional data were used, with the basic unit of observation being the county in census years 1939, 1944, 1949, 1954 and 1959. A random sample of 258 counties represented the entire U. S. cotton area. Three levels of analyses were applied, i.e., state, regional and national levels. At the state level, fifteen analyses were made, one each for North Carolina, South Carolina, Georgia, Alabama, Missouri, Arkansas, Tennessee, Mississippi, Louisiana, Oklahoma, East Texas, West Texas, New Mexico, Arizona, and California. At the regional level, four analyses were made, one each for the Southeastern, the Delta, the Southwestern, and Western Regions.

Generally, the statistical analyses yielded coefficient signs which would be expected, from an economic and technical point of view. The regional analyses were generally superior to those at the state and national levels from the standpoint of the size and the statistical significance of the estimated coefficients. Moreover, the regression results for technical and economic factors from the regional analyses were more consistent internally and more meaningful in terms of the technical and economic expectations than those obtained from either state or national analyses. The results for weather variables, particularly for rainfall, from regional analyses were consistent region to region.

In the state analyses' results, the main problem was the different signs and sizes of estimated coefficients for the same factor in different states. However, the variables used in the state regression models explained 46 to 84 percent of the variation in cotton yield increases. In the national analysis, the coefficient of multiple determination was smaller than that for regional or state analyses, indicating some heterogeneity in the relationships among the cross-sectionally combined states.

The results indicate that the increase in cotton yields over the period 1939-59 was mainly imputed to three major factors. These factors are: (a) increased use of fertilizer, (b) shifts in location of production toward higher yielding areas, and (c) time-related factors, i.e., those factors which affected yields over time and were not explicitly included in the analyses, such as improvement in seed varieties, production techniques and insect control.

CHANGES IN UNITED STATES COTTON YIELDS, 1939-1959--THE INFLUENCES OF WEATHER, TECHNOLOGY AND ECONOMIC FACTORS

By

Kamal Ahmed El-Ganzoury

A THESIS

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DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

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ACKNOWLEDGMENTS

I wish to thank my major professor, Dr. Lawrence W. Witt, for his patient guidance and assistance throughout my doctoral program and especially for his constructive guidance during this research. His constant encouragement and willingness to help on many problems, academic or otherwise, enabled me to pursue my study at Michigan State University.

Many thanks are extended to Dr. Richard G. Heifner, who served on my guidance committee, for making valuable comments and suggestions throughout the course of this study.

Thanks are due to other members of my guidance committee, Doctors James T. Bonnen, Victor E. Smith, and Robert D. Stevens, for reading a draft of the thesis and making helpful comments.

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Of course, any errors of commission or omission are entirely my own.

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CHAPTER I

INTRODUCTION

In recent years, there has been a substantial increase in the yield per acre of many of the major crops in the United States. This phenomenon has created some problematic situations for agricultural researchers. Such a phenomenal increase in major crop yields has prompted agricultural researchers to investigate the different factors related to changes in yields of agricultural crops. A large number of studies of crop yields have been made, and most have been concerned with food crops. For instance, wheat, corn, oats, and barley were investigated on a national basis by Johnson and Gustafson.[1] These same crops were studied by other researchers on a state or regional basis.[2] Grain sorghums and soybeans were investigated by Thompson,[3] and there is a further study being carried out

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[1]D. G. Johnson and R. C. Gustafson, Grain Yields and American Food Supply (Chicago: University of Chicago Press, 1962).

[2]L. H. Shaw and D. D. Durost, The Effect of Weather and Technology on Corn Yields in the Corn Belt, 1929-62, U.S.D.A. Econ. Rpt. 80, July, 1964.

[3]L. M. Thompson, "Evaluation of Weather Factors in the Production of Grain Sorghum," Agronomy Journal, Vol. 55 (1963), 182-185.

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Sorghum,"
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on the former crop by Abel.[4] But, few studies have been concerned with cotton yields, particularly on a national basis, even though cotton is one of the most important cash crops in the United States, and cotton production is one of the most important enterprises found on American farms. Therefore, it was decided to investigate U. S. cotton yields on a state, regional, and national basis. It should be pointed out that the knowledge acquired and the methods developed in this study may be helpful in analyzing cotton yields in other countries.

The Problem

As mentioned, there has been a phenomenal increase in the cotton yield per acre, which has introduced many interesting questions, such as: How much of this dynamic increase in cotton yields can be attributed to weather? How much to technological advance? How much to favorable prices which may lie behind changes in technology and some changes in the areas of production? The answers to these questions have very important implications for agricultural policy. For instance, if the increase in cotton yields has been the result of improved technology, policies of cutting back cotton production are likely to require more

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[4] F. Abel, "A Study of Change in Yield per Acre in Grain Sorghum," (Ph.D. Thesis at Michigan State University, not yet completed).

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Objectives

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acreage reduction than originally contemplated. On the other hand, if the increase in cotton yields has been the result of favorable weather, then the presumption is that averaging will essentially occur; so there is no need to contemplate other policies.

Objectives

The main objective of this study was to analyze the relative importance of the following factors related to past changes in yields per cotton acre:

1. Weather
2. Fertilizer
3. Mechanization
4. Labor
5. Irrigation
6. Shifts in production
7. Value of land
8. Price of cotton

Cotton and Climate

Cotton is considered a warm climate crop. It is generally agreed that the climatic requirements for successful commercial production of cotton are a mean annual temperature of not less than 60°F., a frost-free season of 180-200 days, annual rainfall of not less than 20 and not more than

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: more than 75 inches.[5] "In the United States the most vorable conditions for cotton production are a mild spring th light but frequent showers; a moderately moist summer, rm both day and night so so as to maintain even and contin- us growth and fruiting; and a dry, cool, and prolonged tumn. Cold weather with rain in the spring may rot the ed in the ground, retard the growth of the seedlings, favor seedling diseases. Too much rain during the grow- g season causes the development of surface roots at the pense of the deeper roots. This results in wilting and edding of leaves and bolls if the weather turns very dry the summer."[6]

tton Regions

Cotton is currently grown in twenty states. "Cotton lt is bounded on the north by the frost line which marks e northern limit of 200 day frost-free growing season d a mean summer temperature of not less than 70°F., the ea dips irregularly to the south around the higher alti- des of the southern Appalachian to the north again in the v elevations of Mississippi and then tends to the south- st in response to both inadequate rainfall and low tem-

[5]U. S. Department of Agriculture, 1941 Yearbook of riculture: Climate and Man, p. 34.

[6]Ibid., p. 353.

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. On the east and south the cotton belt is fringed
ropical border, beginning at the Carolinas and fol-
round the Gulf including practically all of Florida."[7]
ever, the United States Cotton Belt usually is divided
r regions. An area extending from North Carolina
South Carolina, Georgia, and Alabama is referred
e Southeast Region. Westward the broad delta or
ttom areas along the Mississippi River and tribu-
n Tennessee, Missouri, Arkansas, and Louisiana is
the Delta Region.[8] The third region is the South-
ion, including Oklahoma and Texas. New Mexico,
and California are known as the Western Region.
r the last three decades, substantial shifts in
creages and production occurred among those four
On the basis of the United States average cotton
on and acreages (1930-34), the Southeastern Region
29 percent with 24 percent of the total cotton
. Another 29 percent was produced by the Delta
ith 27 percent of the acreage. Oklahoma and Texas,
outhwestern Region, produced only 38 percent on
nt of the acreage. And, 3 percent was produced

Y. Patil, "A Study of Recent Changes in Cotton
on Pattern and Techniques in the United States and
plicability to Indian Conditions." (unpublished
Thesis, Michigan State University, 1955), p. 21.

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Western Irrigated Region with only 1.3 percent of
eage.

wever, all these figures have been substantially
over time. On the basis of the United States aver-
ton production and acreages (1960-64), the South-
Region has been producing only 14 percent from 16.5
of the total cotton acreage, whereas the Delta
has produced 33 percent from 28 percent. Oklahoma
as have produced 33.6 percent from 45.3 percent.
Western Irrigated Region, the percentage of cotton
ion and acreages has been substantially increased
9.8 and 9.3 percent, respectively, of the United
cotton production and acreages. A large part of
crease in the cotton production of the Western Region
to expanded cotton production in Southern California
thwest Arizona after 1950.[9]

Yields

gures 1-A and 1-B show the trend for the United
average yield per acre of cotton in the period
. This trend for the whole period can be divided
o distinct linear patterns. The first period is
00 to 1933. The trend during this period was down-

.S.D.A., E.R.S., Agr. Econ. Rpt. No. 99, Costs and
ng Upland Cotton in the U.S., 1964, September 1966.

Figure

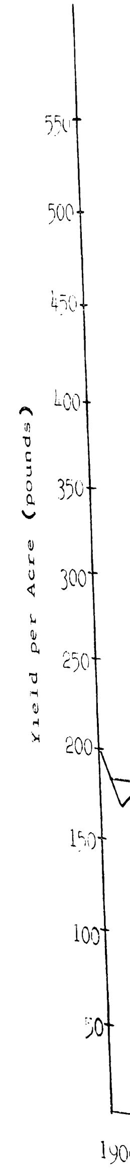
Yield per Acre (pounds)
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Figure 1-A. United States Average Yield per Cotton Acre (1900-1933)

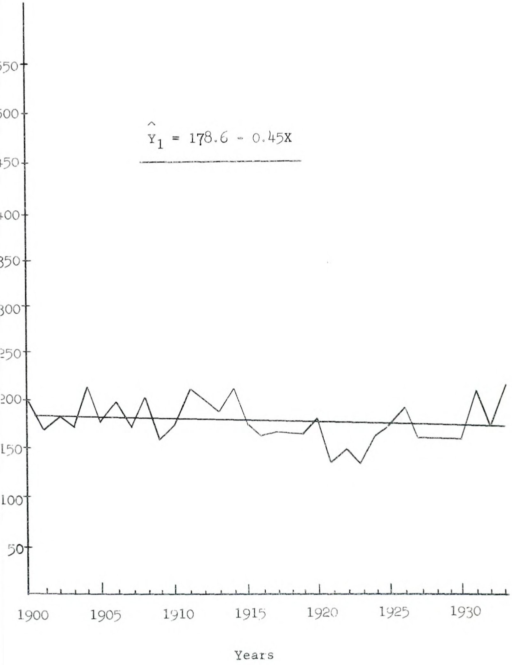


Figure 1

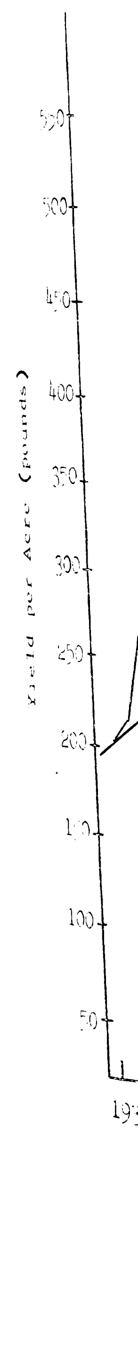
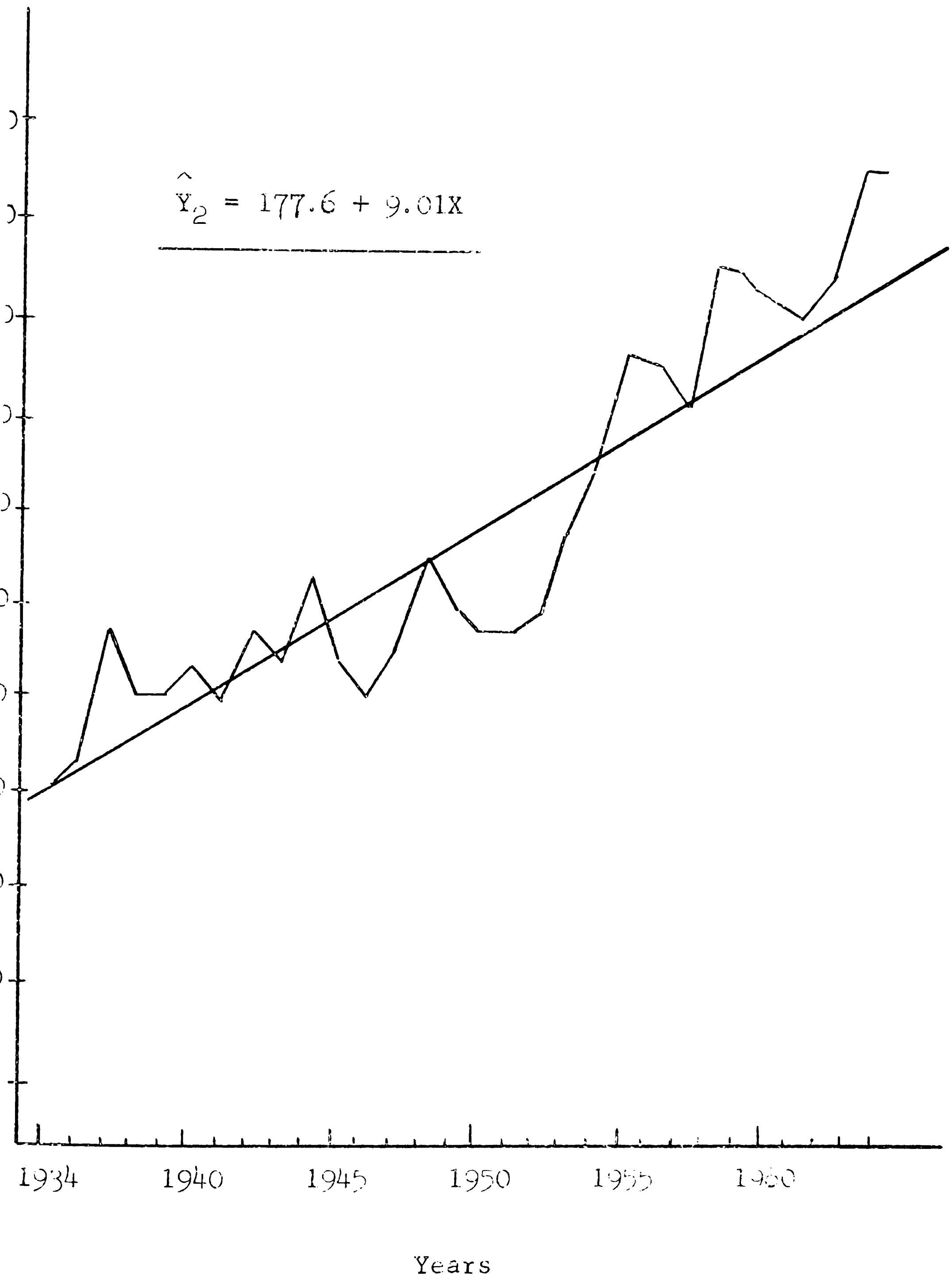


Figure 1-B. United States Average Yield per Cotton Acre (1934-1964)



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with a very slight slope as shown in Figure 1-A. The
: squares line of the best fit decreases very slightly
ne rate of 0.45 pound per year.[10] The fluctuations
: trend were relatively small as compared with the later
od. The second distinct period begins in 1934 and runs
964. Throughout this period the trend was upward with
latively sharp slope as shown in Figure 1-B. The least
res line of the best fit rises at the rate of 9.01 pounds
year.[11] Hence, all emphasis in this present study is
ted to the second period in which a substantial increase
otton yields has occurred.

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10 $\hat{Y}_1 = 178.6 - 0.45X.$

11 $\hat{Y}_2 = 177.6 + 9.01X.$

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CHAPTER II

REVIEW OF LITERATURE

large number of crop yield studies have been made.
ve been concerned with food crops. However, the
al crop yield studies related to the present study
reviewed as the following two groups:

1. Studies employing the weather index approach.
2. Studies which attempt to establish direct relationships between weather variables, temperature, rainfall, etc., and yield.

example of the first group of studies is that by
gs.[1] He developed indexes of the influence of wea-
ing a plot data approach. The method, which was
rlier by Johnson[2] and Hathaway[3] is essentially this:

. L. Stallings, "Indexes of the Influence of Weather
cultural Output" (unpublished Ph.D. Thesis, Michigan
niversity, 1958).

L. Johnson, Burley Tobacco Control Program, Ken-
gr. Exp. Sta. Bul. 580, 1952.

E. Hathaway, The Effects of the Price Support Pro-
the Dry Bean Industry in Michigan, M.S.U. Tech.
, 1955.

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·xperiments where practices have been controlled, ·-year variation in yield data is due primarily to ·. A trend is fitted to the data to describe the ·ariation due to changes in factors which were not ·nstant, such as soil conditions or changes in farm- ·ctices. The influence of weather is then measured · year as that year's actual yield as a percentage computed trend yield. For example, if for 1930 the ·ield is 40 bushels per acre and the actual yield ·ushels, the weather effect would be measured as 125. ·r words, yields in 1930 were 25 percent higher be- ·f favorable weather. A weather index value of 100 ·ndicate a year where the trend yield and actual ·re identical."[4]

·e question that might be raised about this method · sampling problem" common to many index number con- ·ons. That is, are the locations and the data used · representative?[5] Also, in this method, control ·or yield experiments are used where technology is ·nstant.

·is method was modified by Shaw and Durost in their ·f the effects of weather and technology on corn

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·.S.D.A., ERS-72, Measuring the Effects of Weather · Output, October 1962, p. 2.

·ohnson and Gustafson, op. cit

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in the corn belt.[6] They used data from variety
est plots where technology is not held constant.
tatistical model was based on time series data
2). Their study led them to the conclusion that
ogy was introduced in two stages during a period
o 1942, and a period after 1954. Also their study
wn that through the use of better varieties of corn
roved cultivation and fertilization practices, man
uced variation in yields in both good and bad wea-

other example of studies employing weather index
h is that by Heady and Auer.[8] Their study was deal-
h the imputation of crop yield and production in-
among several variables or technologies for corn,
oats, barley, soybeans, cotton, grain sorghums, and
y. Their statistical models were based on time
data (1939-60). They estimated production functions
s by states. The independent variables for tech-
were: an index of variety, fertilizer rate, index
acreage, and a time variable to represent other
of technology. The weather variable was an index

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haw and Durost, op. cit.

bid., p. iv.

. O. Heady and L. Auer, "Imputation of Production
nologies," Journal of Farm Economics, Vol. 48, No.
1966).

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ıer calculated from data on experimental and test Concerning cotton yield analysis, their study led the following conclusions: fertilizer and variety ıents had fairly large positive effects on cotton ɔer acre. An increase of 42 pounds was imputed to zer and 35.5 pounds to variety improvement. Pro- location had a negative effect during part of the ar II and post-war periods when acreage expanded, lly in the Southern Plains, where an additional 5.8 acres were planted between 1950 and 1951. But, ıly about half of the United States cotton produc- s included in their analysis of cotton yields, much cotton yield increase due to shifts from lower yield- ieties in the Southeast to irrigated cotton in the st was not considered, and the overall picture was plete.[9]

e second group of studies attempts to establish relationships between weather variables, temperature, l, etc., and yield. However, from the many studies, esponsible for shaping the ideas of this present an be very briefly reviewed as follows.

W. Smith, in 1914, studied the effect of weather yields.[10] By using simple correlation, he deter-

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eady and Auer, op. cit., p. 319.

. W. Smith, "The Effect of Weather Upon the Yield ," Monthly Weather Review, Vol. 42 (1914), 78-87.

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ie most important weather factors in corn production
. He found that: "the controlling weather factor
great corn-growing districts of the United States
fall . . . . If the rainfall for calendar months
idered that for July has a far greater effect upon
n yield than rainfall for any other month."[11]
llace, in 1920, made an important contribution to
understanding of corn production and weather factors
oying linear regression techniques.[12] He was one
first to use multiple regression methods to predict
elds from selected weather variables. His study
to the conclusion that: "Careful examination of
l, temperature, and corn yield data in the various
lt states leads to the belief that while that the
of correlation coefficients is very useful for pre-
y examination of the data, and while this method
airly good predicting formula in the southern part
corn belt, yet it is not at all well adapted to the
n part of the corn belt, ... The relationship
corn yield and July temperature, for instance, is
ctly linear . . ."[13]

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bid., p. 87.

. A. Wallace, "Mathematical Inquiring Into the
f Weather on Corn Yield in the Eight Corn Belt
Monthly Weather Review, Vol. 48 (1920), 439-56.

bid., p. 445.

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sher, in 1924, studied the influence of rainfall : yield at Rothamsted, and introduced a new tech-[1] This technique is to fit a polynomial function to a set of weather data representing successive me periods within the growing season.[15] The main e of Fisher's technique is to incorporate a priori that the effect of each weather factor on yield gradually from month to month. Clearly, the num-veather variables used in this technique is less the conventional regression technique; thus the correlation coefficient (R^2) is reduced. However, ilts are more consistent with a priori notions of ess over time in the weather effects on crop yields. 1928, Kincer studied the relationship between wea-ndition and the cotton boll weevil.[16] Yet he made npt to measure the part of variation in cotton yields boll weevil damage. B. B. Smith also made several concerning cotton production. In his study of the nship between cotton yields and weather, he made esting analysis to estimate that part of variation

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. A. Fisher, "The Influence of Rainfall on the Wheat at Rothamsted," Philosophical Transactions oyal Society of London, Vol. 213, pp. 89-142, 1924.

. H. Sanderson, Methods of Crop Forecasting (Cam- Harvard University Press, 1954).

. B. Kincer, "Weather and Cotton Boll Weevil," Weather Review, Vol. 56 (1928). 301-304.

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tton yields due to boll weevil damage.[17]

In 1936, a study of corn yield and climate in the corn was made by Rose.[18] He used correlation methods on for 55 corn belt counties, and found that no specific tic factor gave significant correlation for all parts e corn belt.

In 1940, Davis and Pallesen used Fisher's technique tting polynomial function to weather data to study ffect of rainfall and evaporation during the growing n on yields of corn and spring wheat.[19]

In 1941, Ezekiel used multiple curvilinear regression iques to study weather and corn production.[20] He used verage summer temperature, monthly total rainfall for hree summer months and combined production of eight s to capture the effect of weather on corn yields.

In 1942, Houseman used curvilinear regression tech- to determine the period of the growing season when

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17B. B. Smith, "Relation Between Weather Conditions ield of Cotton in Louisiana," Journal of Agricultural rch, Vol. 30 (June, 1925), 1083-1086.

18J. K. Rose, "Corn Yield and Climate in the Corn Belt," aphical Review, Vol. 26 (January, 1938), 88-102.

19F. E. David and J. E. Pallesen, "Effect of Amount stribution of Rainfall and Evaporation During the g Season on Yields of Corn and Spring Wheat," Jour- Agricultural Research, Vol. 60 (1940), 1-23.

20M. Ezekiel, Methods of Correlation Analysis (New 1941).

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crease in rainfall or temperature was most favorable st damaging.[21]

In 1943, Hendricks and Scholl used multiple linear ssion techniques to study the joint effects of temure precipitation on corn yields.[22] They used monthly all, monthly temperature and monthly rainfall-temperanteractions as weather variables to measure the effects ather on corn yields. Their study led them to the usion that high temperatures are damaging to the crop accompanied by low levels of rainfall, and beneficial rainfall is excessive.

Fulmer and Botts, in 1951, studied the factors influ- cotton yields and their variability in the upper ont of South Carolina and Georgia and Rolly Plains of n Texas.[23] In their study, the farm was taken as bservation unit, and the multiple correlation technique sed to measure the effect of some technical and econ- factors on the changes in cotton yields among farms.

Recently, Runge and Odell studied weather and crop

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1 E. E. Houseman, Methods of Computing A Regression eld on Weather, Iowa Agr. Exp. Sta. Research Bul. 302,

2 W. A. Hendricks and J. C. Scholl, The Joint Effects perature and Precipitation on Corn Yields, North na Agr. Exp. Sta. Tech. Bul. 74, 1943.

3 J. L. Fulmer and R. R. Botts, Analysis of Factors ncing Cotton Yields and Their Variability, U.S.D.A., Bul. No. 1042, 1951.

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relationships. In 1958, they studied weather and ields.[24] In 1960 they studied weather and soybean .[25] In both studies, they fitted a polynomial func- f time to capture the weather effects on corn and n yields.

ohnson and Gustafson in their study of grain yields, n aggregate analysis.[26] The analysis was essentially sectional with states being the unit of observation. sed the following technical variables: fertilizer, mechanization, variety index, summer fallows, value d, total cropland harvested, and irrigation. The eather variable was the average annual precipitation. conclusions on the effect of the weather agree with drawn from a study of weather and technology in corn ybeans production by Thompson.[27] These conclusions that yields were adversely affected by weather in rly fifties and favorably affected by weather in the

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4E. C. A. Runge and R. T. Odell, "The Relation Between itation, Temperature and the Yield of Corn on the my South Farm, Urbana, Ill." Agronomy Journal, Vol. 58), 448-454.

5E. C. A. Runge and R. T. Odell, "The Relation Between itation, Temperature and the Yield of Soybeans on the my South Farm, Urbana, Ill." Agronomy Journal, Vol. 60), 245-247.

6Johnson and Gustafson, op. cit.

7L. M. Thompson, Weather and Technology in Produc- f Corn and Soybeans, CAED, Rt. 17, Iowa State Univer- 1963.

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e recently, the most important studies which have ducted where direct weather variables have been adjust yields are those by Thompson. He studied tionship between weather and production of wheat[28], rghums[29], and corn and soybeans[30]. Monthly total ation, monthly average temperature, and monthly ation-temperature interactions for the principal f the growing season were used as weather variables re the weather effects on yield per acre.

the present time, Abel is conducting a study on rghum.[31] His study is concerned with developing al production function for grain sorghum, and measure he influence of weather, technology and location ction on per acre yields of grain sorghum, by using on analysis. The independent variables for technology re: acres of grain sorghum harvested per farm, spent on gas and oil per acre of cropland harvested,

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. M. Thompson, "Evaluation of Weather Factors in uction of Wheat," Journal of Soil and Water Conser- Vol. 17, No. 4 (July and August, 1962).

. M. Thompson, "Evaluation of Weather Factors in on of Grain Sorghums," Agronomy Journal, Vol. 55 182-185.

ee Reference No. 27.

. Abel, "A Study of Changes in Yield Per Acre in rghum," (Ph.D. Thesis at Michigan State University, completed).

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acres of cropland harvested per tractor, propor-
rain sorghum irrigated, man-hours of labor per
nds of nutrients applied per acre, acres cultivated
llow, and value of land per acre. For weather
, Abel is fitting a polynomial function of time
of weather data representing successive short time
weeks) within the growing season.

present study represents an attempt to identify
t relationships between certain weather variables
n yields. This approach was chosen for the fol-
asons:

It is possible to determine which, if any,
weather factor is limiting production.

This technique can be used on any crop and
with any kind of observation units and does
not depend upon the availability of a spec-
ially constructed weather index.

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CHAPTER III

CONCEPTUAL FRAMEWORK AND TECHNIQUES

f Study

ıe whole United States cotton area was taken as the tion. For the purpose of analysis, this cotton area vided into four regions: Southeast, i.e., North na, South Carolina, Georgia, and Alabama; Delta, , Missouri, Arkansas, Tennessee, Mississippi, and ana; Southwest, including Oklahoma and Texas; and namely, New Mexico, Arizona, and California.

ince a smaller area presumably has the advantage of r homogeneity of production techniques, weather, topo- , soil and climate, each state of the above fourteen was analyzed separately. Moreover, Texas was divided vo parts--eastern and western Texas--and each part ısidered as a separate state.

ıd Observation Unit

ıe county was the basic geographical unit of this study. ıoice limited data to the agricultural census years 1944, 1949, 1954, 1959), as they were the only years .ch there were reasonably complete and consistent data

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ıties. A combination of time-series data and cross-
data was used in this study. The reasons for select-
se years can be summarized in the following points:

Although data on cotton yields were available prior to 1939, the data on the other variables were not.

Major changes in technology appear to come often since 1939.[1]

g Method

mentioned, the county was taken as the observation this study. Since the number of counties growing cres or more of cotton in 1959 was 676,[2] and since ion of data on the variables associated with each was too arduous, it was decided to sample. The samp-thod was as follows:

On the basis of the harvested cotton acreage in 1959, all counties harvesting 1,000 or more acres of cotton constituted the universe. The total cotton acreage of these 676 counties represented 94 percent of the

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M. Thompson, "Evaluation of Weather Factors in luction of Wheat," Journal of Soil and Water, Vol. 4 (July and August, 1962).

e Table 1.

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United States cotton acreage in 1959.[3] The sample was constructed by randomly selecting 40 percent of the counties in each state except that at least 8 and no more than 45 counties were selected for each state. The eight counties were used as minimum because the number of counties which grew 1,000 or more acres of cotton in 1959 was only 8 in some states. The total number of counties chosen by the above method to represent the whole cotton area was 258; the distribution of these counties is shown in Table 1.

Analyses

ee different levels of analyses have been made. each was used for the same purpose of measuring cts of different factors related to past changes n yields per acre, each part was devoted to a dif- evel. The state analyses were made first, and will ssed in Chapter IV. On a more aggregate level, nd part was used for the regional analyses which introduced in Chapter V.

S.D.A., 1959 Census of Agriculture, Vol. 1, Parts 8, 31-37, 42-43, and 48.

Table 1. Nu
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1. Number of Counties that Grew 1,000 Acres or More of Cotton in 1959, and the Number of Counties Selected in Each State

e	Number of Counties That Grew 1,000 or More of Cotton Acres in 1959 [a]	Number of Counties Selected in Each State [b]
Carolina	42	17
Carolina	44	18
a	75	30
a	65	26
ri	27	11
as	73	29
see	8	8
sippi	45	18
ana	32	13
ma	47	19
	192	45
xico	8	8
a	8	8
rnia	10	8
Total	676	258

[a]Source: U.S.D.A. 1959 Census of Agriculture, ol. 1, Parts 17, 26-28, 31-37, 42-43, and 48.

[b]See Appendix B for names of counties selected.

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hese first two parts of state and regional analyses he basis for the third and final part. They were s a guide for selecting an adequate procedure for al analyses which will be discussed in Chapter VI.

ing the Variables

he dependent and independent variables which were into the different regression models used in this study sted and described with some emphasis on the basis lecting these factors, as follows:

e dependent variable:

e single dependent variable which was considered in is study was the county average yield in pounds of tton lint per acre of cotton harvested.

e independent variables:

Technical and Economic Variables:

(a) Pounds of fertilizer nutrients per acre of cotton:[4]

This variable was included, since it is well known that fertilizer is one major input in cotton production. Thus, it is expected that fertilizer has had a major effect on changes

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Available only on a state basis.

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in yields per acre of cotton.

(b) Man-hours of labor per acre of cotton:[5]

This variable was included to measure the effect of changes in labor used per acre on yields. It is believed that this factor has had some inverse relationship with yields. In other words, it is expected that as man-hours of labor per acre have decreased in the last three decades as the result of extensive mechanization, the yields per acre of cotton have increased. However, Johnson and Gustafson in their study of grain yields found that the decrease in the man-hours of labor were just offset by the increased mechanization and the net effect on yields per acre was negligible.[6] Thus, it is expected that the net effect of the combined mechanization and man-hours of labor variables have had a minor effect on yield.

(c) Number of tractors per 1,000 acres of harvested cropland, and

(d) Dollars spent on gas and oil per acre of harvested cropland:

These two variables were included as a possible

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ailable only on a state basis.

nnson and Gustafson, op. cit.

approximate indicator of the extent of mechanization. Mechanization can affect yields by timeliness of operations, and in other ways. Thus, one could expect that, as mechanization increases, the yields per acre increase. Since it is known that the mechanization of cotton has proceeded rapidly during the last three decades, it is expected that this has had some effect on increasing yields of cotton.

(e) Proportion of cotton acreage irrigated:
On the basis of the fact that irrigated land yields significantly more than non-irrigated land, it is expected that as the proportion of cotton acreage irrigated increases, the yields per acre increase.

(f) Size of the cotton enterprise:
This variable was included to measure the effect the scale of operations has on yields per acre. It is expected that more specialized equipment is used as the size of cotton farms increases. Then, one could say that while the effect of increased mechanization is measured explicitly by the above two variables (c) and (d), the effect of a shift to more specialized equipment is measured by this variable.

(g) Relative changes in cotton acreage:

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This variable was included, since it appears reasonable that an increase in acreage should result either in land less well adapted to cotton production being added or in farmers with less management skill in cotton production entering production. In either case, increased acreage should result in a decrease in average yield per acre and vice versa. Hathaway in his study on the dry bean industry in Michigan introduced the same argument in selecting similar factor in fitting a yield model.[7] On this basis, one could say, since cotton production requires high quality land with high management skill, then as total cotton acreage decreases, one could expect that higher quality land will be kept and higher yields per acre will be obtained.

(h) Percentage of total harvested cropland in cotton: It is believed that this figure can be taken as a possible indicator of the comparative advantage for cotton in specific areas. In other words, if this percentage is high in a certain county, it indicates that that county has a comparative advantage for cotton relative to other harvested crops. Thus, it is expected that

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E. Hathaway, op. cit.

this value has had some positive relationship with cotton yields per acre.

(i) Value of land and buildings per acre:
This variable was included because it is believed that value of land reflects the basic productivity of land. Thus, this variable is expected to estimate the relationship of land productivity and yields per acre. Moreover, Johnson and Gustafson used this variable as an independent factor in analyzing grain yields. In this respect, they argue: "There has been fairly wide variation, among states, in the changes in land values which occurred between the two periods under study. One would expect, on economic grounds, that such changes would have some effect on yields, to the extent that yields are subject to human influence. If, in an initial period, farms are being operated more or less optimally, or 'in economic equilibrium,' and then the cost of land increases, everything else remaining the same, either yields must be increased to maintain the equilibrium, or the crop will no longer be grown. Of course, we know that 'equilibrium' as used in economic theory never exists perfectly, but it is reasonable to hypothesize that there is a tendency to move

toward it."[8] At the same time, traditional economic theory and the concepts of land economics argue that an increase or decrease in yields and economic value will be capitalized into higher or lower land values. Thus, the statistical model used here operates as if land values affected yields, while the economic model would argue that yields affect the value of land and buildings. Independence and dependence in the statistical model do not require formal cause-effect relationships, except in the specific mathematical balancing of data fitted to formulas. Johnson and Gustafson apparently are arguing that motivation may be influenced by a rise in land values.

(j) Price of cotton for previous season:
The inclusion of this variable can be explained in the following way: "Production economics assumes that if the expected price to be received for a commodity increases, an increase in the rate of variable inputs and higher yields should result."[9] It is believed that a major element of the expected price to which cotton producers

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nson and Gustafson, op. cit., p. 72.

haway, op. cit., p. 30.

respond, is the price received in the previous season. Thus, it is expected that this variable had fairly large positive effects on cotton yields per acre.

Weather Variables:

(a) Monthly total rainfall.

(b) Monthly average temperature.

(c) Squared monthly total rainfall.

(d) Squared monthly average temperature.

(e) Monthly rainfall and temperature interaction.

(f) Successive month rainfall interaction.

By having the above six weather variables for each month of the growing season, then the weather variables for the whole growing season were 53. When all these weather variables were included in the initial regression models used in this study, the estimated regression coefficients for these variables were not consistent with a priori notions that the effect of each weather factor on crop yields changes gradually from month to month. Hence, it was decided to transform these monthly weather variables (53) to new variables (18), by employing a quadratic function of time to monthly weather data. This was accomplished by defining the new weather variables as weighted sums of the old variables, e.g., wh

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$$Z_{10} = \sum_{p=1}^{P} Z_p$$

$$Z_{11} = \sum_{p=1}^{P} pZ_p$$

$$Z_{12} = \sum_{p=1}^{P} p^2 Z_p$$

where $Z_1, Z_2, \ldots Z_p$ were the original observations for one variable, say monthly total rainfall, monthly average temperature, or squared monthly total rainfall, and Z_{10}, Z_{11}, and Z_{12} were the new variables.[10] The number of periods P, is 9 for all but the successive month rainfall variables where it is 8. Clearly, the multiple correlation coefficient (R^2) was less than for the initial regression models, but the results were more consistent with a priori notions of smoothness over time in the weather effects on crop yields.

However, the weather variables were included in the regression models to measure the effect of weather on yields per cotton acre. The data on yields of cotton harvested, show great variation in both cross-section and time series. Then, it

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his process is discussed in greater detail by Fred
on in his book, op. cit.

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is expected that major parts of the variation have been caused by weather factors while a large part of trend has been caused by technical and economic factors.

Rainfall and temperature were included as the weather variables because they are the dominant meteorological influences in yields, and because data on rainfall and temperature were readily available.

The squares of weather variables (monthly temperature and rainfall) were used, since many studies have shown that crop yields were curvilinear instead of linear functions of weather variables.[11] "In linear regression it is assumed, for example, that each additional inch of rain in July would have the same effect on yield as the first inch. This is not the case, however, because each additional inch has less effect until a point is reached where additional rain may actually reduce yields."[12]

Also, the interaction between monthly temperature and rainfall and the interaction between rainfall for successive months were included in this

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M. Thompson, Weather and Technology in Production and Soybeans, CAED, Rep. 17, Iowa State University,

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study, since Hendricks and Scholl used such interactions in their study of the joint effects of temperature and rainfall on corn yields, and they obtained valuable results.[13]

Dummy variables:

Two different sets of dummy variables were used for the national analyses. One set was concerned with time and the other was concerned with location. The set of dummy variables for time was used to measure the effect of factors that changed over time and were not considered in the national regression analyses. Thus, factors such as improvement in varieties, improvement in production techniques, and improvement in insect control can be recognized. The dummy variables for time were five, one for each year included in this study. To obtain non-singular matrix and allow estimation of the parameters built in the models, the dummy variable for 1939 was dropped.

The second set of dummy variables concerned with location were 31, one for each economic sub-region. The dummy variable for economic sub-region No. 16 was dropped to avoid singular matrix. The main

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A. Hendricks and J. C. Scholl, The Joint Effects rature and Rainfall on Corn Yields, N. Carolina Agr. ., Tech. Bull. 74, 1943.

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objective of this second set of dummy variables was to group the counties into relatively homogeneous production areas so the basic production differences that persist over time might be measured.

t this point, it seems necessary to point out that f the above technical and economic variables were only ed in the initial regression models, but dropped in nal models which will be discussed in the following rs. These variables were proportion of cotton acrerrigated, number of tractors per 1,000 acres of har- cropland, percentage of cropland harvested in cotton, tton prices for previous season.

he irrigated cotton land was used only in the western , namely, New Mexico, Arizona, and California, and he whole period of study, all cotton acreages in these states were irrigated. This means that proportion ton acreages irrigated was constant over the whole l of study. Hence, this variable was dropped from nal models to obtain non-singular matrix and allow tion of parameters.

he other three variables, number of tractors, percent- f cropland harvested in cotton, and cotton prices, were ed from the final models because of high correlation en each of these three variables and some other technical and e

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and economic factors.[14] Thus, the reason of dropping three variables was the existence of multicollinear- oblem between these variables and some other technical onomic factors. However, it seems useful to give pace for discussion of the multicollinearity problem.

ollinearity problem

problem of multicollinearity arises when some or all explanatory variables in a relation are so highly ated that it becomes very difficult to disentangle separate influences and obtain a reasonably precise te for their individual effects. When this problem sent the variances of the estimated coefficients in- . Of course, lack of statistical significance is not due to the multicollinearity problem. Johnson and son argue: "Lack of statistical significance in an te might be due to one or more of several things: e true effect of the variable may really be zero or ible; (2) the true effect may not be zero but may be ll that it is submerged by the random or unexplain- ariations in the dependent variable; (3) the true

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4 Some examples of the high correlation between these les and other variables are the following, found in Carolina data. The simple correlation between cotton for previous season and either fertilizer nutrients d per cotton acre or man-hours per cotton acre were d -.92, respectively. See Appendix C.

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may be obscured by (a) improper specification of the (b) inadequacy, inaccuracy, or insufficiency of avail- ata, (c) high intercorrelations among the explanatory es."[15]

owever, simple correlation coefficients among each f variables used in this study have been estimated, ese have indicated the existence of multicorrelinear- oblems among some variables.

ne method used in this study to examine the effect of istence of multicollinearity problem among some var- , and to improve the estimated coefficients of other les, was simply running regression models alternately ng (or adding) some independent variables and observ- w the estimated coefficient was affected by the presence ence of any other variables. The result of this method e decision to drop the variables, number of tractors, tage of cropland harvested in cotton, and cotton prices evious season, from all the final models discussed following chapters.

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5 Johnson and Gustafson, op. cit., p. 67.

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CHAPTER IV

STATE ANALYSES

· the state analyses, two statistical models were :o data on weather, technical and economic factors ıre the effects of these factors on each state's rields. The first model was used for each of the ıon-irrigated cotton states, and the second for each other three states, with irrigated cotton.

odel I

e model used for each of the non-irrigated states follows:

$$Y_{ct} = b_o + \sum_{i=1}^{I} b_i X_{ict} + V_{ct}.$$

c = 1, 2, . . . , C (counties).

t = 1, 2, . . . , T (Years 1939, 1944, 1949, 1954, 1959).

i = 1, 2, . . . , I (Independent variables).

b_o = The overall constant term.

V_{ct} = The error term associated with county c in year t.

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Y_{ct} = Average pounds of cotton obtained per acre of harvested cotton for county c in year t.[1]

X_{ict} = The value of the i^{th} independent variable for county c in year t. The definition of each independent variable is as follows:

X_1 = Dollars spent on gas and oil per acre of harvested cropland.[2]

X_2 = Man-hours of labor used per cotton acre.[3]

X_3 = Pounds of fertilizer nutrients applied per cotton acre.[4]

X_4 = Average size of cotton enterprise in acres.[5]

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he values for this variable were obtained by multiply-
ratio of cotton production in bales for a county to
al acres of cotton harvested in that county by 478
the usual net weight of the cotton bale.

hese values were obtained as the ratio of total dollars
n gas and oil in a county to the total acres of crop-
rvested in that county. These values were deflated
index of average prices paid by farmers for motor
s. See Appendix A.

he state averages of pre-harvest and harvest man work
sed per cotton acre were used for this variable, since
averages were not available.

he state averages of fertilizer nutrients in pounds
ed for this variable, since such data were not avail-
a county basis.

hese values were obtained by taking the ratio of total
of cotton acres in a county to the total number of
arvesting cotton in that county.

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X_5 = Ratio of cotton acreage in year t to that in base year (1939).[6]

X_6 = Value of land and buildings per acre.[7]

$X_7 = TR = \sum_{p=1}^{9} R_p$, where $R_1, R_2, \ldots, R_9$ are monthly total rainfall,[8] i.e., R_1 is total rainfall for the first month of growing season (March), R_2 is total rainfall for the second month (April), and so on . . ., R_9 is total rainfall for the last month of growing season (November).

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[6]The total acres of cotton harvested in a particular ear in a county to that in the base year (1939) in that unty supplied this variable.

[7]The values of land and buildings per acre (in current llars) were obtained, as reported in the U. S. Census of riculture. Then, these values were deflated by the conmer price index. See Appendix A.

[8]The data for monthly total rainfall in inches and nthly average temperature in degrees F. for selected weaer stations were obtained from "Climatological Data, by ates, by Months," Weather Bureau, Commerce Department. e weather stations were selected according to the followg criteria:

(a) if there were more than one weather station in a county reporting rainfall and temperature, then the one at or near the center was selected for use in this study.

(b) if there was only one weather station in a county, then it was selected.

(c) if there was none in a county, then the nearest weather station to that county was selected. See Appendix B.

$X_8 = LR = \sum_{p=1}^{9} pR_p$, where R_p are as defined above, and p=1, 2, . . . , 9, i.e., p=1 for the first month of growing season (March), p=2 for (April) and so on . . . , p=9 for (November).

$X_9 = QR = \sum_{p=1}^{9} p^2R_p$, where R_p are as defined, and p^2 are squares of p.

$X_{10} = TR^2 = \sum_{p=1}^{9} R_p^2$, where R_1^2, R_2^2, . . . , R_9^2 are squared monthly total rainfall.

$X_{11} = LR^2 = \sum_{p=1}^{9} pR_p^2$.

$X_{12} = QR^2 = \sum_{p=1}^{9} p^2R_p^2$.

$X_{13} = TT = \sum_{p=1}^{9} T_p$, where T_1, T_2, . . . , T_9 are monthly average temperature.[9]

$X_{14} = LT = \sum_{p=1}^{9} pT_p$.

$X_{15} = QT = \sum_{p=1}^{9} p^2T_p$.

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[9]Refers to previous footnote, page 40.

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X_{19} = TRT = $\sum_{p=1}^{9} R_p T_p$, where R_1T_1, R_2T_2, . . . , R_9T_9 are monthly rainfall and temperature interaction.

X_{22} = TRR = $\sum_{p=1}^{8} R_p \, R_{p+1}$, where R_1R_2, R_2R_3, . . . , R_8R_9 are successive month rainfall interactions of growing season, i.e., R_1R_2 is (March-April) rainfall interaction, and so on . . . , R_8R_9 is (October-November) rainfall interaction.

Of course, the above model and other models used in s study are based on the following standard assumptions:[10]

(a) The expected values of disturbance terms are zero, i.e., $E(V_{ct}) = 0$.

(b) The disturbance terms have equal variances for all observations, i.e., $E(V_{ct}^2) = \sigma^2$.

(c) The disturbance is independent, i.e., $E(V_{ct} \, V_{\acute{c}\acute{t}}) = 0$. $c \neq \acute{c}$ or $t \neq \acute{t}$.

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[10] M. Ezekiel and K. Fox, Methods of Correlation and ression Analysis, 3rd edition, (New York: John Wiley Sons, 1959).

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(d) The independent variables in each model are independent of the disturbance term.

At an initial stage of this study, the conventional regression techniques were used to capture the effects of weather variables on cotton yields, but the resulting coefficients for the weather variables varied irregularly from month to month. A new procedure was sought. Hence, the main objective of using a polynomial function of time in utilizing the weather data in the above model and in other models used in this study, was to incorporate a priori notions that the effect of each weather factor on yields, changes gradually from month to month.[11] Clearly, the number of weather variables used in the above model was less than in the conventional regression model and this led to a reduction in the multiple correlation coefficient (R^2). But, on the basis of the above model, the estimation of regression coefficients for different weather factors in each month of the growing season were more consistent with a priori notions of smoothness over time in weather effects than those obtained from the conventional regression model.

Results for State Model I

The results from applying Model I for the twelve non-

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[11] Sanderson, op. cit.

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irrigated states are summarized in Table 2. In such table, it is noted that the estimated regression coefficients for many variables are not statistically significant. But, the statistical non-significant variables were included because (a) their presence improved the estimated regression coefficients for the other variables in the model, and (b) production theory suggests that they are a relevant part of such model.

However, it seems useful to discuss the result for each variable separately.

Dollars spent on gas and oil per acre of cropland: The sign of estimated regression coefficient (b) for this variable was positive for seven states, but negative for five states, i.e., North Carolina, South Carolina, Missouri, Tennessee, and Louisiana.[12] However, none of these negative coefficients was statistically significant.[13] The size of positive coefficients ranged from 0.5 for Mississippi to 39.1 for

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[12](b) is the estimated regression coefficient which indicates the influence of the variable on average yield per acre. For example, the estimated coefficient 22.3 for X_1 in the Georgia regression analysis indicates that a 1 unit increase (in dollars spent on gas-oil) above average was associated with a 22.3 pound increase in cotton yield per acre, if other things remain the same.

[13]In this chapter, statistical significant refers to 10 percent level of significance. (The significance level is the probability that the estimated regression coefficient would be as much different from zero if the true effect of the variable (i.e., the true value of the corresponding B) were zero--Reference: Johnson and Gustafson, op. cit., p. 76.)

Table 2. The Regression Results for State Analyses of Changes in Cotton Yields, Non-irrigated States

Explanatory Variables	North Carolina (b)[a]	South Carolina (b)	Mo. (b)	Tenn. (b)	La. (b)	Ga. (b)	Ala. (b)	Ark. (b)	Miss. (b)	Okl. (b)	E.T. (b)	W.T. (b)
						[illegible]	5.8	17.1	0.5	29.2	22.9	39.1
											(5.4)	(13.4)

Explanatory Variables	North Caro-lina (b)[a]	South Caro-lina (b)	Mo. (b)	Tenn. (b)	La. (b)	Ga. (b)	Ala. (b)	Ark. (b)	Miss. (b)	Okl. (b)	E.T. (b)	W.T. (b)
X_1:Gas-oil	-3.6 (4.7)[b]	-8.6 (10.9)	-5.2 (44.2)	-7.4 (35.1)	-0.8 (18.2)	22.3 (7.6)	5.8 (15.3)	17.1 (15.5)	0.5 (2.2)	29.2 (12.1)	22.9 (5.4)	39.1 (13.4)
X_2:Man-hours	0.8 (1.4)	3.7 (0.8)	3.5 (2.3)	14.2 (4.1)	1.0 (2.7)	4.2 (0.8)	1.1 (1.1)	2.5 (1.5)	3.2 (8.5)	2.1 (1.1)	-0.9 (2.1)	-1.5 (4.0)
N_3:Nutrients	1.7 (1.5)	1.5 (0.4)	2.1 (1.4)	0.5 (0.9)	1.6 (1.5)	1.1 (0.2)	0.9 (0.7)	0.7 (0.5)	2.0 (3.3)	1.0 (0.6)	0.3 (0.4)	0.3 (0.6)
X_4:Size	-0.5 (4.5)	-1.2 (1.5)	-0.2 (0.5)	4.7 (4.1)	5.3 (2.0)	0.9 (1.0)	3.4 (2.4)	1.9 (1.0)	5.9 (1.2)	0.9 (0.4)	0.5 (0.3)	0.1 (0.4)
X_5:Ratio	-49.5 (34.7)	-58.7 (31.3)	1.1 (52.6)	21.2 (68.0)	9.9 (72.9)	13.8 (22.1)	-23.8 (43.6)	75.9 (34.6)	5.9 (45.1)	0.5 (30.3)	55.7 (18.8)	4.9 (3.0)
X_6:Value	0.4 (0.3)	0.2 (0.2)	1.2 (0.4)	1.3 (0.5)	0.8 (0.4)	1.7 (0.4)	0.4 (0.3)	1.3 (0.4)	0.6 (0.3)	0.4 (0.1)	0.2 (0.1)	1.1 (0.3)
X_7:TR[c]	-134.0 (45.0)	74.8 (17.5)	47.5 (69.1)	-59.8 (37.0)	9.4 (36.1)	18.3 (11.8)	9.5 (15.0)	47.9 (38.8)	0.7 (20.0)	10.7 (13.5)	-10.8 (18.1)	92.9 (58.3)
X_8:LR	39.6 (18.8)	6.3 (7.5)	-0.2 (35.0)	-5.1 (24.4)	-11.0 (16.2)	-15.1 (5.3)	-20.4 (6.9)	-23.4 (12.0)	-32.4 (8.3)	4.0 (7.6)	4.9 (7.2)	-13.4 (18.4)
X_9:QR	-3.4 (1.8)	-0.7 (0.8)	-0.3 (3.3)	1.0 (2.4)	0.8 (1.7)	1.5 (0.5)	2.2 (0.7)	2.4 (1.2)	3.6 (0.8)	-0.2 (0.8)	-0.5 (0.7)	1.5 (1.8)
X_{10}:TR^2	13.2 (3.7)	-1.9 (1.2)	-1.0 (6.9)	3.5 (2.5)	-0.01 (1.6)	-1.2 (0.6)	-1.3 (0.7)	-4.3 (2.8	-1.8 (0.9)	1.5 (1.5)	1.0 (1.6)	-23.8 (8.6)

Table 2 (continued)

Explanatory Variables	North Carolina (b)a	South Carolina (b)	Mo. (b)	Tenn. (b)	La. (b)	Ga. (b)	Ala. (b)	Ark. (b)	Miss. (b)	Okl. (b)	E.T. (b)	W.T. (b)
								[illegible]	[illegible]	-0.5	-0.7	9.7

Explanatory Variables	North Carolina (b)[a]	South Carolina (b)	Mo. (b)	Tenn. (b)	La. (b)	Ga. (b)	Ala. (b)	Ark. (b)	Miss. (b)	Okl. (b)	E.T. (b)	W.T. (b)
X_{11}:LR^2	-5.2	0.5	0.3	-1.2	-0.3	0.3	0.7	1.9	1.4	-0.5	-0.7	9.7
	(1.3)	(0.5)	(3.6)	(1.1)	(0.8)	(0.3)	(0.3)	(1.3)	(0.4)	(0.6)	(0.7)	(3.7)
X_{12}:QR^2	0.5	-0.03	-0.01	0.1	0.04	-0.02	-0.1	-0.2	-0.2	0.03	0.1	-0.09
	(0.1)	(0.1)	(0.3)	(0.1)	(0.1)	(0.03)	(0.04)	(0.1)	(0.1)	(0.1)	(0.1)	(0.4)
X_{13}:TT	-0.5	6.1	-6.3	-3.0	29.6	1.6	4.0	-11.2	3.3	-0.4	-2.0	1.5
	(8.3)	(6.7)	(12.1)	(13.1)	(12.3)	(2.2)	(6.2)	(7.3)	(5.2)	(3.5)	(2.9)	(4.2)
X_{14}:LT	1.2	0.7	5.3	-2.4	-8.0	-1.0	-2.0	5.4	-2.7	-1.5	0.4	-0.1
	(4.10)	(3.2)	(5.8)	(4.6)	(5.1)	(0.7)	(2.7)	(3.1)	(1.7)	(1.9)	(1.2)	(2.6)
X_{15}:QT	-0.3	-0.1	-0.7	0.4	0.3	0.1	0.1	-0.5	0.2	0.2	-0.01	0.04
	(0.4)	(0.3)	(0.6)	(0.5)	(0.5)	(0.1)	(0.2)	(0.3)	(0.1)	(0.2)	(0.1)	(0.3)
X_{19}:TRT	0.6	-1.0	-0.4	0.7	0.3	0.2	0.4	0.1	0.7	-0.3	0.1	-1.3
	(0.6)	(0.2)	(0.9)	(1.0)	(0.7)	(0.2)	(0.3)	(0.5)	(0.3)	(0.2)	(0.3)	(0.8)
X_{22}:TRR	-1.4	-1.0	-1.7	-0.4	-0.3	0.6	0.1	-0.1	-0.4	-0.8	-0.4	6.3
	(0.7)	(0.4)	(2.0)	(0.8)	(0.9)	(0.3)	(0.3)	(0.9)	(0.5)	(0.6)	(0.5)	(1.8)
R^2 [d]	0.5240	0.6814	0.7493	0.8418	0.5752	0.7490	0.5684	0.7600	0.6834	0.7049	0.4553	0.8349

a (b) is the estimated regression coefficient.

b Standard errors are given in parentheses.

c TR, LR, QR, TR^2, LR^2, QR^2, TT, LT, QT, TRT, and TRR are as defined in State Model I.

d R^2 is the multiple coefficient of determination.

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West Texas, and these coefficients were statistically significant in four states, i.e., Georgia, Oklahoma, East Texas, and West Texas.

Since this variable was used as an approximate indicator of the extent of mechanization, and if this relationship is valid, it appears that extent of mechanization has had significantly positive effects on cotton yields per acre in Georgia, Oklahoma, East Texas and West Texas.

Man-hours of labor used per cotton acre: The estimated coefficients for this variable were negative and non-significant for only East and West Texas. They were positive for all other non-irrigated states and statistically significant for South Carolina, Georgia, Arkansas, Tennessee, and Oklahoma. These positive coefficients were relatively large, ranging from 2.1 for Oklahoma to 14.2 for Tennessee.

For the small magnitude and non-significance of either this variable or the above variable (dollars spent on gas and oil per acre), in some states, there are two possible explanations: (a) Both variables were highly correlated for some states, so that it was difficult to disentangle their separate influences and obtain significant estimates for one of them or both,[14] (b) If it is true that mechaniza-

[14] A rather typical example of high correlation between these two variables is the following, found in the Missouri data. The simple correlation between dollars spent on gas and oil per acre, and man-hours of labor per cotton acre was -.91.

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on has been essentially a substitute for labor, then it not too surprising that in a regression model which in-udes variables representing both factors, they, in effect, ncel each other out, and one or both appear non-significant.[15]

However, on the basis of the resulting coefficients for is variable, it appears that man-hours of labor has a latively positive effect on cotton yields per acre in most the non-irrigated states.

unds of fertilizer nutrients applied per cotton acre: The sulting coefficients for this variable were positive for l states, but statistically significant for only South rolina and Georgia. The size of these coefficients was ite small ranging from 0.3 for either East or West Texas 2.1 for Missouri. These results do not necessarily in-cate that more use of fertilizer nutrients has a minor fect on yields, since these unexpected results might be e result of: (a) the high correlation between this var-ble and another variable (cotton prices for previous ear)[16] and this might capture the effect of fertilizer,) the aggregative nature of the values used for this

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[15] Johnson and Gustafson, op. cit., p. 72.

[16] An example of high correlation between these two riables is the following found in the North Carolina data. e simple correlation between pounds of fertilizer nutri-ts per cotton acre and cotton prices for previous season s 0.93.

ariable, i.e., the values used for this variable were state verages rather than county averages (which were not available), and this has reduced the number of observations for ach state analysis to only five (one for each year included n this study). This substantial decrease in degrees of reedom might increase the standard error of coefficient or this variable and lead to a non-significant coefficient, c) in some states, particularly East Texas and West Texas, he pounds of fertilizer nutrients applied per cotton acre ere too low to result in any response on cotton yields.[17]

verage size of cotton enterprise in acres: It was expected hat on farms with a larger average size of cotton enterrise in acres, more specialized equipment would be used, nd higher cotton yields per acre obtained. This variable as included to determine if there were any economies or iseconomies of scale in cotton production. However, the esulting coefficients were negative for three states, including North Carolina, South Carolina, and Missouri. None f these negative coefficients was statistically significant. n all other non-irrigated states, the coefficients were ositive, but only for four of these (Arkansas, Mississippi,

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[17]The average pounds of fertilizer nutrients applied er cotton acre for the whole period of study in East Texas nd West Texas were 30 and 33 respectively, while in South arolina and Georgia they were 116 and 109 respectively.

Louisiana, and Oklahoma) were statistically significant. The size of positive coefficients was relatively small, ranging from 0.1 for West Texas to 5.9 for Mississippi.

Two things can be inferred from the non-significance of the coefficients for this variable in many states: there were no economies or diseconomies of scale, or, there were economies or diseconomies of scale but they were not measured by this variable. This second case could be due to (a) this variable was not the appropriate one for measuring the scale effect, or (b) other variables captured its effects.

Ratio of cotton acreage in a year to that in base year (1939): Since cotton production requires high quality land, it was expected that as total cotton acreages decreased, the higher quality land has been kept in cotton production, and higher average yields per acre were obtained. Thus, the relation between this ratio and cotton yields was expected to be negative. But it seems unnecessary to expect that the relationship between this ratio and yields of cotton would be negative over time for all states. In fact total cotton acreages decreased in some states and increased in others; despite this, cotton yields increased in all states--thus some states had both increased yields and increased acreage.

However, in most Southeastern States, namely North Carolina, South Carolina, and Alabama, where cotton acreages have substantially decreased over time, the resulting coefficients for this variable were negative. One of these coefficients was statistically significant (for South Carolina).

In all Delta and Southwestern States, these regression coefficients were positive, and statistically significant for Arkansas. The positive coefficients for all Delta and Southwestern States may at first seem somewhat surprising since it is known that cotton acreages have substantially decreased over time in most of these states. However, this can be interpreted in this way: there have been shifts in cotton production within each of these states from low-yielding counties with very large cotton acreages to high-yielding counties with relatively small cotton acreages, so that the total cotton acreages have decreased within the state, but increased in high-yielding counties. Further, there is a possibility that many of the latter counties were included in this study to represent these states.[18] Then, the ratio of cotton acreages to that in 1939, has increased in these states and higher cotton yields per acre were obtained.

However, on the basis of the result of this variable, it appears that the reduction in cotton acreages has had a major effect on average cotton yields per acre.

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[18]There is a possibility that cotton acreages in those very low-yielding counties (with large cotton acres) have substantially decreased to be less than 1,000 acres in 1959. If so, these counties were not included in the population from which the counties were selected for this study.

<u>Value of land and buildings per acre of cropland harvested</u>: The estimated coefficients for this variable were positive for all non-irrigated states. Most of these coefficients were statistically significant, but their sizes were quite small, ranging from 0.2 for South Carolina to 1.3 for Tennessee. Since it was assumed that the value of land reflected the potential productivity of land, then, if this is true, it appears that the use of highly valuable land in cotton production has some positive relation with cotton yields per acre.

<u>Weather variables</u>: In State Model I, the weather variables were used in such a way as to be equivalent to forcing the regression coefficients for nine months on each set of original variables[19] to fit a quadratic function of time. The individual coefficients for each month of these original weather variables were derived from the coefficients reported in Table 2, and are listed in Tables 3, 4, and 5.

In Table 3, it is noted that the signs of estimated regression coefficients for monthly total rainfall were negative in all Southeastern and Delta States except South Carolina and Missouri. This means that the increase in rainfall over the average--by itself--has decreased cotton yields

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[19]Monthly total rainfall, squared monthly total rainfall, monthly average temperature.

... Regression Coefficients for Monthly Total Rainfall, March-November, Non-irrigated States

States	March (b)[a]	April (b)	May (b)	June (b)	July (b)	Aug. (b)	Sept. (b)	Oct. (b)	Nov. (b)
North Carolina	-97.7	-68.4	-45.8	-30.0	21.0	-18.8	23.4	-34.8	53.0
Alabama	-8.7	-22.5	-3.19	-36.9	-37.5	-33.5	-25.5	-12.9	4.1
Tennessee	-63.9	-66.0	-66.1	-64.2	-60.3	-54.4	-46.5	-36.6	-24.7
Mississippi	-28.1	-49.7	-64.1	-71.3	-71.3	-64.1	-49.7	-28.1	0.7
Louisiana	-0.8	-9.4	-16.4	-21.8	-25.6	-27.8	-28.4	-27.4	-24.8
East Texas	-6.4	-3.4	-0.6	0.8	1.2	0.6	-1.0	-3.6	-7.2
Arkansas	26.9	10.3	-0.7	-7.3	-9.1	-6.1	1.7	14.3	31.7
Georgia	4.7	-5.9	-13.5	-18.1	-19.7	-18.3	-13.9	-6.5	3.9
South Carolina	80.4	84.6	87.4	88.8	88.8	87.4	84.6	80.4	74.8
Missouri	47.0	45.9	44.2	41.9	39.0	35.5	31.4	26.7	21.4
Oklahoma	14.5	17.9	20.9	23.5	25.7	27.5	28.9	29.9	30.5
West Texas	80.6	72.1	66.2	63.3	63.4	66.5	72.6	81.7	93.8

[a] (b) is the estimated coefficient for monthly total rainfall, and was obtained for each month by the following equation: $b = b_7 + pb_8 + p^2b_9$, where b is the estimated coefficient for total rainfall (for specific month), b_7, b_8, b_9 are the estimated coefficients for weather variables x_7, x_8, x_9 as shown in Table 2, and p, p^2 are as defined before.

States	March (b)[a]	April (b)	May (b)	June (b)	July (b)	Aug. (b)	Sept. (b)	Oct. (b)	Nov. (b)
North Carolina	8.5	4.8	2.1	0.4	-0.3	0.0	1.3	3.6	6.9
Alabama	-0.7	-0.3	-0.1	-0.1	-0.3	-0.7	-1.3	-2.1	-3.1
Tennessee	2.4	1.5	0.8	0.3	0.0	-0.1	0.0	0.3	0.8
Mississippi	-0.6	0.2	0.6	0.6	0.2	-0.6	-1.8	-3.4	-5.4
Louisiana	-0.3	-0.5	-0.6	-0.6	-0.5	-0.4	-0.2	0.2	0.5
East Texas	0.4	0.0	-0.2	-0.2	0.0	0.4	1.0	1.8	2.8
Arkansas	-2.6	-1.3	-0.4	0.1	0.2	-0.1	-0.8	-1.9	-3.4
Georgia	-0.9	-0.7	-0.5	-0.3	-0.2	-0.1	-0.1	-0.1	-0.1
South Carolina	-1.4	-1.1	-0.8	-0.5	-0.4	-0.3	-0.4	-0.5	-0.6
Missouri	-0.7	-0.4	-0.2	0.1	0.3	0.4	0.6	0.8	0.9
Oklahoma	1.0	0.5	0.0	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0
West Texas	-15.0	-8.0	-2.4	0.6	2.2	2.0	0.0	-3.8	-9.4

[a] (b) is the estimated coefficient for squared monthly total rainfall, and was obtained for each month by the following equation: $b = b_{10} + pb_{11} + p^2b_{12}$, where b is the estimated coefficient for squared total rainfall (for specific month), b_{10}, b_{11}, b_{12} are the estimated coefficients for weather variables x_{10}, x_{11}, x_{12} as shown in Table 2, and p, p^2 are as defined before.

States	March (b)[a]	April (b)	May (b)	June (b)	July (b)	Aug. (b)	Sept. (b)	Oct. (b)	Nov. (b)
North Carolina	0.4	0.7	0.4	-0.5	-2.0	-4.1	-6.8	-10.1	-14.0
South Carolina	6.7	7.1	7.3	7.3	7.1	6.7	6.1	5.3	4.3
Alabama	2.1	0.4	-1.1	-2.4	-3.5	-4.4	-5.1	-5.6	-5.9
Mississippi	0.8	-1.3	-3.0	-4.3	-5.2	-5.7	-5.8	-5.5	-4.8
Louisiana	21.9	14.8	8.3	2.4	-2.9	-7.6	-11.6	-15.2	-18.1
Georgia	0.7	0.0	-0.5	-0.8	-0.9	-0.8	-0.5	0.0	0.7
Missouri	-1.7	1.5	3.3	3.7	2.7	0.3	-3.5	-8.7	-15.3
Arkansas	-6.3	-2.4	0.5	2.4	3.3	3.2	2.1	0.0	-3.1
Tennessee	-5.0	-6.2	-6.6	-6.2	-5.0	-3.0	-0.2	3.4	7.8
Oklahoma	-1.7	-2.6	-3.1	-3.2	-2.9	-2.2	-1.1	0.4	2.3
East Texas	-6.1	-1.2	-0.8	-0.4	0.0	0.4	0.8	1.2	1.6
West Texas	1.4	1.5	1.6	1.7	2.0	2.3	2.8	3.3	3.8

[a] (b) is the estimated coefficient for monthly average temperature, and was obtained for each month by the following equation: $b = b_{13} + pb_{14} + p^2b_{15}$, where be is the estimated ceofficient for average temperature (for specific month), b_{13}, b_{14}, b_{15} are the estimated coefficients for weather variables x_{13}, x_{14}, x_{15} as shown in Table 2, and p, p^2 are as defined before.

n these states. This negative effect of rainfall on cotton ields in Southeastern and Delta States may at first seem omewhat surprising. However, it is well known that in relaively humid areas, there may be too much rainfall, and this ight have a deleterious effect on cotton yields. This eleterious effect might occur, since too much rainfall uring the growing season causes the development of surface oots at the expense of the deeper roots. This results in ilting and shedding of leaves and bolls, particularly if he weather turns dry in the summer.[20] The nature of negaive effect of rainfall in all these states, namely North arolina, Georgia, Alabama, Arkansas, Tennessee, Mississippi, nd Louisiana was relatively similar. The least damage from n increase in rainfall on cotton yields was during the lanting and harvesting periods, while the most damage was t the middle of the growing season. In other words, the egative effect of increase in rainfall over the average n cotton yields per acre was during March to April and Sepember to November, while the most negative effect was durng June to August. The most damage from rainfall on cotton ields occurred in summer months in these states; it is known hat a wet summer induces excessive vegetative growth, retards ruiting, and favors rapid increase of the boll weevil in otton crop.

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[20] U.S.D.A., 1941 Yearbook of Agriculture: Man and limate.

In Tables 3 and 4, it is observed that the resulting
fficients for rainfall in all Southwestern States, i.e.,
ahoma, East Texas, and West Texas, and also in South
olina and Missouri were highly positive during the whole
wing season. This means that the increase in rainfall
r the average in these states has increased cotton yields.
the case of Oklahoma, East Texas, and West Texas, the
hly positive effect of rainfall does not seem surprising,
ce it is known that rainfall in such a relatively arid
a is generally lower than optimum. More surprising is
highly positive effect of rainfall in the case of South
olina and Missouri, especially since the effect in all
er relatively humid states was highly negative, as men-
ned above.

In Table 5, it is apparent that the temperature effect
cotton yields per acre in the Southwestern area was
ghtly negative (in Oklahoma and East Texas) or slightly
itive (in West Texas) during the first few months of the
wing season and relatively positive (in all three states)
r the end of the growing season. The other type of tem-
ature effect was in the humid area, particularly North
olina, Alabama, Mississippi, and Louisiana, where the
ect was positive at the beginning of the growing season,
then reduced gradually to become highly negative near
end of the season.

However, the sizes of the regression coefficients for her rainfall or temperature variables have only given e indication for the relative importance of these wea- r factors on cotton yields. To examine the joint effect rainfall or temperature variables on cotton yields, the est has been used for all state analyses and the results reported in Table 6.[21]

Table 6 shows that the joint effects of rainfall var- les[22] on cotton yields were statistically significant all non-irrigated states except Missouri, Louisiana, and st Texas. However, the joint effects of temperature var- les[23] were statistically significant in only six states, ably, North Carolina, South Carolina, Missouri, Mississippi, uisiana and Oklahoma.

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[21]To test the significance of a set of variables in a gression model, let the variables to be tested be repre- nted by $X_{p+1} \ldots X_q$, and let the remaining variables in the del be represented by $X_1 \ldots X_p$. Obtain R^2 from the regres- on on $X_1 \ldots X_p$, $X_{P+1} \ldots X_q$. Then under the null hypotheses e., $B_{P+1} = B_{P+2} = \ldots = B_q = 0$) and the assumption that disturbances are normally distributed: $F(q-p, N-q-1) =$

$$\frac{\ldots - R^2_p}{\ldots - R^2_q} \cdot \frac{N-q-1}{q-p}$$ where N is the number of observations.

erence: R. L. Gustafson, Procedure for Testing the Sig- icance of a Subset of Regression Coefficients, mimeo., higan State University, October 27, 1960.

[22]Monthly total rainfall, squared monthly total rainfall, thly rainfall-temperature interaction, and successive th rainfall interaction.

[23]Monthly average temperature, and monthly temperature- nfall interaction.

State	Rainfall			Temperature		
	Degree of Freedom (N_1,N_2)[a]	F-Value	Level of Significance	Degree of Freedom (N_1,N_2)	F-Value	Level of Significance
N.C.	(8,67)	5.1	.01	(4,67)	2.8	.03
S.C.	(8,72)	7.1	.01	(4,72)	5.3	.01
Ga.	(8,132)	8.0	.01	(4,132)	1.3	.29
Ala.	(8,112)	4.6	.01	(4,112)	0.9	.46
Mo.	(8,22)	0.2	.98	(4,22)	2.4	.08
Ark.	(8,72)	2.5	.02	(4,72)	2.0	.11
Tenn.	(8,37)	3.8	.01	(4,37)	0.4	.78
Miss.	(8,127)	8.3	.01	(4,127)	2.9	.03
La.	(8,47)	1.4	.23	(4,47)	2.8	.04
Okla.	(8,77)	3.5	.01	(4,77)	10.1	.01
E.T.	(8,142)	1.4	.18	(4,142)	0.5	.76
W.T.	(8,47)	2.7	.02	(4,47)	0.8	.53

[a] N_1 is degree of freedom for numerator of F-ratio. N_2 is degree of freedom for denominator of F-ratio.

On the basis of these results, it appears that rainfall s had more effect than temperature on cotton yields in n-irrigated states.

:ate Model II

By applying the previous State Model I, to the weather ıd non-weather data associated with each of the irrigated tates, i.e., New Mexico, Arizona, and California, it was ound that many weather variables were very highly correlated ith each other. This has led to non-significant coeffi- ients for many variables built into the model. Then, by unning the State Model I, alternately dropping (or adding) ome weather variables and observing how the estimated coef- icient was affected by the presence or absence of any other ariables, it was decided to drop seven weather variables rom State Model I to improve the estimates of coefficients or non-weather variables. This modified model - State odel II - was as follows:

$$Y_{ct} = b_o + b_1X_1 + \ldots + b_7X_7 + b_{13}X_{13} + b_{19}X_{19} + b_{22}X_{22} + V_{ct}.$$

f course, the definition of all variables involved in the bove model is as defined before as a part of State Model I.[24]

[24] The weather variables (X_7, X_{13}, X_{19}, and X_{22}) are the eason total for monthly total rainfall, monthly average tem- erature, monthly rainfall-temperature interaction, and suc- essive month rainfall interaction.

ults for State Model II

The results from applying State Model II for the three igated states are summarized in Table 7. It seems appro- ate to discuss the resulting coefficients for each var- le separately.

lars spent on gas and oil per acre of cropland: The ulting coefficients for this variable were positive in irrigated states. They were highly positive in New ico, and Arizona (15.5 and 15.7, respectively) and slightly itive (1.4) in California. All coefficients were statis- ally significant.

Thus, it appears that this variable has had more effect cotton yield increases in the irrigated states than in non-irrigated states. The heavy use of gas and oil ich was associated with an increase in cotton yields per e in the irrigated states is associated with the expansion irrigation in these states.

n-hours of labor used per cotton acre: While the estimated efficients for this variable were negative in only two ates of the non-irrigated states, they were negative in l irrigated states. Moreover, the sizes of these coeffi- ents were relatively large in most of the irrigated states compared with those in non-irrigated states. The coeffi- ents were fairly significant in California, but not at all ble 7. The Regression Results for State Analyses of Cotton Yields, Irrigated States

xplanatory ariables	States		
	New Mexico (b)[a]	Arizona (b)	California (b)
1: Gas-oil	15.5 (6.2)[b]	15.7 (6.2)	1.4 (0.4)
2: Man-hours	-0.9 (5.3)	-3.8 (4.0)	-4.4 (1.2)
3: Nutrients	3.7 (2.4)	2.7 (3.1)	0.1 (0.6)
4: Size	0.1 (0.8)	0.8 (0.2)	0.1 (0.2)
5: Ratio	-0.1 (0.1)	-0.4 (0.3)	0.02 (0.02)
6: Value	-5.0 (5.5)	-0.1 (0.4)	0.2 (0.1)
7: TR[c]	-7.4 (55.8)	47.5 (85.0)	0.1 (53.8)
13: TT	0.4 (1.5)	2.4 (1.4)	-0.7 (0.6)
19: TRT	-0.3 (0.8)	-0.6 (1.0)	-0.5 (0.8)
22: TRR	5.8 (3.5)	2.0 (3.3)	7.1 (9.8)
R^2 [d]	0.7160	0.7826	0.7552

[a](b) is the estimated regression coefficient.

[b]Standard errors are given in parentheses.

[c]TR, TT, TRT, and TRR are as defined in State Model II.

[d]R^2 is the multiple coefficient of determination.

nificant in New Mexico or Arizona.

nds of fertilizer nutrients per cotton acre: The result- coefficients for this variable were positive in all igated states. And, the sizes of these coefficients in se states were relatively larger than in non-irrigated tes. Still, none of these coefficients was significant any irrigated state.

The amount of fertilizer nutrients applied per cotton e is higher in irrigated states than in non-irrigated tes. Thus, it was expected that this variable was posi- e and significant in all irrigated states. This non- nificance could be the result of the high correlation ween this variable and the variable of man-hours of labor d per cotton acre in these states. The simple correlation ween these two variables, for instance, in New Mexico and zona was -0.95 and -0.96, respectively.

rage size of cotton enterprise in acres: This variable included to determine if there were any economies or economies of scale in cotton production in the irrigated tes. The resulting coefficients for this variable in se irrigated states were more consistent with each other n in the case of non-irrigated states. They were posi- e in all irrigated states but significant only in Arizona. magnitude of these coefficients was very small, ranging n 0.1 for New Mexico and California to 0.4 for Arizona.

io of cotton acreage in a year to that in base year 39): None of the coefficients for this variable in all igated states was statistically significant. Moreover, absolute values of these coefficients were less than and these were small compared with those in non-irrigated tes.[25] Thus, it appears that this variable has not had effect on cotton yields per acre in the irrigated states. s perhaps is because of (a) the true effect of this varle was zero or, (b) some other variables included in the el may mask its effect. The latter possibility may be e likely, since the coefficient of this variable was nificant in some non-irrigated states.

ue of land and buildings per acre: The results for this iable in irrigated states were very surprising. While coefficients for this variable were positive in all nonigated states and highly significant in most of them, y were negative and non-significant in two of the irrited states (New Mexico, Arizona). Only in California was s variable's coefficient positive and significant. Thus, value of land does not have a major relationship with

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[25]For example, the regression coefficient for this varle in Arkansas was 75.9.

otton yields per acre in most of the irrigated states, while
: has had a significant and positive relationship with cotton yields in the non-irrigated states. This conclusion as also valid based on the results for this variable in he regional analyses.[26]

eather variables: The results from the F-test have shown hat the joint effects of either rainfall or temperature ariables[27] were not significant in New Mexico and Arizona.[28] ut, these effects were significant in California.[29] These esults could lead to the conclusion that the joint effect f rainfall or temperature has generally had a minor effect n cotton yields per acre in irrigated states, while they

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[26]The regional analyses will be discussed in the next hapter.

[27]Rainfall variables are monthly total rainfall, monthly ainfall-temperature interaction, and successive month rainall interaction. And, temperature variables are monthly verage temperature and monthly temperature-rainfall interction.

[28]New Mexico: F-value for testing the joint effect of ainfall = 1.03 and significance level = 0.40. F-value for esting the joint effect of temperature = 0.09 and signifiance level = 0.91.

rizona: F-value for testing the joint effect of rainfall 0.31 and significance level = 0.81. F-value for testing he joint effect of temperature = 2.10 and significance evel = 0.14.

[29]California: F-value for testing the joint effect of ainfall = 2.31; and significance level = 0.10. F-value or testing the joint effect of temperature = 3.48; and ignificance level = 0.04.

ve had a major effect in non-irrigated states.

ncluding Points

The selected variables used in either State Model I II generally explained a major part of the variation in tton yield increases in different states. The results r state analyses have shown that there were considerable fferences among states[30] in the cotton yield increases tributable to different variables. In case of the technical and economic factors, for instance, mechanization nded to be more important in the Southwestern and Western rigated States than in the Southeastern and Delta States. d, fertilizer tended to have a major effect in the Western rigated States, but a minor effect in the Southwestern ates, namely, Oklahoma, East Texas, and West Texas. In e case of the weather variables, e.g., the monthly total infall during the growing season has had a highly negative fect in most of the relatively humid states, but a highly sitive effect in most of the relatively arid states, i.e., lahoma, East Texas and West Texas. And, the monthly average temperature during growing season has had more effect ither negative or positive) in the Southeastern and Delta an in the Southwestern area.

[30] Particularly among those states within different gions.

However, the results for technical and economic fac-
s used in the state analyses have shown that the signs
all significant coefficients were generally consistent
h the usual economic expectations. But, all coefficients
h signs not consistent with a priori expectations were
-significant.

Generally, the basic problem in the results from state
lyses was the different signs and sizes of estimated
fficients for the same variable in different states.
s problem perhaps was caused by the following factors:

(a) The existence of multicollinearity problem among some variables used in the analyses.

(b) The aggregative nature of the values used for some technical factors, e.g., the values used for fertilizer and labor variables were state averages rather than county averages (which were not available).

(c) The variation among observations associated with a state perhaps was too small to provide reliable estimates. In other words, some states might have a great homogeneity which tends to result in insufficient variability among the observations for each variable to permit reliable estimates.[31]

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[31] Johnson and Gustafson, op. cit., p. 63.

However, some of these difficulties were generally reduced by making the analyses for regional level. These regional analyses will be discussed in the following chapter.

CHAPTER V

REGIONAL ANALYSES

Grouping the counties, which presumably have a rela-ive homogeneity of production techniques, weather, soil, opography and climate, into a region increases the observa-ions associated with each analysis substantially, and this ncrease in degrees of freedom might lead to more reliable stimates. Thus, this aggregative attribute of regional nalyses might result in sufficient variability among the bservations within a region to permit making reliable stimates.

Four regional analyses were made, one each for the outheastern, the Delta, the Southwestern, and Western egions. The analysis for the Southeastern Region, i.e., orth Carolina, South Carolina, Georgia, and Alabama, in-luded ninety-one counties.[1] For the Delta Region, namely, issouri, Arkansas, Tennessee, Mississippi, and Louisiana, eventy-nine counties were involved. In the Southwestern egion, including Oklahoma, East Texas, and West Texas, ixty-four counties were used. Only twenty-four counties

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[1]The sampling method for selecting these counties was escribed in Chapter III.

were involved in the analysis of the Western Irrigated Region, i.e., New Mexico, Arizona and California.

Regional Model

The model used for each regional analysis was as follows:

$$Y_{ct} = b_o + \sum_{i=1}^{24} b_i X_{ict} + V_{ct}.$$ [2]

The definition of all variables in the above model is as defined earlier for the state models. But, in this regional model, there were seven new weather variables, i.e., X_{16}, X_{17}, X_{18}, X_{20}, X_{21}, X_{23}, and X_{24}. The definition of these new weather variables is as follows:

$X_{16} = TT^2 = \sum_{p=1}^{9} T_p^2$, where $T_1^2 . T_2^2, \ldots, T_9^2$ are squared monthly average temperature, i.e., T_1^2 is squared average temperature for the first month of the growing season (March), and T_2^2 is for April, and so on..., T_9^2 is for November.

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[2] In the analysis of the Western Irrigated Region, seven weather variables were dropped because they were highly correlated with each other in this region. These variables were TT^2, LT^2, QT^2, LRT, QRT, LRR, and QRR. With this, the model for this region was exactly like State Model I.

$X_{17} = LT^2 = \sum_{p=1}^{9} pT_p^2$, where p=1, 2, . . ., 9, i.e.,

p=1 is for the first month of growing season (March), p=2 is for April, and so on . . ., p=9 is for November.

$X_{18} = QT^2 = \sum_{p=1}^{9} p^2T_p^2$.

$X_{20} = LRT = \sum_{p=1}^{9} pR_pT_p$, where R_1T_1, R_2T_2, . . . , R_9T_9 are monthly rainfall-temperature interaction, i.e., R_1T_1 is March rainfall temperature interaction, and R_2T_2 is April interaction, and so on . . . , R_9T_9 is November interaction.

$X_{21} = QRT = \sum_{p=1}^{9} p^2R_pT_p$

$X_{23} = LRR = \sum_{p=1}^{8} pR_pR_{p+1}$, where R_1R_2, R_2R_3, . . . , R_8R_9 are successive month rainfall interaction of growing season, i.e., R_1R_2 is March-April rainfall interaction, and R_2R_3 is April-May interaction, and so on . . . , R_8R_9 is October-November interaction. And p=1, 2, . . . , 8, where p=1 for March-April interaction, and p=8 for October-November interaction.

$$X_{24} = QRR = \sum_{p=1}^{8} p^2 R_p R_{p+1}.$$

Results for Regional Model

The results from applying the regional model for each of the four cotton regions are presented in Table 8. These results show that the estimated coefficients for the technical and economic factors X_1 (dollars spent on gas and oil), X_3 (fertilizer nutrients), X_4 (size of cotton enterprise), and X_6 (value of land) were positive in all regions. The coefficients estimated for the other two technical factors X_2 (man-hours of labor) and X_5 (ratio of cotton acreages in a year to that in 1939) differed over different regions. For the man-hours variable, the coefficients were positive in the Southeastern and Delta Regions, and negative in the other two regions. Comparative cotton acreage ratio coefficients were positive in the Southeastern and Western Regions, but negative in the Delta and Southwestern Regions.

More specifically, the fertilizer nutrients variable (X_3) was statistically significant[3] in all regions except in the Southwestern Region. Since, the levels of fertilizer nutrients applied per cotton acre during the whole period of study in the Southeastern, Delta, and Western Regions

[3] In this Chapter statistical significance refers to 10 percent level of significance.

Table 8. The Regression Results for Regional Analyses of Changes in Cotton Yields

Explanatory Variables	I South-eastern Region	II Delta Region	III South-western Region	IV Western Irrigated Region
X_1: Gas-oil	1.59[a] (2.91)[b]	2.56 (2.34)	39.81 (4.51)	1.73 (.48)
X_2: Man-hours	1.61 (0.37)	1.22 (0.40)	-0.75 (0.97)	-4.93 (1.01)
X_3: Nutrients	1.06 (0.17)	0.81 (0.14)	0.04 (0.25)	0.84 (0.49)
X_4: Size	0.84 (0.87)	0.27 (0.29)	0.41 (0.16)	0.33 (0.14)
X_5: Ratio	-0.29 (1.64)	-1.63 (1.64)	-0.02 (0.17)	0.01 (0.01)
X_6: Value	0.44 (0.12)	1.41 (0.14)	0.49 (0.10)	0.06 (0.09)
X_7: TR[c]	76.42 (21.41)	40.01 (26.42)	81.91 (32.46)	47.66 (59.91)
X_8: LR	-25.67 (10.53)	-32.58 (13.56)	-36.25 (16.74)	-24.11 (18.41)
X_9: QR	1.84 (1.03)	3.43 (1.36)	3.35 (1.63)	1.95 (1.64)
X_{10}: TR^2	-0.73 (0.45)	-1.26 (0.70)	-2.61 (1.32)	-5.79 (14.63)
X_{11}: LR^2	0.20 (0.20)	0.69 (0.33)	0.90 (0.59)	2.06 (4.86)
X_{12}: QR^2	-0.02 (0.02)	-0.08 (0.03)	-0.07 (0.06)	-0.15 (0.40)
X_{13}: TT	3.55 (6.34)	-5.86 (21.67)	4.51 (26.09)	-4.73 (5.18)
X_{14}: LT	0.27 (3.34)	-0.53 (7.89)	3.88 (14.71)	2.53 (2.10)
X_{15}: QT	-0.14 (0.42)	0.12 (0.64)	-0.49 (1.37)	-0.26 (0.19)
X_{16}: TT^2	-0.01 (0.05)	0.05 (0.18)	-0.02 (0.18)	d

. . . continued

Table 8 continued.

Explanatory Variables	I South-eastern Region	II Delta Region	III South-western Region	IV Western Irrigated Region
X_{17}: LT^2	0.001 (0.03)	0.001 (0.06)	-0.03 (0.10)	----
X_{18}: QT^2	-0.0001 (0.01)	-0.001 (0.01)	0.003 (0.01)	----
X_{19}: TRT	-1.06 (0.36)	-0.38 (0.45)	-1.59 (0.54)	-0.08 (0.45)
X_{20}: LRT	0.34 (0.16)	0.35 (0.21)	0.66 (0.25)	----
X_{21}: QRT	-0.02 (0.02)	-0.03 (0.02)	-0.06 (0.02)	----
X_{22}: TRR	0.83 (0.56)	1.38 (0.96)	0.12 (1.48)	3.99 (2.26)
X_{23}: LRR	-0.48 (0.31)	-1.0 (0.58)	-0.31 (0.82)	----
X_{24}: QRR	0.05 (0.04)	0.1 (0.09)	0.05 (0.09)	----
R^2 [e]	0.5296	0.5846	0.5609	0.6776

[a]This value is the estimated regression coefficient.

[b]Standard errors are given in parentheses.

[c]TR, LR, QR, TR^2, QR^2, LR^2, TT, LT, QT, TT^2, LT^2, QT^2, TRT, LRT, QRT, TRR, LRR, and QRR are as defined in regional model.

[d]In the Western Irrigated Region, these weather variables (TT^2, LT^2, QT^2, LRT, QRT, LRR, and QRR) were dropped from the analysis.

[e]R^2 is the multiple coefficient of determination.

were very high compared with those in the Southwestern Region,[4] it is not too surprising that fertilizer has had a minor effect on cotton yields in the latter region, but a major effect in the other regions. However, the sizes of the coefficients were smaller than expected. None was more than 1.1. This means that a one pound increase in fertilizer nutrients applied per cotton acre has increased the cotton yields per acre in different cotton regions by about one pound.

Moreover, the estimated coefficients for the fertilizer variable were generally smaller than found in other studies, particularly those based on experimental plots.[5] However, Johnson and Gustafson in their study of grain yields used technical variables in a way similar to the present study and concluded:

> To the extent that the regression coefficient estimates are comparable with the results of other studies, particularly those based on experimental plot or field-trial results, the comparisons are generally consistent with what one would expect: the effects estimated here, based on actual average farm experience, are somewhat smaller than those obtained in experiments carried out under more or less ideal conditions. 6

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[4]The average pounds of fertilizer nutrients applied per cotton acre for the whole period of study in the Southeastern, Delta, and Western Regions were 106, 70, and 76 respectively, while in the Southwestern were only 27.

[5]Fulmer and Botts, _op. cit._

[6]Johnson and Gustafson, _op. cit._, p. 79.

The variable of dollars spent on gas and oil (X_1) was statistically significant in the Southwestern and Western Regions with positive coefficients in all regions. The size of the coefficients in the Southwestern Region was large (39.8) compared with those in the other regions (1.6 to 2.6). Man-hours of labor (X_2) was significant in all regions except in the Western Region, with positive coefficients in the Southeastern and Delta Regions, and negative coefficients in the other two regions. However, the results for these two variables (X_1 and X_2) indicate that mechanization has been primarily a substitute for labor in cotton production, with positive net effects on yields per acre in most cotton regions.

Average size of the cotton enterprise (X_4) was statistically significant in the Southwestern and Western Regions, and not significant in the other regions. The results for this variable (X_4) were quite similar to those obtained for the variable X_1 (dollars spent on gas and oil). Since (X_4) was included to measure the effect of a shift to more specialized equipment, and (X_1) to measure the effect of increased mechanization, and if these are valid, then it appears that the extent of mechanization in cotton production was associated with a shift to more specialized equipment, and these have positively affected the cotton yields per acre.

The coefficients for the ratio of cotton acreages in a year compared with 1939 (X_5) were not significant in any

egion, with negative signs in the Southeastern, Delta, and outhwestern Regions, and positive in the Western Irrigated egion. Furthermore, the coefficients of this variable in ll regions were smaller than expected. None was more than 1.63.

Value of land and buildings per acre (X_6) was signifi- ant in all regions except the Western Region, with positive oefficients in all regions. On the basis of the signifi- ant results for this variable in most regional and state nalyses, it appears that the changes in land values over ime have had positive relationships with cotton yields in ost of the United States Cotton Belt.

Weather variables, rainfall in particular, were con- istent over different regions. Each of the twelve rain- all variables has estimated regression coefficients with he same sign in the four different regions.[7] The rainfall ariables X_7, X_9, X_{11}, X_{20}, X_{22}, and X_{24} have positive signs, nd the variables X_8, X_{10}, X_{12}, X_{19}, X_{21}, and X_{23} have nega- ive signs in the different regions.

Moreover, the results for weather variables as reported n Table 8, have explicitly indicated the seasonal effects f the weather factors on cotton yields. To show the distribu- ion of these weather effects over the growing season, and

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[7]All rainfall variables X_7, ... , X_{12}, X_{19}, ... , $_{24}$ were defined before as a part of regional model.

determine which, if any, weather factor was limiting production, the individual coefficients for each month of the weather variables[8] were derived from the coefficients for weather variables reported in Table 8, and are presented in Table 9.

The estimated coefficients for monthly total rainfall variable in different cotton regions indicated that the effects of this variable were most beneficial to cotton yields in the early part of the season. But, these effects of monthly total rainfall were most injurious at the middle of the season, particularly June to September, then came to be slightly damaging or relatively beneficial in November. The sizes of this variable's coefficients in all regions were larger than expected. For instance, in the Southeastern Region they ranged from -13.1 in September to 52.3 in March.

The results of monthly rainfall-temperature interaction were generally similar for different regions. These rainfall-temperature interactions were slightly injurious to cotton yields at the beginning of the season and changed gradually to be relatively beneficial at the end of the season. In the Delta Region, for example, the coefficient

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[8]Monthly total rainfall, squared monthly total rainfall, monthly average temperature, squared monthly average temperature, monthly rainfall-temperature interaction, and successive month rainfall interaction.

able 9. The Estimated Regression Coefficients for Weather Variables, in Regional Analyses

eather ariables	I South-eastern Region	II Delta Region	III South-western Region	IV Western Irrigated Region
otal Rainfall				
March	52.3[a]	10.9	49.0	25.5
April	32.4	-11.4	22.8	7.2
May	16.0	-26.9	3.3	-7.1
June	3.2	-35.4	-9.5	-17.6
July	-5.9	-37.1	-15.6	-24.1
August	-11.4	-32.0	-15.0	-26.8
September	-13.1	-20.0	-7.7	-25.6
October	-11.2	-1.1	6.3	-20.4
November	-5.6	24.6	27.0	-11.4
quared Total Rainfall				
March	-0.50	-0.65	-1.80	-3.88
April	-0.40	-0.20	-1.10	-2.27
May	-0.30	0.09	-0.50	-0.96
June	-0.20	0.22	-0.10	0.05
July	-0.20	0.19	0.15	0.76
August	-0.20	0.00	0.28	1.17
September	-0.30	-0.35	0.27	1.28
October	-0.40	-0.86	0.12	1.09
November	-0.50	-1.53	-0.17	0.60
verage Temperature				
March	3.7	-6.3	7.9	-2.5
April	3.5	-6.4	10.3	-0.7
May	3.1	-6.4	11.7	0.5
June	2.4	-6.1	12.2	1.2
July	1.4	-5.5	11.7	1.4
August	0.1	-4.7	10.2	1.1
September	-1.4	-3.7	7.7	0.2
October	-3.3	-2.4	4.2	-1.1
November	-5.4	-0.9	-0.3	-3.0
I. Average Temperature				
March	-0.01	0.05	-0.05	b
April	-0.01	0.05	-0.07	---
May	-0.01	0.04	-0.08	---

. . . continued

ıble 9 continued

ɜather ɜriables	I South-eastern Region	II Delta Region	III South-western Region	IV Western Irrigated Region
ı. Average Temperature (cont.)				
June	-0.01	0.04	-0.09	---
July	-0.01	0.03	-0.10	---
August	-0.01	0.02	-0.09	---
September	-0.01	0.01	-0.08	---
October	-0.01	-0.01	-0.07	---
November	-0.01	-0.02	0.05	---
ain and Temperature Interaction				
March	-0.74	-0.06	-0.96	-0.08
April	-0.46	0.20	-0.44	-0.08
May	-0.22	0.40	-0.04	-0.08
June	-0.02	0.54	0.24	-0.08
July	0.14	0.62	0.40	-0.08
August	0.26	0.64	0.44	-0.08
September	0.34	0.60	0.36	-0.08
October	0.38	0.50	0.16	-0.08
November	0.38	0.34	-0.16	-0.08
ain Interaction				
March-April	0.40	0.48	-0.10	3.99
April-May	0.07	-0.22	-0.30	3.99
May-June	-0.16	-0.72	-0.40	3.99
June-July	-0.29	-1.02	-0.30	3.99
July-August	-0.32	-1.12	-0.20	3.99
August-Sept.	-0.25	-1.02	0.10	3.99
Sept.-Oct.	-0.08	-0.72	0.50	3.99
Oct.-Nov.	0.19	-0.22	0.90	3.99

[a] These are the estimated regression coefficients and were obtained by the same procedure mentioned in the last chapter.

[b] In the Western Irrigated Region, these variables were dropped from analysis.

for March rainfall-temperature interaction was -0.06 and then changed upward to 0.34 at November.

The results for successive month rainfall interaction indicated that these interactions have positively affected cotton yields during the beginning of the season in the Southeastern and Delta Regions, and become negative as the season advances. In the Southwestern Region, the pattern of these effects was the opposite, i.e., these effects were slightly negative at the beginning of the season and became positive at the end of the season. In the West, the effects of these interactions were positive throughout the whole season.

Thus, on the basis of the results for regional analyses, it appears that the results for rainfall variables were generally consistent in the different cotton regions. Moreover, the results for temperature variables were relatively consistent from one region to the other, but were not as consistent as the results obtained for the rainfall variables. The coefficients for the monthly average temperature variable were negative throughout the whole season in the Delta Region, with large values for the planting period and smaller values at the end of the season. In the Southeast, these coefficients were highly positive at the early part of the season, and then reduced gradually to become negative for September to November. In the Southwestern Region, these effects of monthly average temperature were positive during the whole season with the largest values in June. But, in the Western Region, these coefficients have a different pattern. They were relatively negative for March and April (-2.5 and -0.7 respectively), then slightly positive during five months, and became negative for October and November.

However, the above results for weather variables show the effect of rainfall or temperature variables taken individually, rather than the effect of either all rainfall or all temperature variables. Hence, to show the effect of rainfall or temperature on cotton yields per acre, the marginal effects of rainfall or temperature in each month of the season were derived from the coefficients reported in Table 9, and are represented in Figures 2 and 3. The marginal effect at the mean for rainfall (or temperature) is the effect of a one-inch increase in rainfall (or a one degree F. increase in temperature) on the cotton yields in pounds per acre. The marginal effects for monthly total rainfall were estimated for each month by the following equation:

$$\frac{\Delta Y}{\Delta R} = b_1 + 2b_2 (\overline{R}) + b_5 (\overline{T}) + b_6 (\overline{R'})$$

where ΔY is the change in cotton yields in pounds per acre due to the change in rainfall in inches (ΔR). b_1, b_2, b_5 and b_6 are the estimated coefficients for monthly rainfall, squared monthly rainfall, monthly rainfall-temperature

Figure 2: The Marginal Effect At The Mean For Monthly Total Rainfall On Cotton Yields Per Acre

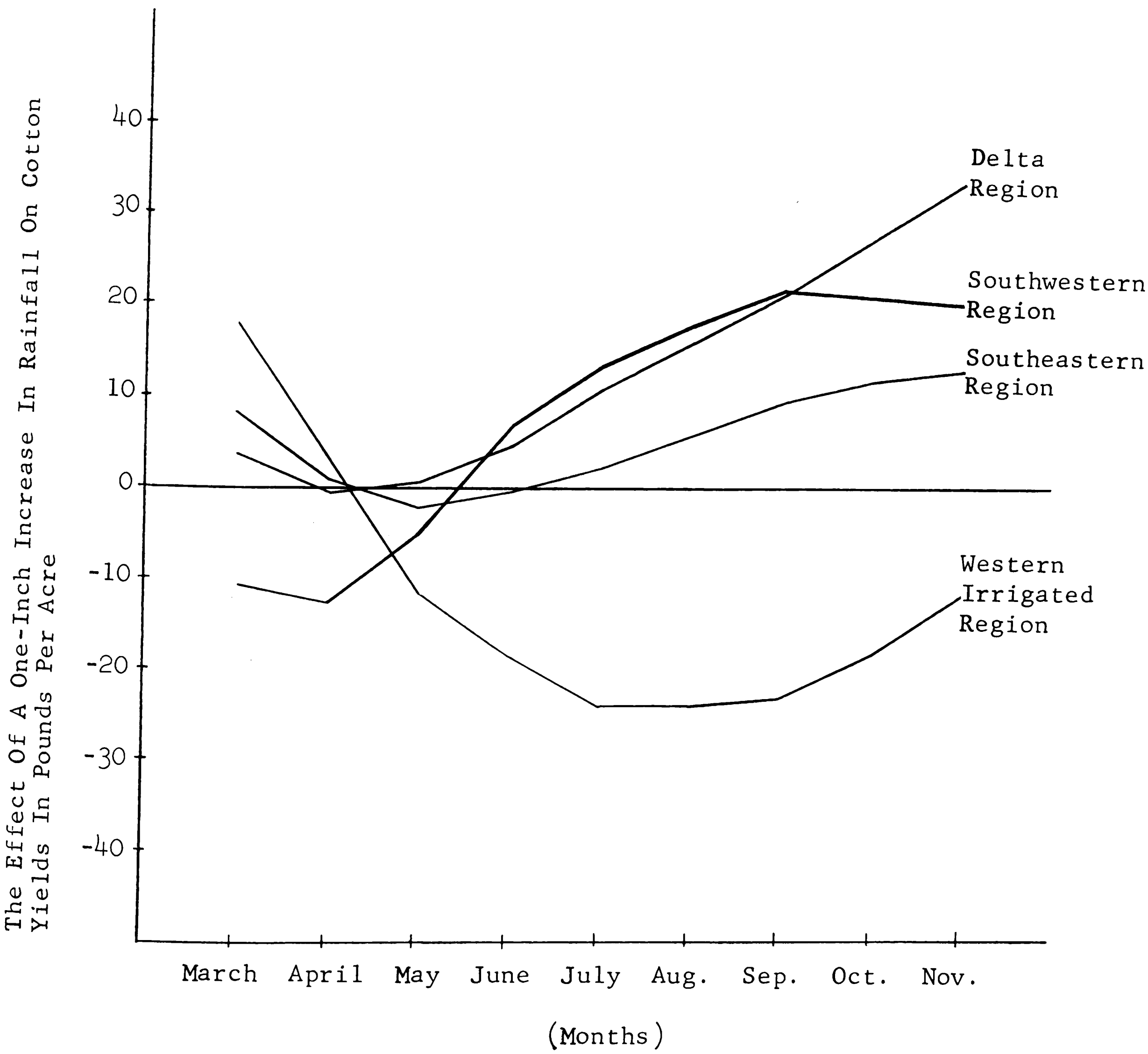
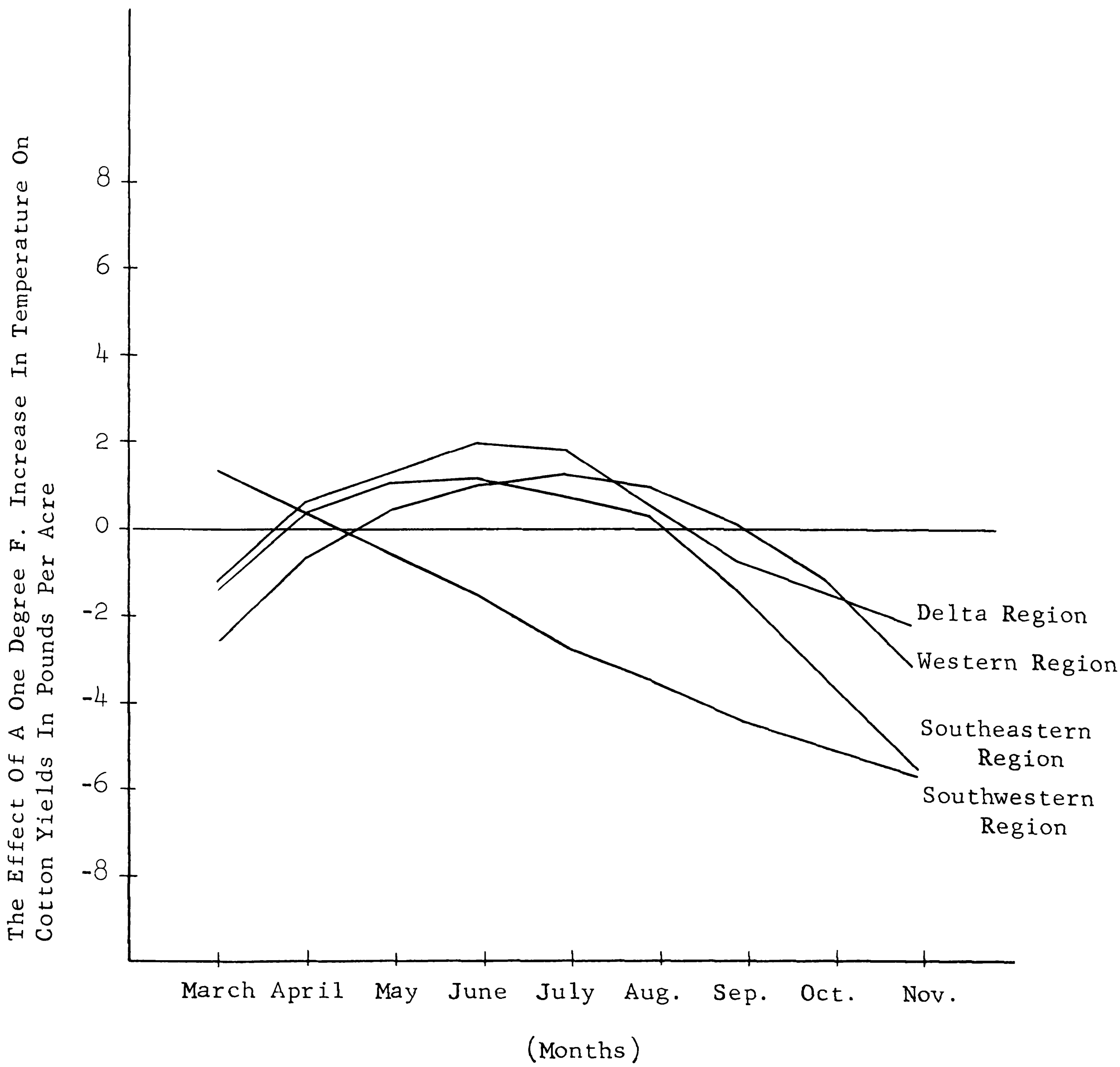


Figure 3: The Marginal Effect At The Mean For Monthly Average Temperature On Cotton Yields Per Acre



interaction, and successive month rainfall interaction[9] respectively, as shown in Table 9. $\overline{R}$ is monthly mean rainfall, $\overline{T}$ is monthly mean temperature, and $\overline{R}'$ is the mean rainfall for the preceding and following months[10] for the whole period of study.

The marginal effects for monthly average temperature were estimated for each month by the following equation:

$$\frac{\Delta Y}{\Delta T} = b_3 + 2b_4 (\overline{T}) + b_5 (\overline{R})$$

where ΔY is the change in cotton yields in pounds per acre due to the change in temperature in degrees F. (ΔT). b_3, b_4, and b_5 are the estimated coefficients for monthly temperature, squared monthly temperature, and monthly rainfall-temperature interaction respectively, as shown in Table 9. $\overline{T}$ is monthly mean temperature and $\overline{R}$ is monthly mean rainfall for the whole period of study.

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[9] b_6 for March is actually the estimated coefficient for March-April rainfall interaction, and for November is the estimated coefficient for October-November rainfall interaction as shown in Table 9. But for other months, b_6 is the average value of estimated coefficients for that month and following month, i.e., b_6 for April, for example, is the average value of estimated coefficients for March-April rainfall interaction and April-May rainfall interaction.

[10] $\overline{R}'$ for March is actually the mean rainfall for March and April, and for November $\overline{R}'$ is the mean rainfall for October and November. But for other months, $\overline{R}'$ is the mean rainfall for preceding and following months, i.e., $\overline{R}'$ for April, for example, is the mean rainfall for March and May.

Figure 2 shows that the pattern of the marginal effects for rainfall was generally similar in all non-irrigated regions. These marginal effects for rainfall in March were positive in the Southeastern and Delta Regions and negative in the Southwestern Region, and became negative in all non-irrigated regions during the following two months. In July, these marginal effects for rainfall turned up to become positive in all non-irrigated regions, and increased as the season advanced to have largest values at the end of the season. The marginal effects for rainfall, for example, were 1.9, 11.0, and 11.9 in July in the Southeastern, Delta and Southwestern Regions respectively, and increased gradually to be 12.7, 33.2, and 20.3 at the end of the season (November) in the Southeastern, Delta, and Southwestern Regions respectively. This means that an increase of one inch in rainfall in the Southeastern Region in July increased the regional average yield per acre by 1.9, while such increase in rainfall in November increased the regional average yield by 12.9 pounds. The pattern of the marginal effects for rainfall in the Western Irrigated Region was much different from that in the non-irrigated regions. In the Western Region, the marginal effects for rainfall were most beneficial at the beginning of the season, reduced gradually to become highly negative for July and August and turned up to become relatively negative in November.

Figure 3 indicates that the marginal effects for temperature on cotton yields were generally similar in the Southeastern, Delta and Western Regions. In these three regions, the marginal effects for temperature were unfavorable during the planting and harvesting time, and were favorable in the middle of the season with largest values in June. In the Delta Region, for example, the marginal effects for temperature on cotton yields in pounds per acre were -1.2, 2.1, and -2.1 for March, June and November respectively. This means that a one degree F. increase in temperature in March or November decreased the regional average yield per cotton acre by 1.2 and 2.1 pounds respectively, while such an increase in temperature in June increased the regional average yield per acre by 2.1 pounds. In the Southwest, the marginal effects for temperature were slightly positive for March, and reduced gradually to be highly negative at the end of the season.

However, to test the significance of the joint effect of either rainfall or temperature variables, the F-test was applied to all regional analyses and the results are reported in Table 10.

It should be noted that the set of rainfall variables tested was $X_7, \ldots, X_{12}, X_{19}, \ldots, X_{24}$, and the set of temperature variables was $X_{13}, \ldots, X_{21}$.[11]

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[11]See Table 8.

Table 10. The F-Test Results Indicating the Significance of Weather Effects on Cotton Yields in Different Regions

Regions	Rainfall			Temperature		
	Degrees of Freedom (N_1,N_2)[a]	F Value	Level of Significance	Degrees of Freedom (N_1,N_2)[a]	F Value	Level of Significance
Southeast	(12,430)	9.4	.01	(9,430)	3.3	.01
Delta	(12,370)	6.4	.01	(9,370)	2.1	.03
Southwest	(12,295)	1.2	.29	(9,295)	4.6	.01
West	(8,102)	3.2	.01	(4,102)	0.5	.72

[a] N_1 is degree of freedom for the numerator of the F-ratio, and N_2 is degree of freedom for the denominator of the F-ratio.

Table 10 shows that the joint effects of rainfall variables on cotton yields were statistically significant in all regions except in the Southwestern Region, while the joint effects of temperature variables were significant in all regions except in the Western Region.

Concluding Points

The regression results for technical and economic factors obtained from regional analyses were generally more internally consistent and statistically meaningful in terms of the technical and economic expectations than those obtained from state analyses. Moreover, the results for weather variables, particularly rainfall variables, obtained from regional analyses were consistent from region to region.

But, one question concerning the results for technical and economic variables obtained from the regional analyses is that the estimated effects of these explanatory variables on the regional average yield were generally smaller in magnitude than was expected. This might generally be caused by the lack of appropriate data or the poor measure of some of the explanatory variables,[12] and the existence of a multi-collinearity problem among some of these variables.[13]

In this respect, Johnson and Gustafson argued that: "It appears likely that much of this inadequacy will be remediable by the future accumulation of more complete and more accurate data. On the other hand, the problems caused by high intercorrelations among some of the explanatory variables are probably to some extent an unavoidable characteristic of the procedure."[14]

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[12]Particularly the measure of technical variables X_3 (fertilizer nutrients) and X_2 (man-hours of labor).

[13]See Appendix D.

[14]Johnson and Gustafson, <u>op. cit.</u>, p. 90.

CHAPTER VI

NATIONAL ANALYSES

The prime motivation for the national analyses was the potential improvement of the estimates through taking into account a wider range of variation in the variables as well as the gain in degrees of freedom. At the same time, an economic and policy justification for doing these analyses was to understand better the relationships (between yields and related factors on the national level) so that an appropriate policy can be undertaken.

In the national analyses two sets of dummy variables were added. One set was concerned with time and the other was concerned with location of production.

Dummy variables for time were used to measure the effect of those factors that changed over time and were not explicitly considered in the model such as: improvement in seed varieties, production techniques, and insect control. The second set of dummy variables for location was included to measure the effect of shifts in location of production among counties.

The value of these dummy variables is either one or zero. A one is used if the observation belongs to the class represented by the variable; otherwise a zero is used. For example, consider the first dummy variable for location. The value one is assigned to this variable for each county of sub-region 1, while the value zero is assigned to each county of all other sub-regions.[1]

A detailed discussion for the national model is in the following section.

National Model

The model used for national analyses was as follows:

$$Y_{ct} = b_o + \sum_{i=1}^{6} b_i X_{ict} + \sum_{i=7}^{24} b_i X_{ict} + \sum_{i=25}^{28} b_i X_{ict} + \sum_{i=29}^{58} b_i X_{ict} + V_{ct}$$

c = 1, 2, ..., 258 (counties in each year with a total of 1290 counties for all 5 years of the study).

t = 1939, 1944, 1949, 1954, 1959 (years).

i = 1, 2, ..., 58 (independent variables); and

= 1, 2, ..., 6 (technical and economic variables),

= 7, 8, ..., 24 (weather variables),

= 25, ..., 28 (dummy variables for time),

= 29, ..., 58 (dummy variables for location).

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[1]The definition of these sub-regions is in: Economic sub-regions of the U. S., Series Census- BAE, No. 19, June 1953.

b_o (constant term), V_{ct} (error term), Y_{ct} (dependent variable), $X_{1ct}, \ldots, X_{6ct}$ (technical and economic variables), and $X_{7ct}, \ldots, X_{24ct}$ (weather variables) are as defined in the previous chapters.

The definition of each of the other independent variables is as follows:

X_{25} = 1 for all counties in 1944, and
= 0 for all counties in all other years.

X_{26} = 1 for all counties in 1949, and
= 0 for all counties in all other years.

X_{27} = 1 for all counties in 1954, and
= 0 for all counties in all other years.

X_{28} = 1 for all counties in 1959, and
= 0 for all other counties.

X_{29} = 1 for counties in subregion 1 (N.C., county no. 2, 4, 11)[2] and
= 0 for all other counties.

X_{30} = 1 for counties in subregion 2 (N.C., 5, 13 and S.C., 7, 8, 14), and
= 0 for all other counties.

X_{31} = 1 for counties in subregion 3 (N.C., 6, 7, 10, 12, 14, 16, 17), and

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[2]See Appendix B.

= 0 for all other counties.

X_{32} = 1 for counties in subregion 4 (N.C., 1, 3, 8, 9, 15 and S.C., 5, 9, 17, 18), and

= 0 for all other counties.

X_{33} = 1 for counties in subregion 5 (S.C., 2, 3, 6, 10, 12, 13, 15, and Ga., 15, 30), and

= 0 for all other counties.

X_{34} = 1 for counties in subregion 6 (S.C., 4, 11, and Ga., 18), and

= 0 for all other counties.

X_{35} = 1 for all counties in subregion 7 (S.C., 1, 16, and Ga., 8, 13, 21, 23, 24, 25, 26, 28, and Ala., 5, 11, 19, 24) and

= 0 for all other counties.

X_{36} = 1 for all counties in subregion 8 (Ga., 1, 5, 6, 7, 10, 11, 12, 19, 29), and

= 0 for all other counties.

X_{37} = 1 for all counties in subregion 9 (Ga., 2, 4, 14, 16, 17, 27, and Ala., 2, 4, 8, 9, 10, 15, 17), and

= 0 for all other counties.

X_{38} = 1 for all counties in subregion 10 (Ga., 3, 9, 20, 22, and Ala., 18, 25), and

= 0 for all other counties.

X_{39} = 1 for counties in subregion 11 (Ala., 1, 6, 14, 20, 23), and

= 0 for all other counties.

X_{40} = 1 for counties in subregion 12 (Ala., 3, 12, 16, 22, 26, and Miss., 6, 20), and

= 0 for all other counties.

X_{41} = 1 for counties in subregion 13 (Ala., 13, 21, Miss., 15, and La., 10), and

= 0 for all other counties.

X_{42} = 1 for counties in subregion 14 (Ala., 7, and Miss., 2, 5, 7, 12, 13, 14, 19, 23, 24, 27, 28), and

= 0 for all other counties.

X_{43} = 1 for counties in subregion 15 (Miss., 1, 21, 26, and Tenn., 1, 2, 4, 7, 9, 11), and

= 0 for all other counties.

X_{44} = 1 for counties in subregion 17[3] (Ark., 9, 17, 18), and

= 0 for all other counties.

X_{45} = 1 for counties in subregion 18 (Ark., 1, 3, 7, 8, 10, 11, 13, 15), and

= 0 for all other counties.

X_{46} = 1 for counties in subregion 19 (Ark., 5, 6, 14, 16, Miss., 3, 11, 16, 22, 25, Mo., 1, 2, ..., 8, and La., 2, 3, 4, 6, 7, 9, 11, 12, 13), and

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[3]Dummy variable for subregion 16 (Miss., 4, 8, 9, 10, 17, 18, 29, and Tenn., 3, 5, 6, 8, 10) was dropped to obtain non-singular matrix and allow estimation of parameters built into the model.

= 0 for all other counties.

X_{47} = 1 for counties in subregion 20 (La., 1, and E. Tex., 11, 18, 29), and

= 0 for all other counties.

X_{48} = 1 for counties in subregion 21 (La., 5, 8, Okla., 17, Ark., 2, 4, 12, and E. Tex., 1, 4, 6, 7, 8, 19, 22, 24, 27), and

= 0 for all other counties.

X_{49} = 1 for counties in subregion 22 (Okla., 1, 10, 18), and

= 0 for all other counties.

X_{50} = 1 for counties in subregion 23 (Okla., 4, 14, 16, 19, and E. Tex., 12, 14, 23, 25), and

= 0 for all other counties.

X_{51} = 1 for counties in subregion 24 (E. Tex., 9, 13, 16, 17, 21, 28), and

= 0 for all other counties.

X_{52} = 1 for counties in subregion 25 (E. Tex., 2, 3, 5, 15, 20, 26, 30, 31, 32), and

= 0 for all other counties.

X_{53} = 1 for counties in subregion 26 (Okla., 2, 5, 7, 8, 11, 12, 13, 15, E. Tex., 10, and W. Tex., 1, 6, 10, 13), and

= 0 for all other counties.

X_{54} = 1 for counties in subregion 27 (W. Tex., 4, 9, 12), and

= 0 for all other counties.

X_{55} = 1 for counties in subregion 28 (Okla., 3, 6, 9, and W. Tex., 2, 3, 5, 8, 11), and

= 0 for all other counties.

X_{56} = 1 for counties in subregion 29 (N. Mex., 1, 2, 11, 8, and W. Tex., 7), and

= 0 for all other counties.

X_{57} = 1 for counties in subregion 30 (Ariz., 1, 2, ..., 8, and Calif., 2), and

= 0 for all other counties.

X_{58} = 1 for counties in subregion 31 (Calif., 1, 3, 4, ..., 8), and

= 0 for all other counties.

The results from applying the above model for all 258 counties included in this study[4] are reported in Table 11. The results for each group of technical and economic, weather, time, and location factors will be discussed respectively in the following four sections.

Results for Technical and Economic Factors

Table 11 indicates that the technical and economic factors X_1 (dollars spent on gas and oil per acre), X_2 (man-

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[4]The total number of observations for the whole period of five census years was 1290.

Table 11. The Regression Results for National Analyses of Changes in Cotton Yields

Explanatory Variables	Estimated Regression Coefficients	Explanatory Variables	Estimated Regression Coefficients	Explanatory Variables	Estimated Regression Coefficients
X_1: Gas-Oil	1.588[a] (0.604)[b]	X_{11}: LR^2	-0.0629 (0.341)	X_{21}: QRT	-0.0263 (0.022)
X_2: Man-hours	0.685 (0.522)	X_{12}: QR^2	0.0056 (0.035)	X_{22}: TRR	1.041 (0.925)
X_3: Nutrients	0.573 (0.342)	X_{13}: TT	-5.433 (6.841)	X_{23}: LRR	-0.864 (0.533)
X_4: Size	0.528 (0.164)	X_{14}: LT	2.631 (3.480)	X_{24}: QRR	0.102 (0.065)
X_5: Ratio	-0.001 (0.139)	X_{15}: QT	-0.272 (0.423)	X_{25}: 1944	33.769 (25.385)
X_6: Value	0.325 (0.090)	X_{16}: TT^2	0.0265 (0.052)	X_{26}: 1949	-17.500 (26.206)
X_7: TR	53.993 (30.100)	X_{17}: LT^2	-0.0131 (0.028)	X_{27}: 1954	10.468 (33.241)
X_8: LR	-14.722 (14.825)	X_{18}: QT^2	0.0015 (0.003)	X_{28}: 1959	101.931 (42.110)
X_9: QR	0.956 (1.449)	X_{19}: TRT	-1.0095 (0.497)	X_{29}: Location 1	-16.738 (59.818)
X_{10}: TR^2	0.1405 (0.712)	X_{20}: LRT	0.3329 (0.223)	X_{30}: Location 2	-41.112 (49.497

Table 11. (continued)

Explanatory Variables	Estimated Regression Coefficients	Explanatory Variables	Estimated Regression Coefficients	Explanatory Variables	Estimated Regresssion Coefficients
X_{31}: Location 3	-49.594 (45.130)	X_{41}: Location 13	9.678 (57.262)	X_{51}: Location 24	-125.456 (59.491)
X_{32}: Location 4	-36.957 (42.812	X_{42}: Location 14	-55.667 (37.407)	X_{52}: Location 25	-101.481 (61.361)
X_{33}: Location 5	-68.800 (42.875)	X_{43}: Location 15	-54.034 (39.504	X_{53}: Location 26	-137.847 (59.108)
X_{34}: Location 6	-54.571 (60.929)	X_{44}: Location 17	-63.030 (60.319)	X_{54}: Location 27	-114.426 (75.042)
X_{35}: Location 7	-83.291 (37.224)	X_{45}: Location 18	-21.760 (42.517)	X_{55}: Location 28	-73.755 (63.402)
X_{36}: Location 8	-58.690 (44.101)	X_{46}: Location 19	104.972 (33.054)	X_{56}: Location 29	158.196 (58.722)
X_{37}: Location 9	-73.610 (40.456)	X_{47}: Location 20	-3.362 (63.430)	X_{57}: Location 30	160.157 (58.073)
X_{38}: Location 10	-84.741 (46.021)	X_{48}: Location 21	-52.512 (45.935)	X_{58}: Location 31	242.445 (70.240)
X_{39}: Location 11	-87.353 (48.499)	X_{49}: Location 22	-78.921 (72.310)		
X_{40}: Location 12	-116.915 (44.527)	X_{50}: Location 23	-118.213 (58.089)		

[a] These are the estimated regression coefficients.

[b] Standard errors are given in parentheses.

hours of labor per cotton acre), X_3 (pounds of fertilizer nutrients applied per cotton acre), X_4 (average size of cotton enterprise in acres), and X_6 (value of land and buildings per acre) have positive relations with cotton yields per acre. Meanwhile, the effect of X_5 (ratio of cotton acreage in a year to that in 1939) was virtually zero.

National average cotton yield per acre has substantially increased over the period of study (1939-59). A word of caution should be added, particularly in the interpretation the positive relationship between the different technology factors and cotton yields. This positive relationship does not necessarily mean that the increase in the levels of those factors over time has increased the cotton yields, but it might also mean that a decrease in the level of some factor of these has decreased--by itself--the yields.

The extent of mechanization, more use of fertilizer nutrients, larger size of cotton farm, and increase in values of land over the period of study are associated with increased cotton yields per acre. The factor X_2, man-hours of labor per cotton acre, has decreased, while the effect of X_6, a decrease in the ratio of cotton acreage in a year to that in year 1939, was virtually zero.

More specifically, the estimated regression coefficients, as shown in Table 11, indicate that an increase of one dollar spent on gas and oil per acre (over average) has increased the yields by about 1.6 pounds, while a decrease of each one man-hour of labor per acre has decreased such yields by about 0.7 pound. This implies that mechanization has been primarily just a substitute for labor in cotton production, with positive net effects on the yields. In other words, a substitution of mechanization (as measured by dollars spent on gas and oil) for labor has increased the yields. Also, the use of an additional pound of fertilizer nutrients per acre (above average) has increased the yields by 0.6 pound. A one acre increase in the average size of a cotton farm increased the yields by 0.5 pound. And, an increase of one dollar in values of land per acre is associated with a positive yield increase of 0.3 pound. This increase in the yields related to the increase in values of land seems quite meaningful in terms of the economic expectations. The traditional economic theory argues that an increase or decrease in yields and economic value will be capitalized into higher or lower land values.

In general, the above results seem meaningful in terms of the economic and technical expectations. Even so, these results for different technical and economic factors and particularly for X_1 (dollars spent on gas and oil), and X_3 (pounds of fertilizer nutrients) provide estimated coefficients smaller than expected. This may result from high correlation between each of these X_1 (gas and oil),

X_3 (fertilizer) and the time factors (X_{25}, ..., X_{28}).

However, Table 11 indicates that the estimated regression coefficients for most technical and economic factors were large relative to their standard errors. For X_1 (gas and oil), X_3 (fertilizer), X_4 (farm size), and X_6 (land value) the estimated coefficients were significantly different from zero at less than the 10 percent level. But, the coefficients for X_2 (labor) or X_5 (ratio) were not statistically significant.[5]

In the last section of this chapter, the relative importance of each of these factors in explaining national average yield will be discussed in detail.

Results for Weather Factors

In the national model, the weather factors (X_7, ..., X_{24}) were used in such a way as to be equivalent to forcing the regression coefficients over the whole growing season (nine months) for each set of original factors[6] to fit a quadratic function of time. However, these regression coefficients only indicate the effect of different weather

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[5]The significance levels for the coefficients for X_2 (labor) and X_5 (ratio) were .19 and .94, respectively.

[6]Monthly total rainfall, squared total rainfall, monthly average temperature, squared average temperature, monthly rainfall-temperature interaction, and successive month rainfall interaction.

factors on the yields over the entire growing season; they do not explicitly show the distribution of these weather factor effects within the season. Hence, the individual coefficients for each month of these original weather factors were derived from the coefficients reported in Table 11, and are listed in Table 12.

The estimated regression coefficients for monthly total rainfall variable, as shown in Table 12, indicate that the increase in rainfall above average was most beneficial to cotton yields in the early part of the season. Then, as the season advanced, the effects of an increase in rainfall above average became less and less to become relatively injurious late in the season.

Concerning the monthly average temperature variable, their estimated coefficients indicate that an increase in temperature over the average in the early and late parts of the season have unfavorably affected yields. During the middle of the season, that is, May through August, a higher temperature favorably affected yields.

Table 12 also shows that the effect of rainfall-temperature interaction was negative at the beginning of the season and changed gradually to be slightly positive in August and September, then turned down to become slightly negative.

The estimated coefficients for successive month rainfall interactions, as listed in Table 12, indicate that

Table 12. The Estimated Regression Coefficients for Monthly Weather Variables

Weather Variables	(b)[a]	Weather Variables	(b)[a]	Weather Variables	(b)[a]
(Total Rainfall)		(Av. Temperature)		(Rainfall-Temp. Interaction)	
March	40.227	March	-3.074	March	-0.703
April	28.373	April	-1.259	April	-0.449
May	18.431	May	0.012	May	-0.248
June	10.401	June	0.739	June	-0.099
July	4.283	July	0.922	July	-0.003
August	0.077	August	0.561	August	0.041
September	-2.217	September	-0.344	September	0.032
October	-2.599	October	-1.793	October	-0.030
November	-1.069	November	-3.786	November	-0.144
(Squared Total Rainfall)		(Sq. Av. Temp.)		(Rainfall Interaction)	
March	0.083	March	0.015	March-April	0.279
April	0.037	April	0.006	April-May	-0.279
May	0.002	May	0.001	May-June	-0.633
June	-0.022	June	-0.002	June-July	-0.783
July	-0.034	July	-0.002	July-August	-0.729
August	-0.035	August	0.002	August-September	-0.471
September	-0.025	September	0.008	Sept.-October	-0.009
October	-0.004	October	0.018	Oct.-November	0.657
November	-0.028	November	0.030		

[a]This is the estimated regression coefficient.

these interactions negatively affected yields at the beginning of the season, became less important as the season advanced, and turned positive in November.

The above results for weather variables show the effect of individual rainfall or temperature variables rather than the effect of rainfall or temperature as a whole on the national yields. To show the effect of rainfall or temperature in general on the national yields, the marginal effects for rainfall and temperature in each month of the season were derived from the coefficients listed in Table 12, and are reported in Table 13. These marginal effects for either rainfall or temperature were estimated as defined in the previous chapter. The marginal effects for rainfall were most beneficial for the first month of the season (March) and slightly beneficial throughout June to August. But these marginal effects for rainfall were injurious during April-May and October-November. The marginal effects for temperature unfavorably affected yields during the planting and harvesting time, and favorably affected yields in the middle, i.e., during the period of late vegetative growth and the early part of fruiting growth.

To test the significance of the joint effect of rainfall or temperature variables on the national average yield, the F-test was used. The results for the F-test indicated that the joint effect of rainfall variables was statistically significant, while the joint effect of temperature

Table 13. The Marginal Effects at the Mean for Monthly Total Rainfall and Monthly Average Temperature

Months	Marginal Effects for Rainfall [a]	Marginal Effects for Temperature[b]
March	1.9	-4.2
April	-0.2	-2.2
May	-1.9	-1.3
June	0.4	0.1
July	1.0	0.7
August	0.9	1.1
September	0.6	1.0
October	-3.6	0.4
November	-7.3	-0.9

[a]These are the effects of a one-inch increase in rainfall on cotton yields in pounds per acre. These effects were estimated for each month by the following equation:

$$\frac{\Delta Y}{\Delta R} = b_1 + 2b_2 (\overline{R}) + b_5 (\overline{T}) + b_6 (\overline{R}')$$

where ΔY is the change in cotton yields in pounds per acre due to the change in rainfall in inches (ΔR). b_1, b_2, b_5 and b_6 are the estimated coefficients for monthly rainfall, squared monthly rainfall, monthly rainfall-temperature interaction, and successive month rainfall interaction respectively, as shown in Table 12. $\overline{R}$ is monthly mean rainfall, $\overline{T}$ is monthly mean temperature and $\overline{R}'$ is the mean rainfall for the preceding and following months for the whole period of study.

[b]These are the effects of a one degree F. increase in temperature on cotton yields in pounds per acre. These effects were estimated for each month by the following equation:

$$\frac{\Delta Y}{\Delta T} = b_3 + 2b_4 (\overline{T}) + b_5 (\overline{R})$$

where ΔY is the change in cotton yields in pounds per acre due to the changes in temperature in degrees F. (ΔT). b_3, b_4, and b_5 are the estimated coefficients for monthly temperature, squared monthly temperature, and monthly rainfall-temperature interaction respectively, as shown in Table 12. $\overline{T}$ is monthly mean temperature, and $\overline{R}$ is monthly mean rainfall for the whole period of study.

variables was not significant.[7]

However, it seems interesting to show not only how each of the mentioned weather factors has affected yields, but also how much of the change in yields was attributable to changes in weather as a whole over the period of study. Therefore, the net effect of changes in weather conditions as a whole on the national average yield over time was calculated and will be discussed in detail in the last section of this chapter.

Results for Time Factors

As mentioned, the four dummy variables for time (X_{25}, ... , X_{28}) were used to measure the effect of changes in time-related factors. In other words, these dummy variables were included to measure the effect of those factors which presumably affected yields over time and were not explicitly included in the analyses. These factors include improvement in seed varieties, production techniques, and insect control. Moreover, these dummy variables for time may also pick up

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[7]The set of rainfall variables tested was X_7, ..., X_{12}, X_{19}, ..., X_{24}, and the set of temperature variables was X_{13}, ..., X_{21}, as shown in Table 11. The degrees of freedom for numerator (N_1) and denominator (N_2) of the F-ratio for testing rainfall variables were 12 and 1231, respectively, and the F-value and significance level (α) obtained were 2.027 and 0.02, respectively, while for the testing temperature variables, $N_1 = 9$, $N_2 = 1231$, the F-value = 1.193 and (α) was 0.20.

year to year variations in weather that were not otherwise accounted for.

One of these dummy variables was used for each year of the study, except that 1939 was dropped to obtain a non-singular matrix. Then, the estimated coefficients for these variables actually measure the consistent differences in the national average yield between 1939 and indicated subsequent years. For example, Table 11 indicates that the estimated coefficient for the first dummy variable X_{25} (1944) was positive with the size equal to 33.8. This means that the changes in these time related factors over the period of 1939-44 have increased the national average yield by 33.8 pounds. These 33.8 pounds are actually the net effect of changes in other technical and economic factors, weather, and location of production over the period of 1939-44. Moreover, Table 11 shows that the estimated coefficient for the last dummy variable X_{28} (1959) was also positive with a much larger size (101.9). This implies that an increase of 101.9 pounds in the national average yield per acre over the period of 1954-59 was attributable to changes in these time related factors.

Since, the more rapid improvement in those time related factors (particularly seed varieties and insect control) have occurred in the later years of the study, it was expected that time related factors have the largest effect on yields in the last period (1954-59) relative to earlier periods.

The results obtained for time factors are generally consistent with the above expectation. However, the result for time factor X_{26} (1949) is not in agreement with such a priori expectation. The estimated coefficient for factor X_{26}, as shown in Table 11, was -17.5. Statistically, the negative sign of this time factor X_{26} can be interpreted as the result of unfavorable weather for that year that was not picked up in the weather variables (X_7, ..., X_{24}).

However, the investigation of the relative importance of these time factors among other factors influencing the national average yield will be discussed in the last section of this chapter.

Results for Location Factors

It was expected that the shifts in location of production toward higher yielding areas would have substantially increased the national average yield. Therefore, two different methods were used to measure the effect of these shifts over time. One method was concerned with the shifts in location of production among counties, and the other was concerned with the shifts in location among states. Both methods can be described in detail as follows:

Shifts in location of production among counties: the estimated regression coefficients for location factors X_{29}, ..., X_{58} as shown in Table 11, were used to measure the effect of shifts in location among counties on the national average yield. The way in which these coefficients for location factors were used is represented in the following equations:

$$L_t = \frac{\sum_{r=1}^{R} b_r A_{rt}}{\sum_{r=1}^{R} A_{rt}} \text{ , and}$$

$$\Delta L_t = L_1 - L_o = \frac{\sum_{r=1}^{R} b_r A_{r1}}{\sum_{r=1}^{R} A_{r1}} - \frac{\sum_{r=1}^{R} b_r A_{ro}}{\sum_{r=1}^{R} A_{ro}}$$

where $\sum_{r=1}^{R}$ = the summation overall subregions, r=1, 2, ..., R, and R=31.

b_r = the estimated regression coefficient for the dummy variable representing subregion r, as shown in Table 11.

A_{rt} = the cotton acreage harvested in subregion r in year t, where t is 1939 or 1944, 1949, 1954, 1959.

L_t = the weighted average location effect on the yield in year t, by adopting the following two assumptions:

(1) changes in yield due to technology and weather are those due to changes in the average levels of technology and weather.

(2) Furthermore, these average levels of technology and weather are held constant in estimating yield changes due to changes in location.[8]

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[8]To show the reason for adopting these assumptions in estimating changes in yield due to changes in location, let subregion average yield (Y_{rt}) = b_r + ($\overline{X}_{rt}$) b, where b_r is the estimated coefficient for a dummy variable representing subregion r, $\overline{X}_{rt}$ is average level of technology or weather variable for subregion r, b is the estimated coefficient for this variable, (disturbance term was omitted for simplicity).

Then, $L_t = \sum_{r=1}^{R} P_{rt}\, b_r + \sum_{r=1}^{R} P_{rt}\, \overline{X}_{rt}\, b$, where $P_{rt} = \dfrac{A_{rt}}{\sum_{r=1}^{R} A_{rt}}$

$$\Delta L_t = L_1 - L_o = \sum_{r=1}^{R} b_r\,(P_{r1} - P_{ro}) + \sum_{r=1}^{R} (P_{r1}\overline{X}_{r1} - P_{ro}\overline{X}_{ro})\, b,$$

and by having the above two assumptions, the second term on the right side becomes zero, and then:

$$\Delta L_t = L_1 - L_o = \sum_{r=1}^{R} b_r\,(P_{r1} - P_{ro})$$

$$= \sum_{r=1}^{R} b_r\, P_{r1} - \sum_{r=1}^{R} b_r\, P_{ro}$$

$$= \frac{\sum_{r=1}^{R} b_r\, A_{r1}}{\sum_{r=1}^{R} A_{r1}} - \frac{\sum_{r=1}^{R} b_r\, A_{ro}}{\sum_{r=1}^{R} A_{ro}}$$

ΔL_t = the change in the weighted average location effect over t, where t = 1939 or 1944, 1949, 1956, 1959.

The results for the weighted average effects of shifts in location over time on the national average yield are summarized in Table 14.

The second column in Table 14 indicates that these weighted average effects of changes in location of production over successive years were positive. These positive effects of shifts in the location of production on national average yield imply that cotton acreages have been moving toward higher yielding areas over the period of 1939 to 1959. More specifically, the third column in Table 14 indicates that the shifts in location of production over the period (1939-59) have increased the national average yield per acre by 42 pounds. Since the actual increase in the national average yield per acre over the same period (1939-59) was 223 pounds, then 19 percent of this increase in the national average yield was due to the shifts in the location of production toward higher yielding counties.

For comparative purposes, another method was used to measure the effect of shifts in the location of production among states rather than among counties.

Shifts in location of production among states: The method used here was independent of the previous multiple

Table 14. The Weighted Average Effects Upon Cotton Yields of Shifts in Production Among Counties [a]

(in pounds per acre)

Year	(L_t) Weighted Average Location Effects	($\Delta L_t = L_1 - L_o$) Changes in Weighted Average Location Effect Over Successive Years	($L_{1959} - L_{1939}$) Changes in Weighted Average Location Effect Over 1939-59
1939	-26.7		
		4.8	
1944	-21.9		
		17.6	
1949	-4.3		42.0
		10.8	
1954	6.5		
		8.8	
1959	15.3		

[a]These were estimated by using the following equations:

$$L_t = \frac{\sum_{r=1}^{R} b_r A_{rt}}{\sum_{r=1}^{R} A_{rt}} \quad \text{, and}$$

$$\Delta L_t = L_1 - L_o = \frac{\sum_{r=1}^{R} b_r A_{r1}}{\sum_{r=1}^{R} A_{r1}} - \frac{\sum_{r=1}^{R} b_r A_{ro}}{\sum_{r=1}^{R} A_{ro}}$$

Where b_r = the estimated regression coefficient for the dummy variable representing subregion r as shown in Table 11, and r=1, 2, ..., 31.

A_{rt} = the cotton acreage harvested in subregion r in year t.

L_t = the weighted average location effect in year t.

ΔL_t = change in the weighted average location effect over time.

regression models.[9] Data on cotton acreages and yields by states from 1937 to 1961 were used as source material for this method.[10] These data were used to obtain weighted averages for 1939, 1944, 1949, 1954, and 1959 (1937-41 averaged for 1939, and 1942-46 averaged for 1944, etc.). Thus, there were available, by states, five sets of averages for acreage, and five for yield. State by state, each of the five acreage figures was multiplied by each of the five yield averages--a total of twenty-five combinations. The results for each of these twenty-five combinations were summed and standardized by being divided by the sum of corresponding acreages. It is obvious that the effect of shifts in the location of production by using this method was confounded with the effects of all other factors influencing yields, particularly weather factors. Therefore, five year averages for yield were used to smooth out (approximately) the annual weather effect.

The method used here to measure the effect of shifts in location of production among states can be summarized in the following equation:

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[9]This method has been used by Johnson and Gustafson in their study, op. cit.

[10]Data on Cotton acres and yields by states were obtained from: U.S.D.A., Agriculture Statistics, 1938-1962.

$$Y^*_{t,\acute{t}} = \frac{\sum_{s=1}^{S} Y_{st} A_{s\acute{t}}}{\sum_{s=1}^{S} A_{s\acute{t}}}$$

$\sum_{s=1}^{S}$ = the summation over all states, s=1, 2, ..., S, and S=15.

Y_{st} = yield per acre in state s in period t.

$A_{s\acute{t}}$ = acreage in state s in period $\acute{t}$.

$t, \acute{t}$ = census years; 1939 or 1944, 1949, 1954, 1959--t represents census years for state yield figures, and $\acute{t}$ represents census years for state acreage figures.

$Y^*_{t,\acute{t}}$ = calculated national average yield, assuming no change in state acreage distribution over time--by moving across the columns of Table 15-A or assuming no change in state yield over time--by moving across the rows of the same table.

The results of using the above method are reported in Table 15-A. By moving across a row in Table 15-A, yield is held constant and the differences in the national average yield are due to different acreage distributions. These differences are listed in Table 15-B.

Each of the different rows in Table 15-A and 15-B indicates that the change in distribution of cotton acreage among

Table 15-A. The Calculated National Average Yield[a] of Cotton Using Different Acreage Distributions for Weights, 1939-59.

(in pounds per acre)

Yields Used	Acreage distribution used				
	1939	1944	1949	1954	1959
1939	246	250	257	264	267
1944	258	262	265	269	270
1949	269	272	280	289	292
1954	329	333	343	354	359
1959	399	403	419	433	440

[a]The calculated national average yield is what the average yield in year t would have been if acreage distribution in year t had prevailed. The calculated national average yield is:

$$Y^*_{t,\acute{t}} = \frac{\sum_{s=1}^{S} Y_{st} A_{s\acute{t}}}{\sum_{s=1}^{S} A_{s\acute{t}}}$$

s = 1, 2, ..., 15 states; $t, \acute{t}$ = 1939, 1944, 1949, 1954, or 1959.

$A_{s\acute{t}}$ = acreages in state s year $\acute{t}$; Y_{st} = yield in state s year t.

$Y^*t,\acute{t}$ = calculated national average yield.

Table 15-B. The Estimated Effect of Shifts in Location of Production Among States on the National Average Yield of Cotton Per Acre Over Time, 1939-59. [a]

(in pounds per acre)

Yields Used	Interval				
	1939-44	1944-49	1949-54	1954-59	1939-59
1939	4	7	7	3	21
1944	4	3	4	1	12
1949	3	8	9	3	23
1954	4	10	11	5	30
1959	4	16	14	7	41

[a]Derived from Table 15-A.

the states had the effect of increasing the national average yield. In the fifth row in Table 15-A, for example, yield is held constant at the 1959 level and the state acreage distributions change over time. This shift in acreages among states has resulted in an increase in the national average yield from 399 pounds in 1939 to 440 pounds in 1959. (Note however, that the actual yield using the actual acreage distribution was 246 pounds for the five year period centering on 1939.)

Thus, on the basis of the calculations used in this method, it appears that the change in the distribution of cotton acreages among the states had the effect of increasing the national average yield over the period 1939-59 by 41 pounds compared with average yield in 1959. Since the actual increase in the national average yield over the same period was 223 pounds, then about 18 percent of this increase in the national average yield was due to the shifts in the location of production toward higher yielding states. Needless to say, this figure (18.4 percent) is almost equal to that (18.8 percent) obtained from the other procedure for estimating the consequences of shifts among counties.

An additional purpose for using the above method of measuring the effects of shifts in the location of production among states was to show how the national average yield would have changed due to the influences that affected yields in each of the states if the distribution of acreages among various states had not changed over time. In other words, if cotton acreages had remained constant in each and every state, how much effect would the other factors (technical, economic, and weather factors) have had on the national average yield? The information relevant to this question is also found in Table 15-A. By moving across a column in Table 15-A, acreage is held constant so that the differences in the national average yield are due to all factors (affecting yields) other than the shifts in location of production. These differences are listed in Table 15-C. In the first column (Table 15-C), the acreage distribution is held constant at the 1939 acreages by states while the yields are

Table 15-C. The Estimated Effects of Factors (Influencing Yields) on the National Average Yield of Cotton, Holding Acreage Constant, 1939-59. [a]

(in pounds per acre)

Interval	Acreage distribution used				
	1939	1944	1949	1954	1959
1939-1944	12	12	8	5	3
1944-1949	11	10	15	20	22
1949-1954	60	61	63	65	67
1954-1959	70	70	76	79	81
1939-1959	153	153	162	169	173

[a]Derived from Table 15-A.

allowed to change in each state in accordance with the actual changes that did occur. Then, if the 1939 acreage distribution had been maintained, the national average yield would have increased by 153 pounds. This is a smaller increase, by 70 pounds, than the actual increase. If the 1959 acreage distribution had existed throughout the whole period, the national average yield would have increased by 173 pounds, which is less than the actual increase. Also, if 1944 or 1949, 1954 acreage distribution had existed throughout the whole period, the national average yield would have increased by less than the actual increase.

Thus, on the basis of the above calculations, it is quite obvious that the shifts in location of production among states over time have generally increased the national average yield.

In the next section of this chapter, the relative importance of this increase in the national average yield, due to the shifts in location of production toward higher yielding areas, will be considered in some more detail.

Summary

After the above long presentation of the results, factor by factor influencing cotton yields, it seems helpful to put them together to show the relative importance of these factors on past changes in the national average yield. In other words, it is useful to show how much of the increases in the national average yield over time were attributed to technology advance, how much to favorable weather, and how much to the shifts in location of production toward higher yielding areas.

The estimated regression coefficients for all different technical, economic, weather, time, and location factors, as shown in Tables 11 and 12, were used to answer the above questions. The way in which these coefficients were used was as follows: the average levels of each factor by years were estimated. Then, by multiplying this average for each factor in a specific year by its estimated coefficient, the calculated average effect of that factor on the national average yield in that year was obtained. These calculated average effects for all different factors are presented in Table 16. Moreover, by subtracting the calculated average effect of a factor in a specific year from that in the following year, the calculated average effects of change in the level of such factor over time on the national average yield were obtained. These calculated average effects of changes in the levels of factors, over time, on the national average yield are reported in Table 17.

Table 17 indicates that changes in all technical and economic factors (except man-hours of labor) over the whole period of study (1939-59) had positive effects on the national average yield. Particularly, fertilizer and changes in value of land had fairly large positive relationships. An increase of 51.7 pounds in the national average yield was imputed to more use of fertilizer and 19.6 pounds is associated with the changes in land value. Also, an increase of 5.1 pounds was attributed to the extent of mechanization (as measured by dollars spent on gas and oil), and 7.5 pounds to economies of scale (as measured by the average size of cotton farm).

Man-hours of labor used per cotton acre was the only technical factor which had a negative effect on the national average yield. This negative effect was related with a substantial decrease in the amount of man-hours of labor

Table 16. The Calculated Average Effects of Factors on the National Average Yield of Cotton Per Acre, 1939-59.[a] (in pounds per acre)

Factors	Years 1939	1944	1949	1954	1959
A. Technology-Economic					
1. Gas-oil	1.4	2.2	5.5	5.2	6.5
2. Man-hours	70.9	62.6	54.6	51.1	48.0
3. Nutrients	20.9	26.7	32.7	55.5	72.6
4. Size	10.7	12.1	19.8	17.4	18.2
5. Ratio	-0.001	-0.001	-0.001	-0.001	-0.001
6. Value	16.1	17.1	21.1	25.7	35.7
Total	120.0	120.7	133.7	154.9	181.0
B. Time	---	33.8	-17.5	10.5	101.9
C. Weather	-159.0	-151.5	-159.9	-144.2	-167.9
D. Location	-26.7	-21.9	-4.3	6.5	15.3

[a]These calculated average effects for all factors (except location factor) are actually products of the average level of each of these factors in a specific year and its estimated regression coefficient (as shown in Table 11, 12). For the location factor, they are:

$$L_t = \frac{\sum_{r=1}^{R} b_r A_{rt}}{\sum_{r=1}^{R} A_{rt}}$$

r = 1, 2, ..., 31 subregions; t = 1939, 1944, 1949, 1954, or 1959

A_{rt} = acreages in subregion r year t; b_r = estimated coefficient in subregion r (as shown in Table 11).

Table 17. The Calculated Average Effects on Cotton Yields of Changes in the Levels of Factors, for Indicated Periods, 1939-59. [a]

(in pounds per acre)

	Interval				
	1939-44	1944-49	1949-54	1954-59	1939-59
A. Technology-Economic					
1. Gas-oil	0.8	3.3	-0.3	1.3	5.1
2. Man-hours	-8.3	-8.0	-3.5	-3.1	-22.9
3. Nutrients	5.8	6.0	22.8	17.1	51.7
4. Size	1.4	7.7	-2.4	0.8	7.5
5. Ratio	0.0	0.0	0.0	0.0	0.0
6. Value	1.0	4.0	4.6	10.0	19.6
Total	0.7	13.0	21.2	26.1	61.0
B. Years	33.8	-17.5	10.5	101.9	128.7
C. Weather	7.5	-8.4	15.7	-24.7	-9.9
D. Location	4.8	17.6	10.8	8.8	42.0
Total	46.8	4.7	58.2	113.1	221.8

[a]Derived from Table 16.

used per cotton acre. A decrease of 22.9 pounds in the national average yield was imputed to the decrease in man-hours of labor used per cotton acre over time.

Table 17 also indicates that the net effects of technology as a whole have increased the national average yield over time (1939-59) by 61.0 pounds. This represents 27.4 percent of the actual increase in the national average yield over the same period. Moreover, it is apparent that the major increase in the national average yield as the results of the technology advance has occurred after 1949. In other words, over the period (1939-49) the technology advance increased the national average yield by only 13.7 pounds, while over the following period (1949-59) it increased such yields by 47.3 pounds.

Concerning the effect of shifts in the location of production, Table 17 shows that this effect has been positive over time, indicating that acreages have been moving toward higher yielding areas. Also, an increase of 42 pounds in the national average yield was imputed to the shifts in the location of production toward higher yielding areas. This increase of 42 pounds in the national average yield due to the shifts in location of production represents about 19 percent of the actual increase.

For weather factors, the net effect of changes in these factors as a whole over time had a minor influence on the national average yield. Over the period 1939-59, a decrease of only 9.9 pounds in the national average yield was attributed to unfavorable weather.

By considering the calculated effects of time factors, i.e., the effects of those which were not explicitly included in the regression analyses and were related to time, Table 17 indicates that a 128.7 pound increase in the national average yield was associated with changes in time. A word of caution should be added in the interpretation of these calculated time effects. Time is actually a residual. It represents an increase in the national average yield which was not explained by the regression equations. Then, the explained variation (increase) in the national average yield by the regression equations was less than 50 percent of the actual variation (increase) in yields. Moreover, the unexplained variation measured by time factors cannot be attributed to specific factors. This may be the result not only of other technical and economic factors but also of other weather factors or any other factor not explicitly considered in the regression analyses.

In short, the actual increase in the national average yield over the period 1939-59 was 223 pounds. The explained variation (increase) in the national average yield by the regression equations is as follows: sixty-one pounds of the increase was imputed to changes in the levels of technical and economic factors. Forty-two pounds of the increase was attributed to the shifts in location of production toward higher yielding areas. Measured weather factors by themselves accounted for a 9.9 pound reduction in the national average yield. On the other hand, a 129.9 pound increase in the national average yield was left unexplained in the national regression model. However, it appears that a major proportion of this unexplained variation (increase) in the national average yield was associated with changes in the levels of factors related with time such as price of cotton, improvement in seed varieties and insect control.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The main objective of this study was to analyze the relative importance of factors related to past changes (1939-59) in cotton yields. The factors considered were weather, fertilizer, mechanization, labor, value of land and buildings, shifts in location of production, irrigation and the price of cotton.[1]

Regression techniques employing a quadratic function of time to represent monthly weather data were the tools for the analyses. A combination of time series and cross-sectional data were used, with the basic unit of observation being the county in census years 1939, 1944, 1949, 1954 and 1959. A sample of 258 counties was randomly selected to represent the entire U. S. cotton area. Three levels of analyses were applied, i.e., state, regional and national levels.

Generally, the statistical analyses yielded coefficient signs which would be expected, from an economic and technical point of view. However, the regional analyses were generally

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[1]The last two factors were dropped from the analyses because of certain statistical problems. These problems were discussed earlier in Chapter III.

superior to those at the state level and at the national level from the standpoint of the size and the statistical significance of the estimated coefficients. Moreover, the regression results for technical and economic factors obtained from the regional analyses were more consistent internally and more meaningful in terms of the technical and economic expectations than those obtained from either state or national analyses. The results for weather variables, particularly for rainfall, from regional analyses were consistent region to region.

In the state analyses' results, the main problem was the different signs and sizes of estimated coefficients for the same factor in different states. This problem appears to have been caused by the following factors: (a) the existence of a multicollinearity problem among some variables used in the analyses, (b) the aggregative nature of the values used for some technical factors, and (c) too small a variation among observations associated with a state to provide reliable estimates. In other words, some states might have substantial homogeneity such as to prevent sufficient variability among observations for each variable, this tending to reduce the possibility of making reliable estimates.

For the national analysis, the coefficient of multiple determination was smaller[2] than that for regional or state

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[2] R^2 for the national analysis is 0.3658.

analyses,[3] indicating some heterogeneity in relationships among the cross-sectionally combined states.

At the state level, fifteen analyses were made. The variables used in the state regression models explained 46 to 84 percent of the variation in cotton yield increases. The results from the state analyses show that there were substantial differences among states in the cotton yield increases attributable to different factors. For technical and economic factors, the effects of mechanization on yields tended to be more pronounced in the Southwestern and Western Irrigated States than in the other states. At the same time, the size of cotton farms had more effect on yields in the Southwestern and Western Irrigated States. In contrast, labor was less used in the Southwestern and Western Irrigated States than in the other states. The results are consistent with the hypothesis that mechanization is a substitute for labor in the Southwestern and Western states to a greater degree than in other states. Fertilizer tended to have a major effect on yields in all states except Oklahoma and Texas. And, higher values of land and buildings were more associated with yield increases in all non-irrigated states than in the irrigated states. In the case of weather factors, monthly total rainfall during the growing season had

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[3] R^2 for the regional analyses is ranged from 0.5296 to 0.6776, and for the state analyses is ranged from 0.5240 to 0.8418 (except for E. Texas is 0.4553).

a high negative effect in most of the relatively humid states, particularly North Carolina and Tennessee, but a highly positive effect in most of the relatively arid states which are not irrigated, namely Oklahoma and Texas. Monthly average temperature had more effect (either negative or positive) in the Southeastern and Delta states than in the other states.

Four regional analyses were made, one each for the Southeastern, the Delta, the Southwestern, and Western Regions. Grouping the counties which presumably have a relative homogeneity of production techniques, weather, soil, topography and climate, into a region, increases the observations associated with each analysis substantially, and this increase in degrees of freedom could lead to more reliable estimates. Thus, this aggregative attribute of regional analyses might result in sufficient variability among the observations within a region to permit making reliable estimates.

However, the results of regional analyses did not completely conform to these expectations. Among regions, there were substantial differences in the cotton yield increases attributable to different factors. For technical and economic factors, mechanization had more effect in the Western and Southwestern Regions than in the Southeastern and Delta Regions. Similarly, the larger size of cotton farm was more related with an increase in yields in the former regions than in the latter regions. Since, the variable of cotton farm size was used to measure the effect of a shift to more specialized equipment, it appears that the extent of mechanization in the Southwestern and Western Regions was associated with shift to more specialized equipment. In contrast, labor had less influence in the Southwestern and Western Regions than in the other two regions. Fertilizer had a major effect in all regions except the Southwest. And, the value of land and buildings was more closely related to an increase in yields in the Southeastern, Delta and Southwestern Regions than in the Western Irrigated Region. But, the effect on yields of a relative change in cotton acreage in a year compared to 1939 was virtually zero for all regions.

The results for weather variables, rainfall in particular, were consistent among different regions. The analyses show that monthly total rainfall variable was most beneficial in all regions in the early part of the season, was most injurious in the middle of the season, particularly June to September, then was slightly damaging in November in the Southeastern and Western Regions, and relatively beneficial in the Delta and Southwestern Regions. Monthly rainfall-temperature interactions were slightly injurious to cotton yields in all regions at the beginning of the season and changed gradually to become relatively beneficial at the end of the season, according to the statistical analysis. Successive month rainfall interactions positively affected cotton yields during the beginning of the season in the

Southeastern and Western Regions, and turned negative as the season advanced. In the Southwestern Region, these successive month rainfall interactions were slightly negative at the beginning of the season and turned positive at the end of the season. In the West, the effects of these interactions were positive throughout the whole season. The calculation of marginal effects for rainfall on cotton yields indicates that these effects were generally similar in all non-irrigated regions. The marginal effects for rainfall in March were positive in the Southeastern and Delta Regions and negative in the Southwestern Region, and became negative in all non-irrigated regions during the following two months. In July, these marginal effects for rainfall turned positive in all non-irrigated regions, and increased as the season advanced to have the largest values at the end of the season. The pattern of the marginal effects for rainfall in the Western Irrigated Region was very different from that in the non-irrigated regions. In the Western Irrigated Region, the marginal effects for rainfall were most beneficial at the beginning of the season, reduced gradually to be highly negative for July-August, and turned up to become relatively negative in November. Moreover, the results for the temperature variables were relatively consistent from one region to the other, but were not as consistent as the results obtained for rainfall variables. The coefficients for monthly average temperature variable were negative throughout the entire season in the Delta Region, with large values for the planting period and smaller values at the end of the season. In the Southeast, these coefficients were highly positive for the early part of the season, and then reduced gradually to become negative for September to November. In the Southwest, these effects of monthly average temperature were positive during the whole season with largest values for June. But, in the Western Region these effects have a different pattern. They were relatively negative for March and April, then slightly positive during five months, and became negative for October and November. The marginal effects for temperature on cotton yields were generally similar in the Southeastern, Delta, and Western Regions. In these three regions, the marginal effects for temperature were unfavorable during the planting and harvesting time, and were favorable in the middle of the season with largest values for June. In the Southwestern Region, the marginal effects for temperature were slightly positive in March, and reduced gradually to be highly negative at the end of the season.

At the national level, data for 258 counties were included into the analyses. Statistically, the prime motivation for the national analyses was the potential improvement of the estimates through taking into account a wider range of variation in the variables as well as the gain in degrees of freedom. At the same time, an economic and policy justification for making the national analyses is to understand better the relationships (between cotton yields and related factors on the national level) so that appropriate policy can be undertaken.[4]

The results for the national analyses imply that changes in all technical and economic factors (except man-hours of labor) over the period 1939-1959 had positive effects on the national average yield.

Fertilizer in particular, and the change in the value of land and buildings had fairly large positive relationships with the increase in yields. An increase of 51.7 pounds in the national average yield was imputed to more use of fertilizer and 19.6 pounds was associated with the changes in land value. These results for the effect of fertilizer on the national average yield are somewhat consistent with those obtained by Heady and Auer in their study of the imputation of production to technologies. Heady and Auer found that an increase of 41.8 pounds in the national average yield per cotton acre over the period 1930-1960 was imputed to more use of fertilizer.[5] Concerning the results for land value, the high positive relationships between the increase in land value and the increase in

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[4]Also, as a citizen of Egypt, the writer has an interest in understanding better the macro-economic relationships that exist within the cotton sector of a major competing nation.

[5]Heady and Auer, op. cit., p. 319.

cotton yields indicate that the better yielding cotton land has benefitted with higher prices. Moreover, an increase of 5.1 pounds was attributed to the extent of mechanization, and 7.5 pounds to economies of scale. Decreases in man-hours of labor used per cotton acre were the only changes in technical and economic factors which had a negative effect on the national average yield. Actually, this negative effect was related with a substantial decrease in the amount of man-hours of labor used per cotton acre. A decrease of 22.9 pounds in the national average yield was imputed to the decrease in man-hours of labor used per cotton acre over time.

The shifts in location of production positively affected the national average yield indicating that acreage has been moving toward higher producing areas. An increase of 42 pounds in the national average yield was imputed to the shifts in the location of production toward higher yielding areas.

The measured effect of changes in weather factors as a whole over time had a minor influence on the yields. Over the period 1939-59, a decrease of only 9.9 pounds in the national average yield was attributed to unfavorable weather.

Furthermore, for time related factors, i.e., the factors which presumably affected the yields and were related to changes in time, a 128.7 pound increase in the national average yield was indicated.

Actually, these findings on past changes in yield have implications for future policy decisions. Also, the possibilities for a further increase in cotton yields can be assessed from the results of these analyses of past increases, and, these possibilities may provide important implications for agricultural policy.

On the basis of the results obtained from this study, it is apparent that the increase in cotton yields over the period 1939-59 was mainly imputed to three major factors. These factors are: (a) increased use of fertilizer, (b) shifts in location of production toward higher yielding areas, i.e., toward irrigated areas, and (c) time related factors.

The greater use of fertilizer in cotton production or for other crops, in the last three decades could be the result of a growing awareness by farmers of using this input.[6] Moreover, Griliches in his study of the demand for fertilizer, concluded that the increased use of fertilizer in U.S. agriculture could be largely explained by the decline in the real price of fertilizer.[7] The real price of fertilizer is simply the price of fertilizer divided by the price of farm crops.

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[6] M. I. Petit, "Econometric Analysis of Feed-Grain Livestock Economy," (unpublished Ph.D. Thesis, Michigan State University, 1964).

[7] Z. Griliches, "The Demand for Fertilizer: An Economic Interpretation of a Technical Change," Journal of Farm Economics, Vol. 40 (August, 1958), 591-606.

Over the period (1920-29) to (1950-59), the absolute price of fertilizer has risen by less than 14 percent, and the price of fertilizer relative to the price of cotton has fallen by more than 30 percent.[8] Then, if the decline in the relative price of fertilizer to cotton continues, one could expect more increase in fertilizer use, or the same result may occur if farmers continue to learn more about the use of fertilizer, even if the relative price of fertilizer does not decline further.

Concerning the shift in the location of production, this was mostly toward Western irrigated areas with high yielding land. If this shift in location of cotton production continues toward these Western irrigated lands, and if some of the new irrigated lands are devoted to cotton, one can expect that the expansion of irrigation will lead to a further increase in cotton yields. But, the expansion of the irrigated land will generally depend on a number of political and economic factors. In other words, the governmental development of the irrigated land will mainly be determined by political factors, but the private development will mostly be determined by economic factors and policy decisions on allotments. Wooten and Anderson, for example, have estimated that about 6 million acres of new irrigated

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[8]These figures were derived from data obtained from: U.S.D.A., Agriculture Statistics, 1945 and 1966.

land might be developed between 1954 and 1975.[9] Again, if the location of cotton production continues to shift toward these western areas, and if some part of these new expected irrigated lands are devoted to cotton, one could expect a further increase in cotton yields.

Furthermore, time related factors, particularly changes in cotton prices, improvement in production techniques, improvement in seed varieties and insect control seem likely to continue to have major effects. For cotton prices, changes in these prices may lie behind changes in technology and some changes in the location of production. Over the period 1930-39 to 1950-59 the absolute price of cotton rose by about 255 percent.[10] For other related factors, i.e., improvement in production techniques, seed varieties and insect control, one can expect further improvement in these factors as the result of continuing research activities of the federal and state governments and of private firms.

The major part of past increase in cotton yields can be attributed to changes in some technical and economic factors. Since it seems probable that such relationships will continue and dominate, then, to keep cotton production

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[9] H. H. Wooten and J. R. Anderson, <u>Agricultural Land Resources in the United States</u>, U.S.D.A., Agr. Inf. Bul. No. 140, 1955.

[10] This figure was derived from data obtained from: U.S.D.A., Agriculture Statistics, 1955 and 1966.

at the present level, further consideration should be given to different policies of production control. The use of policies which cut back cotton acreage is likely to require progressively more acreage reduction to attain the same production cutback. Moreover, even past acreage reductions as a form of production control do not seem to have been very effective. Allotment programs do not always control production. With acreage restricted, farmers tend to step up the use of yield-increasing practices. In this respect, Hathaway argues:

> The inability of acreage reductions to control the output of the specific crop rests largely upon the fact that land is only one input, and not a major one at that, for most crops. There are other inputs which are substitutes for land in crop production. Moreover, for most of these substitutes--fertilizers, irrigation, improved seed, insecticide, etc.--their marginal value product already exceeds their acquisition cost at recent price levels. Therefore, with acreage allotments and unlimited price supports there is a powerful dual incentive to use new inputs to maintain or increase crop output on the reduced acreage.[11]

In spite of these problems, acreage reductions as a form of production control have persisted; further procedures to make acreage reduction more effective seem to be required. Analytically, it seems clear that other forms of production control need further consideration. Some

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[11] D. E. Hathaway, Government and Agriculture, Public Policy in Democratic Society (New York: The MacMillan Company, 1963), pp. 297-298.

possibilities include rationing of yield-increasing inputs (such as fertilizer) or a reduction in public-supported, yield-increasing expenditures (such as reclamation projects, fertilizer, lime, tiling and irrigation). Another possibility is direct volume control, i.e., specific level of yield per acre. This yield control might be different from state to state according to the historical yield level of each state. The writer recognizes that a variety of political forces are involved in each of the above alternatives. It is not appropriate to discuss them. Moreover they are beyond the scope of this thesis.

At this point, it should be pointed out that, as this study progressed, the need for further research in several areas became evident. For instance, further research is required to analyze the effect of different forms of production control on cotton yields, the effect of these forms of control on yields of other crops, and the effect of other factors which may lie behind this dynamic increase in cotton yields, such as the improvement in seed varieties and insect control.

Moreover, the results for national analyses in this study call attention to the need for further analysis in which only non-irrigated states would be included, rather than joining together all non-irrigated and irrigated states. The national analysis presented in this thesis has indicated some heterogeneity in relationships among these states, probably because of combining non-irrigated and irrigated states.

The results obtained in attempting to use prices as a factor affecting yields were not satisfactory because of certain statistical problems. Research is needed which would resolve these problems and thus provide a better understanding of the relationships between cotton prices, cotton yields and the aggregate level of production.

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APPENDICES

APPENDIX A

THE DATA: SOURCES AND ESTIMATION METHODS OF MISSING DATA

The Dependent Variable:

A. County Average Yield per Harvested Acre (in Pounds):

The values for this variable were obtained by multiplying the ratio of cotton production (in bales) for a county to the total acres of cotton harvested in that county by 478 pounds. The data for cotton production and acreage were obtained from U.S.D.A., Census of Agriculture 1939, 1944, 1949, 1954, and 1959, as shown in Table A-1.

The Independent Variables:

A. Technology Variables:

a. Dollars Spent on Gas and Oil per Acre:

These values were obtained as the ratio of total dollars spent on gas and oil in a county to the total acres of cropland harvested in that county. And then, these values were deflated by the index of average prices paid by farmers for motor supplies. The sources of data for dollars spent on gas and oil, and for total acres of cropland harvested, are shown in Table A-1. The data for index of average prices paid by farmers for motor

Table A-1: Sources of Data on Cotton Production and Acreages, Number of Cotton Farms, Value of Land, Number of Tractors, and Dollars Spent on Gas and Oil.

State	U.S. Census of Agr.	Vol. and Part Nos.	County Table Number for: Cotton Production, Acreage, No. Farms	Value of Land	Total Harvested Acres	No. of Tractors	$ Spent on Gas and Oil
1.North Carolina	1939	1,16	7	1	1	10	10
	1944	1,16	2	1	1	1	a
	1949	1,16	5	1	1	3	3
	1954	1,16	9	1	1	5	6
	1959	1,26	11	1	1	6	7
2.South Carolina	1939	1, 3	7	1	1	10	10
	1944	1,16	2	1	1	1	a
	1949	1,16	5	1	1	3	3
	1954	1,16	9	1	1	5	6
	1959	1,27	11	1	1	6	7
3.Georgia	1939	1, 3	7	1	1	10	10
	1944	1,17	2	1	1	1	a

. . . continued

Table A-1 (continued)

State	U.S. Census of Agr.	Vol. and Part Nos.	County Table Number for: Cotton Production, Acreage, No. Farms	Value of Land	Total Har- vested Acres	No. of Trac- tors	$ Spent on Gas and Oil
3.Georgia (cont.)	1949	1,17	5	1	1	3	3
	1954	1,17	9	1	1	5	6
	1959	1,28	11	1	1	6	7
4.Alabama	1939	1, 4	7	1	1	10	10
	1944	1,21	2	1	1	1	a
	1949	1,21	5	1	1	6	7
	1954	1,21	9	1	1	5	6
	1959	1,32	11	1	1	6	7
5.Mis- souri	1939	1, 2	7	1	1	10	10
	1944	1,10	2	1	1	1	a
	1949	1,10	5	1	1	3	3
	1954	1,10	9	1	1	5	6
	1959	1,17	11	1	1	6	7

. . . continued

Table A-1 (continued)

State	U.S. Census of Agr.	Vol. and Part Nos.	County Table Number for: Cotton Production, Acreage, No. Farms	Value of Land	Total Harvested Acres	No. of Tractors	$ Spent on Gas and Oil
6. Arkansas	1939	1, 5	7	1	1	10	10
	1944	1,23	2	1	1	1	a
	1949	1,23	5	1	1	3	3
	1954	1,23	9	1	1	5	6
	1959	1,34	11	1	1	6	7
7. Tennessee	1939	1, 4	7	1	1	10	10
	1944	1,20	2	1	1	1	a
	1949	1,20	5	1	1	3	3
	1954	1,20	9	1	1	5	6
	1959	1,31	11	1	1	6	7
8. Mississippi	1939	1, 4	7	1	1	10	10
	1944	1,22	2	1	1	1	a
	1949	1,22	5	1	1	3	3

. . . continued

Table A-1 (continued)

State	U.S. Census of Agr.	Vol. and Part Nos.	County Table Number for: Cotton Production, Acreage, No. Farms	Value of Land	Total Harvested Acres	No. of Tractors	$ Spent on Gas and Oil
8. Mississippi (cont.)	1954	1,22	9	1	1	5	6
	1959	1,33	11	1	1	6	7
9. Louisiana	1939	1, 5	7	1	1	10	10
	1944	1,24	2	1	1	1	a
	1949	1,24	5	1	1	3	3
	1954	1,24	9	1	1	5	6
	1959	1,35	11	1	1	6	7
10. Oklahoma	1939	1, 5	7	1	1	10	10
	1944	1,25	2	1	1	1	a
	1949	1,25	5	1	1	3	3
	1954	1,25	9	1	1	5	6
	1959	1,36	11	1	1	6	7

. . . continued

Table A-1 (continued)

State	U.S. Census of Agr.	Vol. and Part Nos.	County Table Number for: Cotton Production, Acreage, No. Farms	Value of Land	Total Har-vested Acres	No. of Trac-tors	$ Spent on Gas and Oil
11.Texas	1939	1, 5	7	1	1	10	10
	1944	1,26	2	1	1	1	a
	1949	1,26	5	1	1	3	3
	1954	1,26	9	1	1	5	6
	1959	1,37	11	1	1	6	7
12.New Mexico	1939	1, 6	7	1	1	10	10
	1944	1,30	2	1	1	1	a
	1949	1,30	5	1	1	3	3
	1954	1,30	9	1	1	5	6
	1959	1,30	11	1	1	6	7
13.Ari-zona	1939	1, 6	7	1	1	10	10
	1944	1,31	2	1	1	1	a

. . . continued

Table A-1 (continued)

State	U.S. Census of Agr.	Vol. and Part Nos.	County Table Number for: Cotton Production, Acreage, No. Farms	Value of Land	Total Harvested Acres	No. of Tractors	$ Spent on Gas and Oil
13. Arizona (cont.)	1949	1,31	5	1	1	3	3
	1954	1,31	9	1	1	5	6
	1959	1,43	11	1	1	6	7
14. California	1939	1, 6	7	1	1	10	10
	1944	1,33	2	1	1	1	a
	1949	1,33	5	1	1	3	3
	1954	1,33	9	1	1	5	6
	1959	1,48	11	1	1	6	7

[a] Data not available.

supplies were obtained from U.S.D.A. Stat. Bulletin No. 319 (1962) and are listed in Table A-2.

Table A-2: Index of Average Prices Paid by Farmers for Motor Supplies [a]

Years	Index of Average Prices Paid by Farmers for Motor Supplies, 1910-14 = 100
1939	102
1944	115
1949	146
1954	162
1959	173

[a]Source: U.S.D.A. Stat. Bul. No. 319, 1962.

As shown in Table A-1, the data for this variable were not available on either county or state level in 1944. However, the data for this variable on the national level have indicated that of the total change in dollars (current) spent on gas and oil over 1939-49, 22.93 percent have occurred by 1944.[1] By assuming that the change in dollars (current) spent on gas and

[1]U.S.D.A., ERS, Farm Income Situation, Table 17-H, p. 53, July, 1964.

oil in each county has changed in proportion to the change at the national level, then dollars (current) spent on gas and oil in a county for 1944 were estimated as follows: the dollars (current) spent on gas and oil in a county plus .2293 times the change in dollars (current) spent on gas and oil over 1939-49 in that county.

b. Man-Hours of Labor Used Per Cotton Acre:

The state average of pre-harvest and harvest man work units used per cotton acre was the value used for this variable, since the county average was not available. However, the data for this variable were obtained from the following sources:

For 1939: M. R. Cooper, W. C. Holley, H. W. Hawthorne, and R. S. Washburn, Labor Requirements for Crops and Livestock, U.S.D.A., Agrl. Econ., F.M. 40 (processed, 1943).

For 1949: R. W. Hecht and K. R. Vice, Labor Used for Field Crops, U.S.D.A., Stat. Bul. No. 144, 1954.

For 1959: Labor Used to Produce Field Crops, Estimates by States, U.S.D.A. Stat. Bul. No. 346, May, 1964.

Since the data for this variable for 1944 and

1954 were not available, then the average of 1939-49 was used for 1944, and the average of 1949-59 was used for 1954.

c. Pounds of Fertilizer Nutrients Applied per Cotton Acre:

The state average of fertilizer nutrients in pounds was the values used for this variable, since such data were not available on a county basis. However, the data for this variable were obtained from the following sources:

For 1949: Fertilizer Use and Crop Yields in the U. S., 1950 Estimates, U.S.D.A. Agrl. Handbook No. 68.

For 1954: Fertilizer Used on Crops and Pastures in the U. S.: 1954 Estimates, U.S.D.A., Stat. Bul. No. 216, 1957.

For 1959: Commercial Fertilizer Used on Crops and Pasture in the U.S.: 1959 Estimates, U.S.D.A., Stat. Bul. No. 348, 1964.

Since the data for this variable in 1939 and 1944 were not available, then the estimation method for obtaining these data can be summarized as follows:

1. Let the pounds of nutrients per cotton acre in state s in year 1949 = $N_{s,49}$. And the pounds of fertilizer per cotton acre in state s in year 1949 = $F_{s,49}$. Then, the ratio of $\frac{N_{s,49}}{F_{s,49}}$ gives the pounds of nutrients per pound of fertilizer as used on cotton in 1949.

2. Let the ratio of pounds of nutrients per pound of all fertilizer in state s in 1939 $= \frac{N_{s,39}}{AF_{s,39}}$ and in 1949 $= \frac{N_{s,49}}{AF_{s,49}}$.

3. By assuming that in each state, the change in pounds of nutrients per pound of cotton fertilizer was proportional to the change in pounds of nutrients per pound of all fertilizer over the period of 1939-49, i.e.,

$$\frac{\frac{N_{s,49}}{F_{s,49}}}{\frac{N_{s,39}}{F_{s,39}}} = \frac{\frac{N_{s,49}}{AF_{s,49}}}{\frac{N_{s,39}}{AF_{s,39}}}$$

$$\text{Then } N_{s,39} = F_{s,39} \cdot \frac{N_{s,49}}{F_{s,49}} \cdot \frac{\frac{N_{s,39}}{AF_{s,39}}}{\frac{N_{s,49}}{AF_{s,49}}}$$

4. And by the same procedure in case of 1944, then

$$N_{s,44} = F_{s,44} \cdot \frac{N_{s,49}}{F_{s,49}} \cdot \frac{\dfrac{N_{s,44}}{AF_{s,44}}}{\dfrac{N_{s,49}}{AF_{s,49}}}$$

d. Average Size of Cotton Enterprise in Acres: These values were obtained by taking the ratio of total number of cotton acres in a county to the total number of farms harvesting cotton in that county. The sources of data for cotton acres and number of farms are as shown in Table A-1.

e. Ratio of Cotton Acreage in a Year to that in 1939: The total acres of cotton harvested in a particular year in a county to that in the base year (1939) in that county were the values used for this variable.

f. Value of Land and Buildings per Acre: The values of land and buildings per acre (in current dollars) were obtained as reported in the U. S. Census of Agriculture. And then, these values were deflated by the consumer price index. The data for consumer price index were obtained from Business Statistics, 1961 Biennial Edition

of the U.S.D. of Labor, Bureau of Labor Statistics, and are listed in Table A-3.

Table A-3: Consumer Price Index[a]

Years	Consumer Price Index (1947-49 = 100)
1939	59.4
1944	75.2
1949	101.8
1954	114.8
1959	124.6

[a]Source: Business Statistics, 1961 Biennial Edition of U.S.D.L., Bureau of Labor Statistics.

g. Number of Tractors per 1000 Acres of Harvested Cropland:

The values for this variable were obtained by taking the ratio of total number of tractors in a county to 1000 acres of harvested cropland. The sources of data for total number of tractors and acres of harvested cropland are as shown in Table A-1.

h. Proportion of Cotton Acreage Irrigated:

The values for this variable were obtained by taking the ratio of cotton acreage irrigated in

a county to the total cotton acreage in that county. The sources of data on cotton acreage irrigated are reported in Table A-4.

As shown in Table A-4, the data for cotton acreage irrigated in 1944 by counties were not available. However, state totals of irrigated land were obtained from the 1949 U. S. Census of Agriculture, Vol. 1, Parts 30 for New Mexico, 31 for Arizona, and 33 for California. By assuming that the change in cotton acreage irrigated in each county had changed in the same proportion as the change in total acreage irrigated in the state, estimated cotton acreage irrigated in 1944 for a county was obtained as follows:

1. Let total acreage irrigated in 1939, 1944, and 1949 for the state = $I_{s,39}$, $I_{s,44}$, and $I_{s,49}$ respectively. And let cotton acreage irrigated in 1939, 1944, and 1949 for the county = $I_{c,39}$, $I_{c,44}$, and $I_{c,49}$ respectively.

2. Let $I_{s,49} - I_{s,39} = w$ and $I_{s,44} - I_{s,39} = z$.

3. Then, on the basis of the above assumption:

$$I_{c,44} = I_{c,39} + (z/w) \cdot (I_{c,49} - I_{c,39}).$$

Table A-4: Sources of Data on Cotton Acreage Irrigated

U.S. Census of Agr. for	New Mexico			Arizona			California		
	Vol. No.	Part No.	County Table No.	Vol. No.	Part No.	County Table No.	Vol. No.	Part No.	County Table No.
1939	1	6	15	1	6	15	1	6	15
1944	1	30	a	1	31	a	1	33	a
1949	1	30	5a	1	31	5a	1	33	5a
1954	1	30	9a	1	31	9a	1	33	9a
1959	1	42	11a	1	43	11a	1	48	11a

[a] Data not available.

i. <u>Percentage of Cropland Harvested in Cotton</u>:
The values of this variable were obtained by taking the ratio of cotton acreage in a county to total cropland harvested in that county and multiplying this ratio by 100. The sources of data on cotton acreage and cropland acres are shown in Table A-1.

j. <u>Prices of Cotton for Previous Season</u>:
The values of this variable were obtained as reported in U.S.D.A., Agriculture Statistics, 1941, 1946, 1951, 1956, and 1961.

B. <u>Weather Variables</u>:

The data for monthly total rainfall in inches and monthly average temperature in degrees of F. for selected weather stations were obtained from: <u>Climatological Data, by States, by Months</u>, Weather Bureau, U. S. Commerce Department, 1939, 1944, 1949, 1954, and 1959. The weather stations were selected according to the following criteria:

1. If there were more than one weather station in a county reporting rainfall and temperature, then the one at or near the center was selected for use in this study.

2. If there was only one weather station in a

county, then it was selected.

3. If there was none in a county, then the nearest weather station to that county was selected.

APPENDIX B

SELECTION COUNTIES AND WEATHER STATIONS

Table B-1. Selection Counties and Weather Stations in Each State Included in This Study[1]

Selected Counties[2]	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
I. North Carolina:					
1. Anson	Wadesboro	Wadesboro	Wadesboro	Albermarle of Stanly	Albemarle of Stantly
2. Bertie	Lewston	Lewston	Jackson of Northampton	Scotland Neck of Halifax	Scotland Neck of Halifax
3. Catawba	Hickory	Hickory	Hickory	Hickory	Hickory
4. Chowan	Edenton	Edenton	Edenton	Edenton	Edenton
5. Columbus	Whiteville	Whiteville	Whiteville	Southport of Brunswick	Southport of Brunswick
6. Duplin	Fasion	Fasion	Sloan 3 S	Sloan	Sloan
7. Edgecombe	Rocky Mount 8 ESE	Rocky Mount 8ESE	Tarboro	Tarboro	Tarboro
8. Iredell	Statesville 2 NNE	Statesville 2NNE	Statesville 1 W	Statesville	Statesville
9. Lincolin	Lincolnton 4 W	Lincolnton 4 W	Hickory of Catawba	Hickory of Catawba	Hickory of Catawba
10. Nash	Nashville	Nashville	Nashville	Nashville	Nashville
11. Northampton	Jackson	Jackson	Jackson	Enfield (near) of Halifax	Enfield (near of Halifax
12. Pitt	Greenville	Greenville	Greenville 2	Greenville	Greenville
13. Richmond	Hamlet	Hamlet	Cognac Exp. Farm	Weldon of Halifax	Weldon of Halifax
14. Sampon	Clinton 2 S	Clinton 2 S	Clinton	Clinton	Clinton

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
15. Stanly	Albermarle	Albemarle	Albemarle	Albemarle	Albemarle
16. Vance	Henderson 2 Sw	Henderson 2 Sw	Henderson 2 Sw	Henderson	Henderson
17. Wilson	Wilson 2 W	Wilson 2 W	Wilson	Wilson	Wilson
II. South Carolina:					
1. Abbeville	Calhoun Falls	Calhoun Falls	Calhoun Falls	Calhoun Falls	Calhoun Falls
2. Allendalle	Greenwood	Greenwood	Greenwood	Greenwood	Greenwood
3. Bamberg	Bamberg	Bamberg	Orangeburg 2 SE of Orangeburg	Orangeburg 2 SE of Orangeburg	Orangeburg of Orangeburg
4. Berkeley	Pinopolis Dam	Pinopolis Dam	Pinopolis Dam	Pinopolis Dam	Kingstree of Willismaburg
5. Chester	Chester 2 WSW	Chester 2 WSW	Chester	Chester	Chester
6. Darlington	Darlington	Darlington	Darlington	Darlington	Darlington
7. Dillon	Dillon 4 SW	Dillon 4 SW	Dillon 4 SW	Dillon	Dillon
8. Florence	Florence 2 N	Florence 2 N	Florence 2 N	Florence AP	Florence 1
9. Greenville	Caesars Head	Caesars Head	Caesars Head	Caesars Head	Caesars Head
10. Hampton	Hampton	Hampton	Yemassee 4 W	Yemassee	Yemassee
11. Jasper	Ridgeland 2 SE	Ridgeland 2 SE	Ridgeland 2 SE	Ridgeland	Yemassee of Hampton

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Table B-1 (continued

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
12. Kershaw	Kershaw	Kershaw	Kershaw	Kershaw	Kershaw
13. Lee	Bishopville	Bishopville	Bishopville	Bishopville	Bishopville
14. Marion	Marion	Marion	Marion	Marion	Marion
15. Orangeburg	Orangeburg 2	Orangeburg 2	Orangeburg 2 SE	Orangeburg 2 SE	Orangeburg
16. Saluda	Saluda	Saluda	Saluda	Saluda	Saluda
17. Spartanburg	Spartanburg WB, AP	Spartanburg WB, AP	Spartanburg WB, AP	Spartanburg	Spartanburg
18. Union	Union 7 SW	Union 7 SW	Union 7 SW	Stantuck	Stantuck
III. Georgia:					
1. Appling	Lumber City of Telfair	Lumber City of Telfair	Lumber City of Telfair	Lumber City of Telfair	Hazelehurst of Jeff-Davis
2. Baker	Blakley of Early	Hoggards Mill	Hoggards Mill	Hoggards Mill	Blakley of Early
3. Bartow	Allatoona Dam 2	Allatoona Dam 2	Allatoona Dam	Cartersville	Cartersville
4. Ben Hill	Fitzgerald	Fitzgerald	Fitzgerald	Fitzgerald	Fitzgerald
5. Brooks	Quitman	Quitman	Quitman	Quitman	Quitman
6. Bulloch	Brooklet 1 W	Brooklet 1 W	Brooklet 1 W	Brooklet	Brooklet
7. Candler	Swainsboro of Emanuel	Swainsboro of Emanuel	Swainsboro of Emanuel	Stillmore of Emanuel	Stillmore of Emanuel
8. Carroll	Carrollton	Carrollton	Carrollton	Carrollton	Carrollton

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Table 3-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
9. Chattooga	Rome of Floyd	Rome of Floyd	Rome of Floyd	Rome of Floyd	Rome of Floyd
10. Caffee	Douglas	Alma CAA, AP of Bacon	Alma CAA, AP of Bacon	Alama of Bacon	Alama of Bacon
11. Colquitt	Moultrier 2 ESE	Moultrie 2 ESE	Moultrie 2 ESE	Moultrie	Moultrie
12. Cook	Quitman of Brooks	Ouitman of Brooks	Quitman of Brooks	Quitman of Brooks	Quitman of Brooks
13. Coweta	Newman	Newman	Newman	Newman	Newman
14. Crisp	Cordele	Cordele	Cordele	Cordele	Cordele
15. Dodge	Eastman	Eastman	Eastman	Eastman	Eastman
16. Dooly	Cordele of Crisp	Cordele of Crisp	Cordele of Crisp	Cordele of Crisp	Cordele of Crisp
17. Early	Blakley	Blakley	Blakley	Blakley	Blakley
18. Effingham	Swainsboro of Emanuel	Swainsboro of Emanuel	Swainsboro of Emanuel	Stillmore of Emanuel	Stillmore of Emanuel
19. Emanuel	Swainsboro	Swainsboro	Swainsboro	Stillmore	Stillmore
20. Floyd	Rome	Rome	Rome	Rome	Rome
21. Franklin	Hartwell of Hart	Hartwell of Hart	Hartwell 3W of Hart	Hartwell (near) of Hart	Hartwell (near) of Hart
22. Gordon	Calhoun Exp. Sta.	Calhoun Exp. Sta.	Allatoona Dam of Bartow	Cartersville of Bartow	Cartersville of Bartow
23. Greene	Greensboro	Greensboro	Greensboro	Greensboro	Gresnboro

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
24. Hancock	Greensboro of Greene	Greensboro of Greene	Greensboro of Greene	Greensboro of Greene	Greensboro of Greene
25. Hart	Hartwell	Hartwell	Hartwell 3 W	Hartwell (near)	Hartwell (near)
26. Henry	Covington of Newton	Covington of Newton	Covington of Newton	Covington of Newton	Covington of Newton
27. Irwin	Douglas of Coffee	Alma CAA, AP of Bacon	Alma CAA, AP of Bacon	Alma of Bacon	Alma of Bacon
28. Jackson	Hartwell of Hart	Hartwell of Hart	Hartwell 3 W of Hart	Hartwell (near) of Hart	Hartwell (near) of Hart
29. Jeff-Davis	Douglas of Coffee	Alma CAA, AP of Bacon	Alma CAA, AP of Bacon	Alma of Bacon	Alma of Bacon
30. Jefferson	Lousville	Louisville	Louisville	Louisville	Louisville
IV. Alabama:					
1. Autanga	Prattville	Prattville	Prattville	Prattville	Prattville
2. Barbour	Clayton	Clayton	Troy of Pike	Troy of Pike	Eufaula
3. Bullock	Union Springs 5 S	Troy of Pike	Union Springs	Union Springs	Union Springs
4. Butler	Greenville	Greenville	Greenville	Greenville	Greenville
5. Chambers	Lafayette	Lafayette	Lafayette	Auburn of Lee	Auburn of Lee
6. Chilton	Clanton	Clanton	Clanton	Clanton	Clanton
7. Clarke	Whately	Thomasville	Thomasville	Thomasville	Thomasville
8. Coffee	Enterprise	High land home of Grenshaw	High land home of Crenshaw	High land home of Crenshaw	High land home of Crenshaw

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Table B-1 (continued)

Selected Counties	Selected Weather Stations For Each Year of the Study 1959	1954	1949	1944	1939
9. Conecuh	Evergreen CAA AP	Evergreen CAA AP	Evergreen CAA AP	Evergreen	Evergreen
10. Crenshaw	Highland home	Highland home	Highland home	Highland home	Highland home
11. Cullman	St. Bernard	St. Bernard	St. Bernard	St. Bernard	St. Bernard
12. Dallas	Marrion Junction	Marrion Junction	Selma	Selma	Selma
13. Escambia	Atmore State Farm 2 NE	Atmore State Farm 2 NE	Atmore State Farm 2 NE	Atmore State Farm 2 NE	Brewton (near)
14. Fayette	Fayette	Fayette	Fayette	Fayette	Tuscaloosa of Tuscal.
15. Geneva	Geneva	Geneva	Geneva	Geneva	Geneva
16. Hale	Greensboro	Greensboro	Greensboro	Greensboro	Greensboro
17. Houtson	Dothan CAA, AP	Dothan CAA, AP	Dothan CAA, AP	Daothan	Dothan
18. Jefferson	Bessemer 4 SSW	Bessemer 4 SSW	Birmingham WB APT	Birmingham AP	Birmingham AP
19. Lawrence	Moulton 2	Decatur of Morgan	Decatur of Morgan	Decatur of Morgan	Decatur of Morgan
20. Macon	Tuskegge 2	Tuskegee	Tuskegee	Tuskegee	Tuskegee
21. Mobile	Mobile	Mobile	Mobile WB, APR	Mobile AP	Mobile AP
22. Perry	Greesnboro of Hale	Greensboro of Hale	Greensboro of Hale	Greensboro of Hale	Greensboro of Hale
23. Pickens	Fayette of Fayette	Fayette of Fayette	Fayette of Fayette	Fayette of Fayette	Tuscaloosa of Tuscaloosa

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study: 1959	1954	1949	1944	1939
24. Randolph	Rock Mills	Rock Mills	Rock Mills	Rock Mills	University of Tuscaloosa
25. Talladega	Childerburg WTR Plant	Talladega	Talladega	Talladega	Talladega
26. Wilcox	Camden 3 NNW	Camden 3 NNW	Selma of Dallas	Selma of Dallas	Selma of Dallas
V. Missouri:					
1. Butler	Poplar Bluff	Poplar Bluff	Poplar Bluff	Poplar Bluff	Poplar Bluff
2. Dunklin	Malden FAA, AP	Malden 3 N	Campbell	Campbell	Campbell
3. Mississippi	Charleston	Charleston	Marble Hill of Ballinger	Marble Hill of Ballinger	Marble Hill of Ballinger
4. New Madrid	Portageville	Portageville	Wappapells Dam of Butler	Wappapells Dam of Butler	Wappapells Dam of Butler
5. Pemiscot	Caruthersville	Caruthersville	Caruthersville	Caruthersville	Caruthersville
6. Ripley	Doniphan	Doniphan	Doniphan	Doniphan	Doniphan
7. Scott	Charleston of Mississippi	Charleston of Mississippi	Sikeston	Sikeston	Sikeston
8. Stoddard	Advance 5 ESE	Advance 5 ESE	Advance	Advance	Advance
VI. Arkansas:					
1. Arkansas	Stuttgart	Stuttgart	Stuttgart	Stuttgart	Stuttgart
2. Calhoun	Camden 1 of Ouachita	Camden 1 of Ouachita	Camden 1 of Ouachita	Camden of Ouachita	Camden of Ouachita

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
3. Clay	Corning	Corning	Corning	Corning	Corning
4. Columbia	Magnolia 3 N	Magnolia 3 N	Magnolia	Magnolia	Magnolia
5. Crittenden	Wynne of Cross	Wynne of Cross	Wynne of Cross	Wynne of Cross	Wynne of Cross
6. Desha	Dumas 1	Dumas 1	Dumas 1	Dumas	Dumas
7. Greene	Corning of Clay	Corning of Clay	Corning of Clay	Corning of Clay	Corning of Clay
8. Jackson	Newport	Newport	Newport	Newport	Newport
9. Johnson	Ozark of Franklin	Ozark of Franklin	Ozark of Franklin	Ozark of Franklin	Ozark of Franklin
10. Lawrence	Walnut Ridge CAA, AP	Walnut Rige CAA, AP	Walnut Ridge CAA, AP	Batesville of Independence	Batesville of Independence
11. Lonoke	Keo	Keo	Keo	England	England
12. Miller	Texarkana WB, AP	Texarkana	Texarkana	Texarkana	Texarkana
13. Monroe	Helena of Phillips	Helena of Phillips	Helena of Phillips	Helena of Phillips	Helena of Phillips
14. Phillips	Helena	Helena	Helena	Helena	Helena
15. Prairie	Des Arc	Des Arc	Des Arc	Des Arc	England of Lonoke
16. St. Frances	Wynne of Cross	Wynne of Cross	Wynne of Cross	Wynne of Cross	Wynne of Cross
17. White	Searcy	Searcy	Searcy	Searcy	Searcy

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Table B-1 (continued

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
18. Yell	Dardanelle	Dardanelle	Dardanelle	Dardanelle	Dardanelle
VII. Tennessee:					
1. Carroll	Milan of Gibson	Milan of Gibson	Paris of Henry	Paris of Henry	Paris of Henry
2. Chester	Boliver 2 of Hardeman	Boliver 2 of Hardeman	Jackson 2 SE of Madison	Jackson 2 of Madison	Jackson 2 of Madison
3. Crockett	Milan of Gibson	Milan of Gibson	Milan of Gibson	Milan of Gibson	Milan of Gibson
4. Decatur	Boliver 2 of Hardeman	Boliver 2 of Hardeman	Waynesboro of Wayne	Waynesboro of Wayne	Waynesboro of Wayne
5. Dyer	Dyerbrug FAA, AP	Dyerburg FAA, AP	Dyerburg CAA, AP	Newbern	Newbern
6. Fayette	Moscow	Moscow	Moscow	Moscow	Moscow
7. Franklin	Palmetto of Bedford	Palmetto of Bedford	Palmetto of Bedford	Palmetto of Bedford	Palmetto of Bedford
8. Gibson	Milan	Milan	Milan	Milan	Milan
9. Giles	Lynnville 4 SW	Lynnville 4 SW	Lynnville 4 SW	Lynnville 4 SW	Lynneville (near)
10. Hardeman	Bolivar 2	Bolivar 2	Bolivar 2	Bolivar 2	Bolivar 2
11. Hardin	Savannah	Savannah	Savannah	Savannah	Savannah
VIII. Mississippi:					
1. Alcorn	Cornith	Cornith	Cornith	Cornith	Cornith

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Table B-1 (continued)

Selected Counties	Selected Wrather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
2. Attala	Lexington 2 NNW of Holmes	Lexington 2 NNW of Holmes	Kosciusko	Kosciusko	Kosciusko
3. Bolivar	Cleveland	Cleveland	Cleveland	Rochdale	Rochdale
4. Carroll	Winon 4 ENE of Montgomery	Winon 4 ENE of Montgomery	Duck Hill 1 SE of Montgomery	Duck Hill of Montgomery	Duck Hill of Montgomery
5. Choctaw	West Point 3 NNW of Clay	Acherman	West Point Exp. St. of Clay	West Point Exp. St. of Clay	West Point Exp. St. of Clay
6. Clay	West Point	West Point	West Point	West Point	West Point
7. Covington	Collins	Collins	Bay Springs of Jasper	Bay Springs of Jasper	Bay Springs of Jasper
8. De Soto	Hernando	Hernando	Hernando	Hernando	Hernando
9. Grenada	Grenada	Grenada	Greenwood CAA, AP of Leflore	Greenwood of Leflore	Greenwood of Leflore
10. Holmes	Lexington 2 NNW	Lexington 2 NNW	Pickens	Yazoo City of Yazoo	Yazoo City of Yazoo
11. Issaquena	Yazoo City of Yazoo	Yazoo City of Yazoo	Yazoo City of Yazoo	Yazoo City of Yazoo	Yazoo City of Yazoo
12. Jasper	Bay Springs	Bay Springs	Bay Springs	Bay Springs	Bay Springs
13. Jeff-Davis	Collins of Covington	Collins of Covington	Monticello of Lawrence	Monticello of Lawrence	Monticello of Lawrence
14. Kemper	Kipling	Kipling	Kipling	Macon of Noxubee	Macon of Noxubee
15. Lamar	Lumberton	Lumberton	Picayune of Pear River	Poplarville of Pear River	Poplarville of Pear River
16. Leflore	Greenwood CAA, AP	Greenwood CAA, AP	Greenwood, CAA, AP	Greenwood	Greenwood
17. Madison	Canton	Canton	Canton	Canton	Canton

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Table B-1 (continued

Selected Counties	Selected Weather Stations for Each Year of the Study 1959	1954	1949	1944	1939
18. Marshall	Holly Springs 2 N	Holly Springs 2N	Holly Springs	Holly Springs	Holly Springs
19. Montgomery	Winona 4 ENE	Winona 4 ENE	Duck Hill 1 SE	Duck Hill	Duck Hill
20. Noxubee	Macon 2 NE	Macon 2 NE	Macon 2 NE	Macon	Macon
21. Pontotoc	Pontotoc Exp. Sta.	Pontotoc Exp. Sta.	Pontotoc	Pontotoc	Pontotoc
22. Quitman	Cleveland of Bolivar	Cleveland of Bolivar	Cleveland of Bolivar	Rochdale of Bolivar	Rochdale of Bolivar
23. Scott	Forest	Forest	Forest	Forest	Forest
24. Simpson	Dlo	Dlo	Crystal Springs of Copiah	Crystal Springs of Copiah	Crystal Springs of Copiah
25. Sunflower	Moorhead	Moorhead	Moorhead	Moorhead	Moorhead
26. Tippah	Ripley	Ripley	Corinth of Alcorn	Corinth of Alcorn	Corinth of Alcorn
27. Walthall	Lumberton of Lamar	Lumberton of Lamar	McComb CAA, AP of Pike	Magnolia of Pike	Magnolia of Pike
28. Webster	Eupora	Eupora	Eupora	Eupora	Eupora
29. Yazoo	Yazoo City	Yazoo City	Yazoo City	Yazoo City	Yazoo City
IX. Louisiana:					
1. Acadia	Jennings of Jeff-Davis	Crowley Exp. Sta.	Crowley Exp. Sta.	Crowley Exp. Sta.	Crowley Exp. Sta.
2. Avoyelles	Alexandria of Rapids	Alexandria of Rapids	Alexandria CAA, AP of Rapids	Esler Field of Rapids	Chenyville of Rapids

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
3. Bonier	Plain Dealing	Plain Dealing	Plain Dealing	Plain Dealing	Plain Dealing
4. Caddo	Shreverport WB, AP	Shreverport WB, AP	Shreverport WB, AP	Shreverport	Shreverport
5. Caldwell	Calhoun Exp.Sta. of Ouathita	Calhoun Exp.Sta. of Ouathita	Calhoun Exp.Sta. of Ouathita	Calhoun of Ouathita	Calhoun of Ouathita
6. Catahoula	Alexandria of Rapids	Alexandria of Rapids	Alexandria CAA, AP of Rapids	Cheneyville of Rapids	Cheneyville of Rapids
7. Concord	Winsboro of Frankling	Winsboro Franklin	St.Joseph Exp. Sta.ofTensas	St.Joseph of Tensas	St.Joseph of Tensas
8. DeSoto	Longansport	DeSoto of Fire Tower	Longansport	Grand Cane	Grand Cane
9. East Carroll	Lake Providence	Lake Providence	Lake Providence	Lake Providence	Lake Providence
10. East Feliciance	Clinton	Clinton	Clinton 1	Clinton	Clinton
11. Evangeline	Ville Platte 2 SW	Ville Platte 2 SW	Ville Platte 2SW	Ville Platte 2 SW	Ville Platte 2 SW
12. Franklin	Winsboro	Winsboro	Winsboro	Winsboro	Winsboro
13. Lafayette	Lafayette CAA, AP	Lafayette CAA, AP	Lafayette CAA, AP	Lafayette	Lafayette
X. Oklahoma:					
1. Atoka	Atoka 3 SW	Atoka 3 SW	Atoka	Atoka	Atoka
2. Beckham	Erick 4 E	Erick 4 E	Erick	Erick	Erick
3. Blaine	Canten Dam	Canten Dam	Danten Dam	Okeena	Okeena

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study 1959	1954	1949	1944	1939
4. Bryan	Durant se State College	Durant se State College	Durant	Durant	Durant
5. Caddo	Anadarbo	Anadarbo	Anadarbo	Apache	Apache
6. Canadian	El Reno 4 NE	El Reno 4 NE	Fort Reno	Fort Reno	Fort Reno
7. Comache	Chattanooga	Chattanooga	Chattanooga	Chattanooga	Chattanooga (near)
8. Cotton	Walters	Walters	Walters	Walters	Walters
9. Custer	Clinton	Clinton	Clinton	Weatherford	Weatherford
10. Garvin	Pauls Vlley	Pauls Valley	Pauls Valley	Pauls Valley	Pauls Valley
11. Grady	Chickasha	Chickasha	Chickasha	Chickasha	Chickasha
12. Harmon	Hollis	Hollis	Hollis	Hollis	Hollis
13. Jackson	Altus	Altus	Altus	Altus	Altus
14. Jefferson	Wauricka	Wauricka	Wauricka	Wauricka	Wauricka (near)
15. Kiowa	Hobart FAA, AP	Hobart FAA,AP	Hobart CAA, AP	Hobart	Hobart
16. Love	Marietta	Marietta	Marietta	Ardmore of Carter	Ardmore of Carter
17. McCurtain	Bear Mountain	Bear Mountain	Idabel	Idabel	Idabel
18. McIntosh	Eufaula	Eufaula	Eufaula	Okmulgee of Okmulgee	Okmulgee of Okmulgee

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Table B-1 (continued

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
19. Marshall	Madill	Madill	Madill	Ardmore of Carter	Ardmore of Carter
XI. **East Texas**:					
1. Anderson	Palestine	Palestine	Palestine WB city	Palestine	Palestine
2. Aramas	Austwell W.L. Refuge	Austwell W.L. Refuge	Austwell W.L.R. 8 SSE	Goliad of Goliad	Vicoria of Vicoria
3. Atascosa	Poteet	Poteet	Poteet	Beevile of Bee	Beevile of Bee
4. Bastrop	Smithville	Smithville	Smithville	Smithville	Smithville
5. Bee	Beeville 5 NE	Beeville	Beeville	Beeville	Beeville
6. Bowie	Clarksville 2 E of Red River	Clarksville of Red River	Clarksville of Red River	Clarksville of Red River	Mount Pleasant of Titus
7. Brazos	College Sta. FAA, AP	College Sta. FAA, AP	College Sta.	College Sta.	College Sta.
8. Burlesson	College Sta.FAA AP of Brazos	College Sta.FAA AP of Brazos	College Sta.of Brazos	College Sta.of Brazos	College Sta.of Brazos
9. Caldwell	Luling 1 SE	Luling	Luling	Luling	Luling
10. Clay	Henrietta	Henrietta	Henrietta	Henrietta	Henrietta
11. Colorado	Flatonia of Fayette	Flatonia of Fayette	Flatonia of Fayette	Flatonia of Fayette	Flatonia of Fayette
12. Coryell	Gatesville	Gatesville	Gatesville	Temple of Bell	Temple of Bell
13. Dallas	Dallas WB,AP	Dallas WB, AP	Dallas WB,AP	Dallas	Dallas

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
14. Denton	Denton	Dallas WB, AP of Dallas	Dallas WB, AP of Dallas	Dallas of Dallas	Dallas of Dallas
15. Duval	Alice of Jim Wells	Alice of Jim Wells	Allice CAA, AP of Jim Wells	Allice of Jim Wells	Alice of Jim Wells
16. Falls	Marlin	Marlin	Marlin	Mexia of Limestone	Mexia of Limestone
17. Fayette	Flatonia	Flatonia	Flatonia	Flatonia	Flatonia
18. Fort Bend	Rosenberg	Rosenberg	Rosenberg	Sugarland	Sugarland
19. Freestone	Centerville of Leon	Centerville of Leon	Centerville of Leon	Centerville of Leon	Centerville of Leon
20. Goliad	Goliad	Goliad	Goliad	Goliad	Cuers of DeWitt
21. Grayson	Denison Dam	Denison Dam	Denison Dam	Sherman	Sherman
22. Grimes	College Sta.FAA AP of Brazos	College Sta.CAA AP of Brazos	College Sta. of Brazos	College Sta. of Brazos	College Sta. of Brazos
23. Hamilton	Gatesville of Corryell	Gatesville of Corryell	Gatesville of Corryell	Hico	Hico
24. Harrison	Marshall	Marshall	Marshall	Marshall	Marshall
25. Hays	San Morcos	San Morcos	San Morcos	San Morcos	San Morcos
26. Hidalgo	Weslaco 2E	Weslaco 2E	Weslaco Exp. Sta.	Mission	Mission
27. Houston	Crockett	Crockett	Crockett	Palestine of Anderson	Palestine of Anderson
28. Hunt	Greenville 2 SW	Greenville 2 SW	Greenville	Greenville	Greenville

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
29. Jackson	Hallettsville of Lavace	Hallesttsville of Lavace	Hallettsville of Lavace	Hallettsville of Lavace	Hallettsville of Lavace
30. Jim Wells	Alice	Alice	Alice	Alice	Alice
31. Karnes	Poteet of Atascosa	Poteet of Atascosa	Poteet of Atascosa	Goliad of Goliad	Cuers of DeWitt
32. Kleberg	Kingsville	Kingsville	Kingsville	Alice of Jim Wells	Alice of Jim Wells
XII. West Texas:					
1. Borden	Big Spring of Howard	Big Spring of Howard	Big Spring WB, AP of Howard	Big Spring of Howard	Big Spring of Howard
2. Briscoe	Floydada 2 SW of Floyd	Floydada 2 SW of Floyd	Clarendon CAA, AP of Donley	Plainview of Hale	Plainview of Hale
3. Castro	Hereford of Deafsmith	Hereford 1 of Deafsmith	Hereford 1 of Deafsmith	Muleshoe of Bailey	Muleshoe of Bailey
4. Crosby	Crosbyton	Crosbyton	Crosbyton	Crosbyton	Crosbyton
5. Deafsmith	Hereford	Hereford 1	Hereford 1	Amarille of Potter	Amarille of Potter
6. Dickens	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton of Crosby
7. El Paso	El Paso WB,AP	El Paso, WB,AP	El Paso WB,AP	El Paso	El Paso
8. Floyd	Floydada 2 SW	Floydada 2 SW	Hillsboro of Hall	Lubbock of Lubbock	Lubbock of Lubbock
9. Gaines	Longview	Longview	Tahoka of Lynn	Spearman of Lynn	Spearman of Lynn
10. Garza	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton Crosby	Crosbyton Crosby	Crosbyton of Crosby

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Table B-1 (continued

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
11. Hale	Plainview	Plainview	Plainview	Plainview	Plainview
12. Hockley	Levelland	Levelland	Levelland	Lubbock of Lubbock	Lubbock of Lubbock
13. Kent	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton of Crosby	Crosbyton of Crosby
XIII. New Mexico:					
1. Hidalgo	Eicks Ranch	Eicks Ranch	Eicks Ranch	Eicks Ranch	Eicks Ranch
2. Lea	Maljamar 2 SE	Maljamar 2 SE	Maljamar	Maljamar	Lovington
3. Luna	Logan	Logan	Logan	Gage	Gage
4. Otero	Mescalero	Mescalero	Mescalero	Mescalero	Mescalero
5. Quay	Ragland	Ragland	Quay	Obar	Obar
6. Roosevelt	Elida	Elida	Portales	Portales	Portales
7. Sierra	Elephant Butte Dam	Elephant Butte Dam	Chacon	Caballo Dam	Socorro of Socorro
8. Socorro	Socorro	Socorro	Socorro	Socorro AP	Socorro
XIV. Arizona:					
1. Cochise	Bowie	Bowie	Benson	Benson	Bowie

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Table B-1 (continued)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
2. Graham	Safford	Safford	Safford	Safford	Safford
3. Greenlee	Safford of Graham	Safford of Graham	Safford of Graham	Safford of Graham	Safford of Graham
4. Maricopa	Cane Greek	Cane Greek	Alhambra	Barlett Dam	Aguila
5. Pima	Organ Pipe Cactus N.M.	Organ Pipe Cactus N.M.	Organ Pipe Cactus N.M.	Organ Pipe Cactus N.M.	Helvetia (near)
6. Pinal	Florence	Florence	Florence	Casa Grande Ruins	Florence
7. Santa Cruz	Tumacacori N.M.	Tumacacori N.M.	Tumacacori N.M.	Nogales	Nogales
8. Yuma	Parker	Parker	Parker	Parker	Parker
XV. California:					
1. Fresno	Panoche Junction	Panoche Junction	Panoche Junction	Big Greek	Big Greek
2. Imperia	Brawley 2 SW	Brawley 2 SW	Brawley	Brawley	Brawley
3. Kern	Tehachapi	Tehachapi	Tehachapi	Button Willow	Backus Ranch
4. Kings	Avenal 9 SSE	Avenal 9 SSE	Kettleman Sta.	Kettleman Sta.	Big Greek of Fresno
5. Los Angeles	Palmdale FAA AP	Palmdale FAA AP	Palmdale FAA AP	Palmdale	Palmdale
6. Madera	Madera	Madera	Madera	Madera	Madera

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Table B-1 (concluded)

Selected Counties	Selected Weather Stations for Each Year of the Study				
	1959	1954	1949	1944	1939
7. Merced	Merced Fire Sta. 2	Merced Fire Sta. 2	Merced	Merced	Merced
8. Monterey	Carmel Valley	Carmel Valley	King City AP	King City AP	King City

1. The list of stations from which these were selected is: Climatological Data, by States, by Months, Weather Bureau, U.S. Commerce Department, 1939, 1944, 1949, 1954, and 1959.

2. These counties were selected as follows:
   a. On the basis of harvested cotton acreage in 1959, all counties harvesting 1,000 or more acres of cotton have constituted the universe.
   b. The sample was constructed by randomly selected 40% of counties in each State except that at least 8 and no more than 45 counties were selected for each State.

3. These weather stations were selected as follows:
   a. If there were more than one weather station in a county reporting rainfall and temperature, then the one at or near the center was selected for use in this study.
   b. If there was only one weather station in a county, then it was selected.
   c. If there was none in a county, then the nearest weather station to that county was selected.

APPENDIX C

SIMPLE CORRELATIONS OF THE TECHNICAL AND ECONOMIC VARIABLES, BY STATES

Table C-1. Simple Correlations of the Technical and Economics Variables, by States

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
1. North Carolina:	Yield	1.00									
	Nutrients	0.23	1.00								
	Man-hours	-0.14	-0.90	1.00							
	Tractors	0.21	0.69	-0.49	1.00						
	Gas-oil	0.09	0.59	-0.43	0.87	1.00					
	Size	-0.04	*	-0.06	-0.12	-0.26	1.00				
	% Cotton	-0.01	-0.08	-0.02	-0.17	-0.17	0.77	1.00			
	Land Value	0.08	0.48	-0.34	0.69	0.78	-0.36	-0.22	1.00		
	Cotton Price	0.25	0.93	-0.92	0.69	0.57	0.05	-0.08	0.51	1.00	
	Ratio	-0.27	-0.14	-0.04	-0.36	-0.02	-0.24	0.04	-0.05	-0.17	1.00
2. South Carolina:	Yield	1.00									
	Nutrients	0.18	1.00								
	Man-hours	0.21	-0.76	1.00							
	Tractors	0.03	0.64	-0.71	1.00						
	Gas-oil	0.05	0.78	-0.77	0.80	1.00					
	Size	-0.13	0.14	-0.15	-0.12	-0.03	1.00				
	% Cotton	-0.20	-0.34	0.16	-0.30	-0.27	0.38	1.00			
	Land Value	0.20	0.46	-0.38	0.56	0.70	-0.19	-0.02	1.00		
	Cotton Price	-0.15	0.78	-0.99	0.72	0.78	0.14	-0.19	0.39	1.00	
	Ratio	-0.25	-0.42	0.30	-0.53	-0.21	-0.13	0.47	0.04	0.37	1.00

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Table C-1. (continued)

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
3. Georgia:	Yield	1.00									
	Nutrients	0.63	1.00								
	Man-hours	-0.41	-0.80	1.00							
	Tractors	0.58	0.74	-0.78	1.00						
	Gas-oil	0.55	0.75	-0.84	0.87	1.00					
	Size	0.19	0.33	-0.24	0.11	0.16	1.00				
	% Cotton	-0.11	-0.17	0.11	-0.04	-0.25	0.44	1.00			
	Land Value	0.66	0.66	-0.61	0.76	0.79	0.16	-0.13	1.00		
	Cotton Price	0.40	0.80	-0.99	0.77	0.84	0.25	-0.11	0.60	1.00	
	Ratio	-0.52	-0.62	0.48	-0.50	-0.37	0.01	0.32	-0.37	-0.47	1.00
4. Alabama:	Yield	1.00									
	Nutrients	0.57	1.00								
	Man-hours	-0.39	-0.75	1.00							
	Tractors	0.50	0.79	-0.56	1.00						
	Gas-oil	0.52	0.86	-0.62	0.89	1.00					
	Size	0.12	0.21	-0.20	0.11	0.16	1.00				
	% Cotton	-0.23	-0.18	0.08	-0.22	-0.27	0.43	1.00			
	Land Value	0.39	0.39	-0.25	0.75	0.66	0.14	-0.23	1.00		
	Cotton Price	0.47	0.89	-0.07	0.68	0.75	0.22	-0.13	0.31	1.00	
	Ratio	-0.45	-0.68	0.52	-0.48	-0.54	0.21	0.60	0.10	-0.61	1.00

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Table C-1. (continued

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
5. Missouri:	Yield	1.00									
	Nutrients	0.39	1.00								
	Man-hours	-0.01	-0.77	1.00							
	Tractors	-0.08	0.72	-0.85	1.00						
	Gas-oil	0.17	0.73	-0.91	0.74	1.00					
	Size	0.03	0.04	-0.23	0.08	0.25	1.00				
	% Cotton	0.17	-0.19	0.06	-0.15	0.16	0.25	1.00			
	Land Value	0.51	0.46	-0.46	0.16	0.66	0.29	0.62	1.00		
	Cotton Price	0.02	0.77	-0.99	0.85	0.91	0.22	-0.07	0.46	1.00	
	Ratio	-0.48	-0.17	-0.26	0.18	0.08	0.23	0.04	-0.18	0.25	1.00
6. Arkansas:	Yield	1.00									
	Nutrients	0.59	1.00								
	Man-hours	-0.15	-0.49	1.00							
	Tractors	0.28	0.78	-0.67	1.00						
	Gas-oil	0.52	0.79	-0.70	0.77	1.00					
	Size	0.49	0.52	-0.51	0.46	0.61	1.00				
	% Cotton	-0.12	-0.30	-0.09	-0.16	-0.13	0.05	1.00			
	Land Value	0.71	0.52	-0.34	0.25	0.61	0.50	0.19	1.00		
	Cotton Price	0.35	0.76	-0.94	0.81	0.83	0.59	-0.05	0.46	1.00	
	Ratio	0.05	-0.41	-0.01	-0.36	-0.07	-0.01	0.64	0.25	-0.17	1.00

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Table C-1. (continued)

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
7.Tennessee	Yield	1.00									
	Nutrients	0.65	1.00								
	Man-hours	0.24	0.18	1.00							
	Tractors	0.62	0.92	-0.03	1.00						
	Gas-oil	0.66	0.87	-0.12	0.92	1.00					
	Size	0.45	0.19	-0.27	0.23	0.40	1.00				
	% Cotton	0.08	-0.10	-0.26	-0.09	-0.04	0.74	1.00			
	Land Value	0.67	0.39	0.02	0.45	0.62	0.62	0.15	1.00		
	Cotton Price	0.50	0.81	-0.43	0.86	0.88	0.37	0.07	0.37	1.00	
	Ratio	0.32	-0.50	-0.63	-0.30	-0.20	0.39	0.52	0.04	-0.07	1.00
8.Mississ-ippi	Yield	1.00									
	Nutrients	0.56	1.00								
	Man-hours	-0.56	-0.99	1.00							
	Tractors	0.35	0.59	-0.59	1.00						
	Gas-oil	0.32	0.40	-0.40	0.92	1.00					
	Size	0.55	0.35	-0.34	0.22	0.35	1.00				
	% Cotton	0.12	-0.01	0.01	0.72	0.88	0.23	1.00			
	Land Value	0.58	0.45	-0.44	0.38	0.44	0.66	0.31	1.00		
	Cotton Price	0.32	0.78	-0.80	0.52	0.36	0.31	0.06	0.35	1.00	
	Ratio	-0.29	-0.68	0.68	-0.36	-0.17	0.10	0.20	-0.05	-0.41	1.00

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Table C-1 (continued)

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
9. Louisiana:	Yield	1.00									
	Nutrients	0.36	1.00								
	Man-hours	-0.31	-0.88	1.00							
	Tractors	-0.26	0.88	-0.89	1.00						
	Gas-oil	0.29	0.85	-0.87	0.90	1.00					
	Size	0.46	0.38	-0.44	0.38	0.46	1.00				
	% Cotton	-0.06	-0.20	0.07	-0.01	-0.08	0.46	1.00			
	Land Value	0.41	0.55	-0.49	0.37	0.48	0.19	-0.32	1.00		
	Cotton Price	0.22	0.73	-0.05	0.80	0.78	0.37	0.02	0.40	1.00	
	Ratio	0.04	-0.61	0.55	-0.46	-0.52	-0.01	0.52	-0.36	-0.43	1.00
10. Oklahoma:	Yield	1.00									
	Nutrients	0.29	1.00								
	Man-hours	-0.44	-0.75	1.00							
	Tractors	0.40	0.77	-0.76	1.00						
	Gas-oil	0.46	0.73	-0.80	0.93	1.00					
	Size	0.16	0.04	-0.22	-0.03	0.06	1.00				
	% Cotton	-0.14	-0.25	0.19	-0.25	-0.23	0.59	1.00			
	Land Value	0.36	0.27	-0.27	0.15	0.29	0.39	0.11	1.00		
	Cotton Price	0.42	0.69	-0.99	0.73	0.76	0.23	-0.18	0.24	1.00	
	Ratio	-0.27	-0.64	0.59	-0.79	-0.72	0.34	0.36	0.01	-0.55	1.00

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Table C-1 (continued)

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
11. E. Texas:	Yield	1.00									
	Nutrients	0.32	1.00								
	Man-hours	-0.41	-0.77	1.00							
	Tractors	0.37	0.63	-0.69	1.00						
	Gas-oil	0.55	0.58	-0.66	0.88	1.00					
	Size	0.34	0.16	-0.32	0.13	0.23	1.00				
	% Cotton	0.14	-0.27	0.17	0.18	0.20	0.14	1.00			
	Land Value	0.34	0.33	-0.31	0.24	0.24	0.26	-0.04	1.00		
	Cotton Price	0.38	0.64	-0.98	0.64	0.61	0.32	-0.13	0.27	1.00	
	Ratio	0.14	-0.40	0.37	0.33	-0.13	0.22	0.39	0.17	-0.33	1.00
12. W. Texas:	Yield	1.00									
	Nutrients	0.49	1.00								
	Man-hours	-0.47	-0.70	1.00							
	Tractors	0.69	0.45	-0.37	1.00						
	Gas-oil	0.85	0.53	-0.50	0.87	1.00					
	Size	0.12	0.22	-0.58	0.03	0.12	1.00				
	% Cotton	0.28	0.14	-0.24	0.58	0.37	0.56	1.00			
	Land Value	0.74	0.42	-0.48	0.43	0.73	0.22	0.09	1.00		
	Cotton Price	0.43	0.57	-0.98	0.35	0.47	0.62	0.25	0.44	1.00	
	Ratio	0.19	0.29	-0.28	-0.09	0.10	-0.05	-0.28	0.10	0.26	1.00

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Table C-1 (continued)

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
13. New Mexico:	Yield	1.00									
	Nutrients	0.65	1.00								
	Man-hours	-0.63	-0.95	1.00							
	Tractors	0.65	0.52	-0.57	1.00						
	Gas-oil	0.68	0.36	-0.42	0.81	1.00					
	Size	0.11	0.27	-0.39	0.08	0.19	1.00				
	% Cotton	0.48	0.33	-0.42	0.47	0.56	0.75	1.00			
	Land Value	0.10	0.59	-0.63	0.09	-0.15	0.31	0.15	1.00		
	Cotton Price	0.47	0.71	-0.23	0.54	0.40	0.51	0.49	0.56	1.00	
	Ratio	0.10	0.21	-0.23	0.09	0.11	0.13	0.03	-0.10	0.26	1.00
14. Arizona:	Yield	1.00									
	Nutrients	0.71	1.00								
	Man-hours	-0.68	-0.96	1.00							
	Tractors	-0.22	0.07	0.02	1.00						
	Gas-oil	-0.04	0.31	-0.37	0.60	1.00					
	Size	0.40	0.03	0.02	-0.35	-0.22	1.00				
	% Cotton	0.29	0.14	*	-0.07	-0.34	0.42	1.00			
	Land Value	0.52	0.45	-0.47	-0.23	-0.09	0.04	-0.17	1.00		
	Cotton Price	0.57	0.72	-0.57	0.29	0.15	0.15	0.27	0.21	1.00	
	Ratio	-0.06	0.22	-0.19	0.05	*	-0.18	-0.07	-0.11	0.20	1.00

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Table C-1 (continued)

State	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
15. California:	Yield	1.00									
	Nutrients	0.60	1.00								
	Man-hours	-0.69	-0.74	1.00							
	Tractors	0.25	-0.08	0.16	1.00						
	Gas-Oil	0.25	-0.08	0.17	0.99	1.00					
	Size	0.20	0.18	-0.27	-0.20	-0.20	1.00				
	% Cotton	0.17	-0.03	-0.10	-0.25	-0.25	*	1.00			
	Land Value	0.38	0.59	-0.36	-0.12	-0.12	-0.02	-0.34	1.00		
	Cotton Price	0.60	0.55	-0.59	0.06	0.06	0.34	0.24	0.26	1.00	
	Ratio	0.17	-0.01	-0.07	-0.07	-0.07	0.03	0.40	-0.06	0.13	1.00

* Indicates that simple correlation was less than .01.

APPENDIX D

SIMPLE CORRELATIONS OF THE TECHNICAL AND ECONOMIC VARIABLES, BY REGIONS

Table D-1. Simple Correlations of the Technical and Economic Variables, by Regions

Region	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
I. South-east:	Yield	1.00									
	Nutrients	0.43	1.00								
	Man-hours	-0.44	-0.70	1.00							
	Tractors	0.40	0.63	-0.58	1.00						
	Gas-oil	0.37	0.54	-0.52	0.84	1.00					
	Size	-0.06	0.24	-0.15	-0.07	-0.11	1.00				
	% Cotton	-0.22	-0.16	0.09	-0.22	-0.29	0.49	1.00			
	Land Value	0.40	0.35	-0.27	0.66	0.74	-0.24	-0.26	1.00		
	Cotton Price	0.26	0.80	-0.94	0.67	0.58	0.18	-0.10	0.33	1.00	
	Ratio	-0.04	-0.15	0.13	-0.18	-0.14	0.23	0.33	-0.09	-0.12	1.00
II. Delta:	Yield	1.00									
	Nutrients	0.47	1.00								
	Man-hours	-0.25	-0.47	1.00							
	Tractors	0.30	0.62	-0.50	1.00						
	Gas-oil	0.31	0.43	-0.45	0.88	1.00					
	Size	0.26	0.10	-0.26	0.12	0.19	1.00				
	% Cotton	0.01	-0.09	-0.01	0.48	0.68	0.11	1.00			
	Land Value	0.60	0.33	-0.45	0.28	0.39	0.32	0.12	1.00		
	Cotton Price	0.29	0.73	-0.71	0.64	0.49	0.21	0.03	0.34	1.00	
	Ratio	0.14	-0.03	-0.03	-0.05	0.06	0.15	0.21	0.31	0.01	1.00

.....continued

Table D-1 (continued)

Region	Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
III. South-west:	Yield	1.00									
	Nutrients	0.38	1.00								
	Man-hours	-0.29	-0.50	1.00							
	Tractors	0.26	0.54	-0.52	1.00						
	Gas-oil	0.62	0.60	-0.44	0.78	1.00					
	Size	0.35	0.20	-0.10	-0.11	0.18	1.00				
	% Cotton	0.20	-0.05	0.18	0.15	0.26	0.39	1.00			
	Land Value	0.46	0.35	-0.23	0.22	0.39	0.23	0.06	1.00		
	Cotton Price	0.37	0.60	-0.86	0.58	0.58	0.29	-0.03	0.30	1.00	
	Ratio	0.03	-0.03	-0.01	-0.04	-0.04	-0.01	0.03	-0.15	-0.01	1.00
IV. West:	Yield	1.00									
	Nutrients	0.64	1.00								
	Man-hours	-0.63	-0.73	1.00							
	Tractors	0.20	-0.01	0.07	1.00						
	Gas-oil	0.21	-0.01	0.06	0.99	1.00					
	Size	0.25	0.18	-0.06	-0.12	-0.11	1.00				
	% Cotton	0.21	0.19	-0.11	-0.12	-0.13	0.23	1.00			
	Land Value	0.42	0.49	-0.30	-0.01	-0.02	0.23	-0.28	1.00		
	Cotton Price	0.46	0.51	-0.63	0.06	0.05	0.09	0.34	0.10	1.00	
	Ratio	0.15	0.12	-0.10	-0.03	-0.03	-0.01	-0.01	0.05	0.07	1.00

APPENDIX E

SIMPLE CORRELATIONS OF THE TECHNICAL AND ECONOMIC VARIABLES, THE ENTIRE NATION

Table E-1. Simple Correlations of the Technical and Economic Variables, the Entire Nation

Variables	Yield	Nutri-ents	Man-hours	Trac-tors	Gas-oil	Size	% Cotton	Land Value	Cotton Price	Ratio
Yield	1.00									
Nutrients	0.26	1.00								
Man-hours	0.18	0.16	1.00							
Tractors	0.16	0.13	-0.02	1.00						
Gas-oil	0.17	0.07	0.01	0.98	1.00					
Size	0.19	-0.09	-0.18	-0.01	0.03	1.00				
% Cotton	*	-0.15	-0.01	0.01	0.01	0.23	1.00			
Land Value	0.29	0.25	-0.09	0.08	0.07	0.11	-0.05	1.00		
Cotton Price	0.09	0.34	-0.20	0.12	0.07	0.05	0.02	0.35	1.00	
Ratio	0.08	*	0.02	0.02	0.03	0.15	-0.01	-0.04	0.03	1.00

* Indicates that simple correlation was less than 0.01.