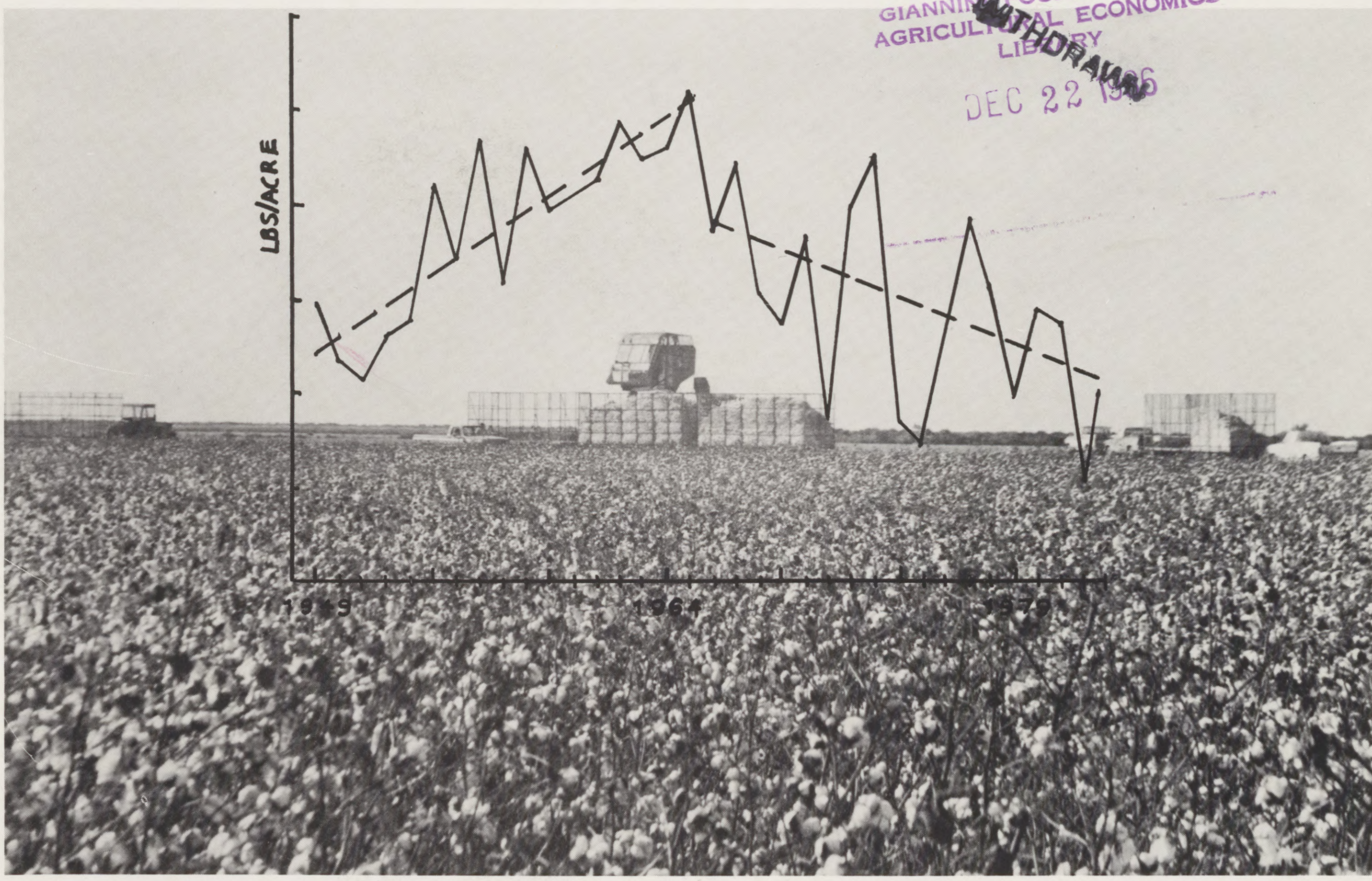
Cotton

ANALYSIS OF TEXAS HIGH PLAINS COTTON YIELD TRENDS



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Abstract

Irrigated and non-irrigated cotton yields in the Texas High Plains have been declining at a rate of 3 to 12 pounds per acre per year since the mid-1960s. An econometric analysis of factors affecting yields in the five subregions of the High Plains was conducted using secondary county-level data for the period 1949 to the present. Numerous factors were found which affected annual variations in yields, but the only factor which had a consistent effect on yield trends was fertilizer price, indicating that fertilizer costs and use, along with possible use of other variable inputs, have contributed to the yield losses.

Acknowledgements

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Table of Contents

List of Tables iii

List of Figures iv

Methods and Procedures 7
    The Model 10
    Data Sources 14
    Expectations 16
    Estimation Procedures 17
    Analysis of Yield Trends 18

Finding 18
    Estimated Equations 19
    Explanation of Yield Trends 23

Summary and Conclusions 27

References 29

Appendix 32

List of Tables

Table 1. Estimated Non-Irrigated and Irrigated Cotton Yields, Northern High Plains. 20

Table 2. Estimated Non-Irrigated and Irrigated Cotton Yields, Central High Plains. 20

Table 3. Estimated Non-Irrigated and Irrigated Cotton Yields, Southern High Plains. 20

Table 4. Estimated Non-Irrigated and Irrigated Cotton Yields, Southwestern High Plains. 21

Table 5. Estimated Non-Irrigated and Irrigated Cotton Yields, Western High Plains. 21

Table 6. Estimated Non-Irrigated and Irrigated Acreage Harvested, Northern High Plains. 21

Table 7. Estimated Non-Irrigated and Irrigated Acreage Harvested, Central High Plains. 24

Table 8. Estimated Non-Irrigated and Irrigated Acreage Harvested, Southern High Plains. 24

Table 9. Estimated Non-Irrigated and Irrigated Acreage Harvested, Southwestern High Plains. 24

Table 10. Estimated Non-Irrigated and Irrigated Acreage Harvested, Western High Plains. 24

Table 11. Actual and Predicted Yield Declines, Non-Irrigated and Irrigated Yields, Texas High Plains Subregions, 1966-1982. 26

Table 12. Trends in Independent Variables for the Years 1966-1982. 26

Table A.1. Mean Values of Variables Which Vary Across Subregions. 35

Table A.2. Mean Values of Variables Which Constant Across Subregions. 35

List of Figures

Figure 1.	Texas High Plains Study Subregions.	2
Figure 2.	Cotton Yields, Irrigated and Non-Irrigated, Northern High Plains.	2
Figure 3.	Cotton Yields, Irrigated and Non-Irrigated, Central High Plains.	5
Figure 4.	Cotton Yields, Irrigated and Non-Irrigated, Southern High Plains.	5
Figure 5.	Cotton Yields, Irrigated and Non-Irrigated, Southwestern High Plains.	6
Figure 6.	Cotton Yields, Irrigated and Non-Irrigated, Western High Plains.	6
Figure 7.	Hypothetical Cotton Production Function.	8

ANALYSIS OF TEXAS HIGH PLAINS COTTON YIELD TRENDS

Tamera J. Neal and Don E. Ethridge[1]

The High Plains of Texas is a major producing area for cotton, where it is produced under both irrigated and non-irrigated conditions. The 25-county High Plains region (Figure 1) is divided into 5 production subregions: the Northern, Western, Central, Southwestern, and Southern (Ethridge et al.). Grain sorghum, wheat, and corn are the crops which compete with cotton for land and other resources. In 1950, the High Plains region planted about 1.8 million acres, or 9.5% of the U.S. cotton acreage, and produced 823,000 bales, or 8.2% of the U.S. production (Ethridge et al.). In 1980, Texas High Plains cotton production accounted for 31.6% of the U.S. cotton production. Of the High Plains cotton crop, 60 to 70% is exported (McArthur, 1980). Therefore, High Plains cotton constitutes a large portion of U.S. production, which makes it important not only to the High Plains economy, but to the U.S. economy as a whole.

There has been concern with cotton yields in the United States cotton industry for about 10 years. At a special session on cotton yields at the National Cotton Council's 1977 Beltwide Cotton Conference, four papers documented the generally stable or declining yields in the four major producing areas of the U.S. (Carter; Chapman; Metzer; Woodall). These trends were highlighted again in 1982 (Meredith; Starbird and Hazera, 1982). Western U.S. cotton yields generally increased until 1965 and have declined or remained constant since.

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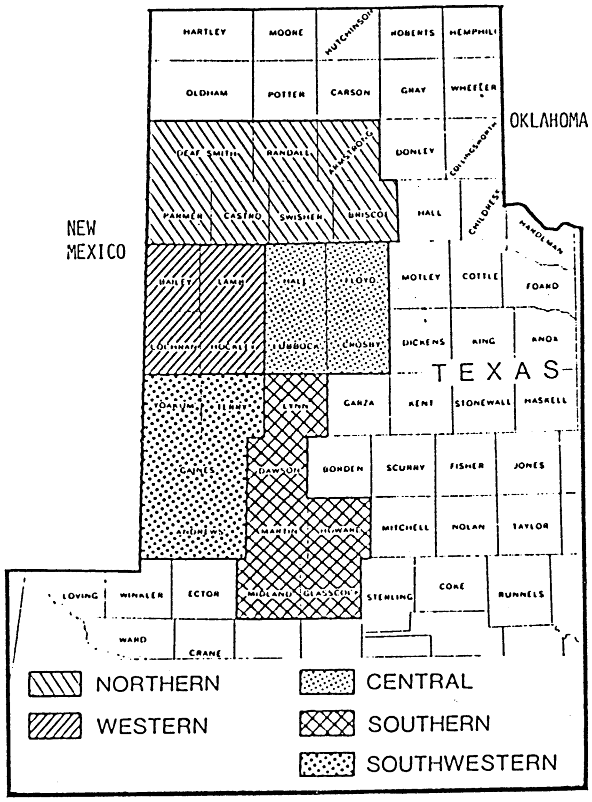

Figure 1. Texas High Plains Study Subregions.

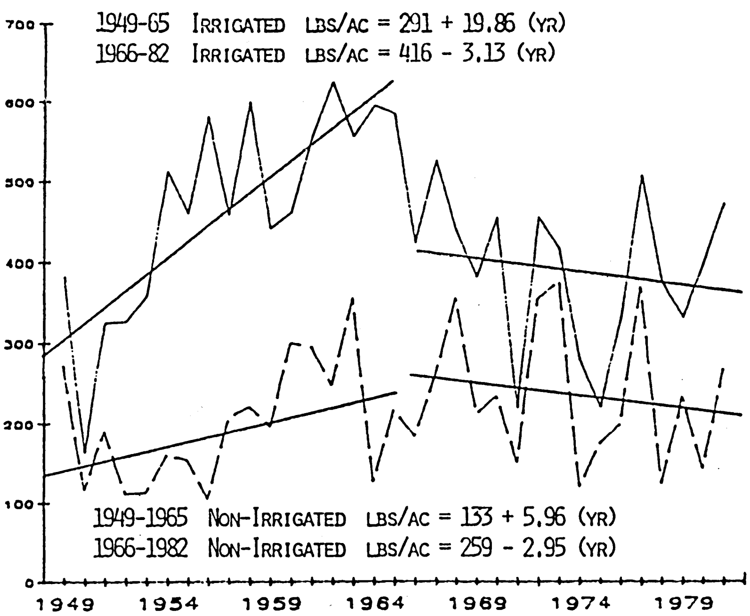

Figure 2. Cotton Yields, Irrigated and Non-Irrigated, Northern High Plains.

Yields for the Southeastern area changed little during 1961-75. Southwest cotton yields have been on a general downward trend since 1965. In the Mid-South, yields also have been declining since the mid-1960s.

Numerous hypotheses regarding potential sources of declining cotton yields have been offered. Hurst suggested poor herbicide application practices, Leigh proposed untimely insecticide use, and Maples indicated excess nitrogen as factors decreasing yields. Brooks discussed soil environment as a yield detriment. Davis and Gallup offered temperature related factors as possible explanations, as did McFarland. Rummel et al. described the bollworm problem in the Texas High Plains, revealing how it may have contributed to declining cotton yields. Orr et al. studied cotton losses due to nematodes in the High Plains, but not over time. All of these studies provide understanding of factors affecting yields, but none analyzed causes of yield trends.

Several analytical studies of factors affecting cotton yields have also been done in recent years, all on yields on an area-wide basis--Mid-South, Southeast, Southwest, and West. Schroder and Headley studied cotton lint yields in the Mid-South for the period 1964-1979. They found that weather variables explained more of the deline in cotton lint yields in Louisiana and Mississippi, but in Arkansas the reductions in applied technology such as fertilizer and herbicides caused more decline in cotton yields than did weather variation. Starbird and Hazera (1983) found that important factors contributing to the variability in cotton yields in the Mississippi Delta, Texas High Plains, and California were temperature, rainfall, acreage planted, and skip-row regulations. These variables explained 82-94% of the variability in cotton yields in the two resource situations (irrigated and non-irrigated), but they did not evaluate the yield trends. Starbird and Hazera (1984) looked at the effects of acres planted, nitrogen application rates, and rainfall and temperature variables on cotton yields in the Southeast (North Carolina, South Carolina, Georgia, Alabama, and Tennessee). These variables explained 86% of the yield variability in North Carolina, Georgia, and Alabama, and 75% of the yield variability in South Carolina and Tennessee.

While the Southwest cotton producing area is experiencing declining cotton yields, the situation varies widely within the area. Cotton yields in the five regions of the Southwest (Lower Rio Grande, Coastal Bend, Blackland, Rolling Plains, and High Plains) show positive cotton yield trends with some indication that yields are stable with the exception of the High Plains region. The five High Plains sub-regions show two distinct yield trends (Figures 2-6); positive for the years 1949-65 and negative for years 1966-82 (Neal, Ethridge, and Stoecker). Therefore, the declining yield trend in the Southwest cotton producing area is due entirely to declining yields in the High Plains.

A decline in cotton yields is a concern because it may affect the per pound production cost and eventually the market price of cotton. In the long-run, cotton would be less able to compete with cotton grown in other countries and with man-made fibers (Neal, Ethridge, and Stoecker). Middlemen who perform marketing services would also have lower incomes from declines in services rendered. However, if the yield decline is in response to economic forces, i.e., rising production costs

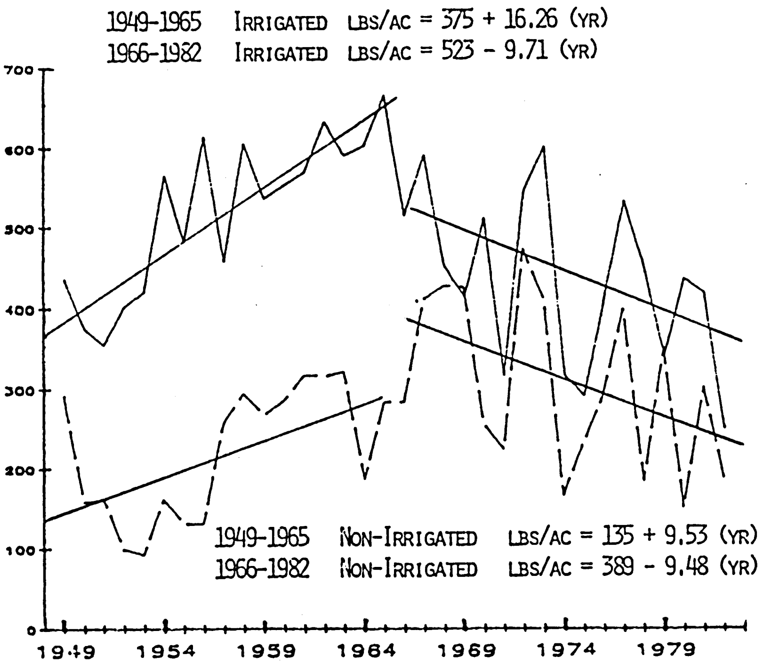

Figure 3. Cotton Yields, Irrigated and Non-Irrigated, Central High Plains.

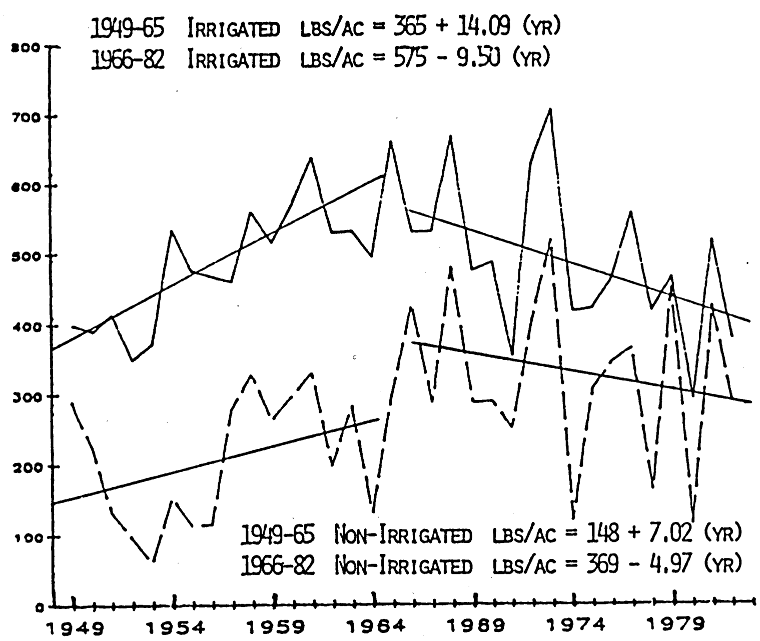

Figure 4. Cotton Yields, Irrigated and Non-Irrigated, Southern High Plains.

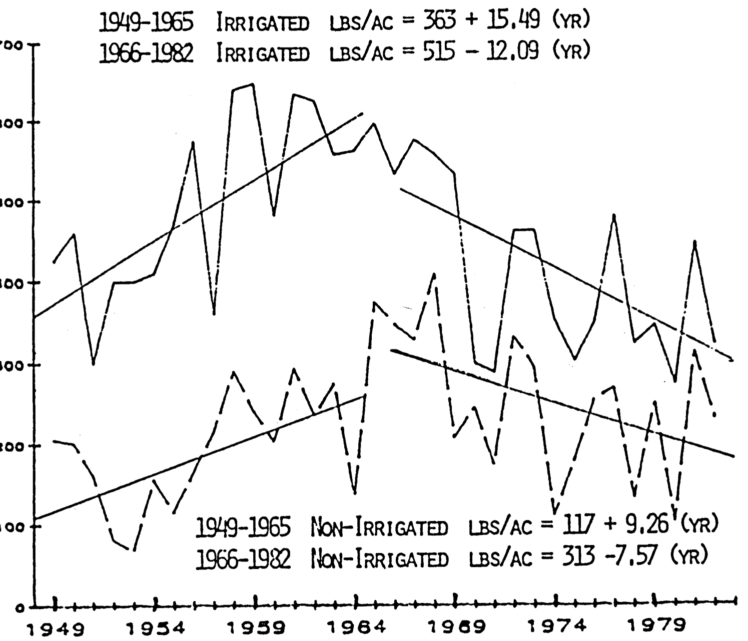

Figure 5. Cotton Yields, Irrigated and Non-Irrigated, Southwestern High Plains.

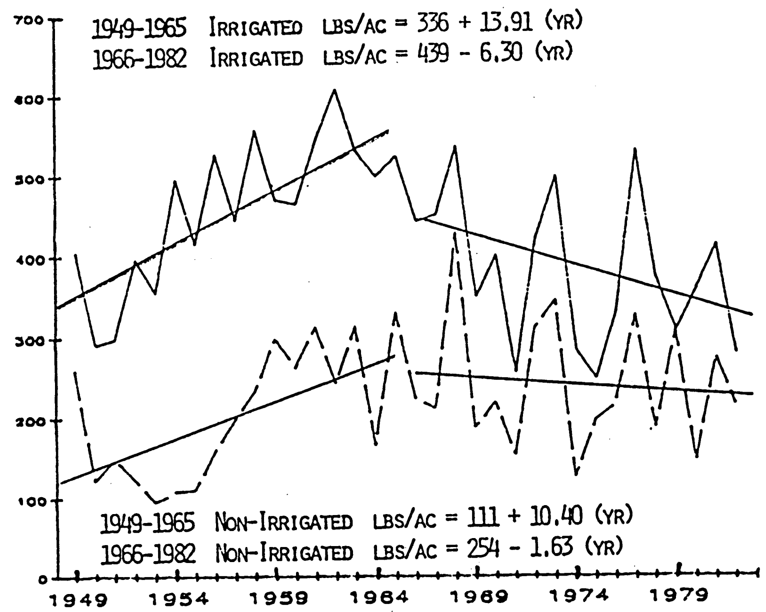

Figure 6. Cotton Yields, Irrigated and Non-Irrigated, Western High Plains.

relative to cotton lint and seed prices, then producers may be making rational and efficient decisions and the decline in cotton yields may be an adjustment to another problem rather than the problem per se. If the cause of the declining yields is environmental, institutional, and/or policy forces, then there is likely a problem of declining efficiency in the industry. Thus, the objective of this study was to identify the major economic, policy, and environmental factors which affect cotton yields in the Texas High Plains and determine the extent to which each explains declining yields.

Methods and Procedures

The general approach was to (1) develop a conceptual model for cotton yield response for the region, considering the data available, (2) use regression analysis to estimate parameters of the model, and (3) interpret the results of the model. Data available for a region-wide study consisted of county, area, state, and national-level secondary data.

Cotton yields change in response to two types of forces: (1) those forces which cause the producer to change the quantity of variable input(s) and move along a production function and (2) those forces which shift a production function either upward or downward (Figure 7). If less of a variable input is used in production, e.g., movement from X_1 to X_2, then less output results; i.e., yield moves from Y_1 to Y_2 on TPP_1. If some external force causes a decrease in yield from TPP_1 to TPP_2, at input level X_1 yield moves from Y_1 to Y_2. Factors which shift a production function tend to be physical or environmental variables.

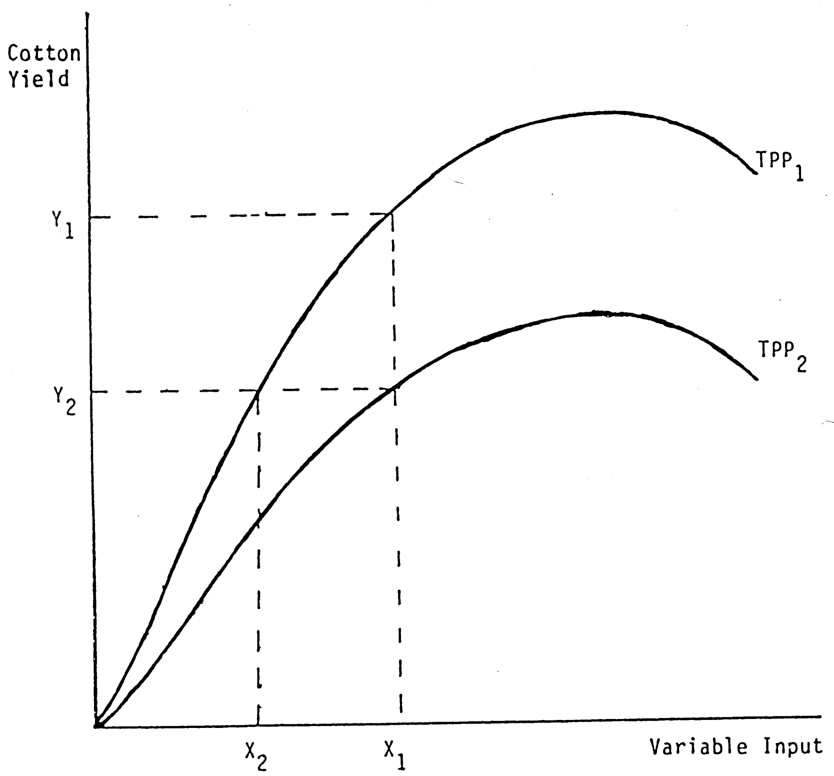

Figure 7. Hypothetical Cotton Production Function.

Those factors which cause the producer to move along a production function tend to be economic or policy variables. The physical/environmental variables cause changes in production <u>without</u> a change in input use, while economic and policy variables cause production to change <u>through</u> a change in input use. The distinction is important because the yield change from a shift in the function results in an increase in the producer's cost structure whereas the input level adjustment may represent an efficient adjustment by producers.

In the conceptual model, both acreage and yield relationships were developed. Acreage equations included government programs in effect for the years of the study, input costs, and commodity prices. Yield equations included acreage harvested, climatic variables, technology, fertilizer prices, and irrigation water available. The acreage variable was included so that those economic and policy factors which have an effect on acres planted and harvested could be linked to the yield equation.

The regression procedures used included ordinary least-squares regression (OLS), autoregressive least squares (ALS), and seemingly unrelated regression (SUR). ALS and SUR were used to correct for statistical problems encountered in the OLS estimation procedures. The variables were then tested for any significant trends for the years 1966-82 and the negative trends explained by the estimated equations were then compared to the actual trends in Figures 2-6. This showed how well the estimated equations explained the negative trend in yields in the Texas High Plains.

The Model

Yield within each sub-area (Figure 1) may be expressed as a function of acreage, climate, fertilization level, technology, and in the case of irrigated cotton, irrigation level. However, these variables must be further defined or disaggregated because they are not readily observable. Climate is composed largely of rainfall and temperature, but the temperature data had too many missing values to be used as an effective variable.

Technology encompasses factors such as improved varieties, herbicides, and insecticides. The aggregated technology indicator used in this study was research and development (R&D) expenditures on cotton production. The effect of R&D expenditures on yields is expected to be a lagged response; i.e., technology adoption occurs over a period of time. Fertilizer use could not be observed, but the level of fertilizer applied, primarily nitrogen, is hypothesized to be a function of the price of nitrogen and the expected price of cotton. Further, the expected price of cotton is based on past prices.

Data on quantity of irrigation water applied in the sub-areas were not available, but irrigation use is affected by quantity of irrigation water available, irrigation fuel cost, and expected price of cotton. Structural equations for non-irrigated and irrigated yields for each of the five subregions were:

$$\begin{aligned} YLD_d = {} & B_1 + B_2ACd + B_3R\&D_{t-1} + B_4R\&D_{t-2} + B_5R\&D_{t-3} \\ & + B_6R\&D_{t-4} + B_7R\&D_{t-5} + B_8R\&D_{t-6} + B_9 \ln PSR \\ & + B_{10}GSR + B_{11}\ln FSR + B_{12}D50 + B_{13}DF + B_{14}\ln Pn \\ & + B_{15}EPc + B_{16}SR1 + B_{17}SR2 \qquad (1) \end{aligned}$$

$$YLDi = B_{18} + B_{19}ACi + B_{20}R\&D_{t-1} + B_{21}R\&D_{t-2} + B_{22}R\&D_{t-3} + B_{23}R\&D_{t-4} + B_{24}R\&D_{t-5} + B_{25}R\&D_{t-6} + B_{26}\ln PSR + B_{27}GSR + B_{28}\ln FSR + B_{29}D50 + B_{30}DF + B_{31}\ln Pn + B_{32}EPc + B_{33}Pf + B_{34}\ln IRR + B_{35}SR1 + B_{36}SR2 \quad (2)$$

where YLD = non-irrigated (d) and irrigated (i) cotton yield in the subregion, lbs/acre;

AC = non-irrigated (d) and irrigated (i) cotton acres harvested in the subregion;

$R\&D_t$ = cotton production research and development expenditures in the U.S. in year t, \$/year;

lnPSR = natural logarithm of total preseason rainfall, January-May, in the subregion, inches;

GSR = total growing season rainfall, June-August, inches;

lnFSR = natural logarithm of total fall season rainfall, previous September-December, inches;

D50 = first date daily low temperature fell below 50°F during growing season, Julian date;

DF = date of first freeze, Julian date;

lnPn = natural logarithm of price of nitrogen, \$/ton;

EPc = expected price of cotton, ¢/lb;

SR1 = skip row policy in effect during the years 1949-61, 1 if 1949-61 and 0 otherwise;

SR2 = skip row policy in effect during the years 1966-67, 1 if 1966-67 and 0 otherwise;

Pf = irrigation fuel cost, ¢/mcf of natural gas;

lnIRR = natural logarithm of quantity of irrigation water available, ft. of saturated thickness/ac.; and

B_i = parameters, i=1,2,..., 36.

In specifying the R&D variable, it was recognized that although funding for research is available in a particular year, its impacts do not occur for several years. Distributed-lag models for the impact of R&D on yields were attempted but provided no satisfactory results. Ten-year lags were considered, but because the number of annual R&D observations were limited, the ten-year lag was judged to be too restrictive. A six-year lag, although a compromise, was used.

Acreage variables are affected by other factors, some of them economic. In order to separate economic forces from other forces impacting yields, acreage must be examined further. The acreage structural equations for two subregions (Northern and Western) were:

$$\begin{aligned} ACd = {} & B_{37} + B_{38}\ln EPc + B_{39}PCcd + B_{40}WHCT + B_{41}MQ \\ & + B_{42}PP + B_{43}TP + B_{44}PIK + B_{45}DP + B_{46}PL1 \\ & + B_{47}PL2 + B_{48}PL3 + B_{49}PL4 + B_{50}PL5 + B_{51}SR1 \\ & + B_{52}SR2 + B_{53}SB \end{aligned} \quad (3)$$

$$\begin{aligned} ACi = {} & B_{54} + B_{55}\ln PROF + B_{56}WHCT + B_{57}CRCT + B_{58}PCwi \\ & + B_{59}MQ + B_{60}PP + B_{61}TP + B_{62}PIK + B_{63}SB \\ & + B_{64}DP + B_{65}PL1 + B_{66}PL2 + B_{67}PL3 + B_{68}PL4 \\ & + B_{69}PL5 + B_{70}SR1 + B_{71}SR2 + B_{72}SB \end{aligned} \quad (4)$$

where lnEPc = natural logarithm of expected cotton prices, ¢/lb;

WHCT = wheat-cotton price ratio, \$/bu ÷ ¢/lb;

MQ = years when acreage controls were in effect, 1 if 1950, 1954-70 and 0 otherwise;

PCcd = variable production costs for dryland cotton, \$/ac;

PCwi = variable production costs for irrigated wheat, \$/ac;

PP = years when two price system in effect, 1 if 1956-64 and 0 if otherwise;

TP = years when target prices and deficiency payments in effect, 1 if 1974-84 and 0 otherwise;

PIK = years when payment-in-kind program in effect, 1 if 1983 and 0 otherwise;

PL1 = years when payment limitation of \$55,000 in effect, 1 if 1971-73 and 0 otherwise;

PL2 = years when payment limitation of \$20,000 in effect, 1 if 1974-77 and 0 otherwise;

PL3 = years when payment limitation of \$40,000 in effect, 1 if 1978 and 0 otherwise;

PL4 = years when payment limitation of $45,000 in effect, 1 if 1979 and 0 otherwise;

PL5 = years when payment limitation of $50,000 in effect, 1 if 1980-83 and 0 otherwise;

DP = years when direct payments in effect, 1 if 1966-73 and 0 otherwise;

SB = years when Soil Bank diversion in effect, 1 if years 1956-58 and 0 otherwise; and

lnPROF = natural logarithm of expected profit, $/ac.

The acreage structural equations for the other three subregions (Central, Southern, and Southwestern) utilized the same variables as the other two sub-areas with the exception of WHCT and CRCT; the grain sorghum price ratio (GSCT) in $/cwt ÷ ¢/lb was used instead. The variable lnPROF is the log of expected cotton price times expected irrigated yield (EYLD), minus irrigated cotton production costs.

By analyzing the effects of variables in equations (3) and (4) on cotton acres in equations (1) and (2), market forces included in the acreage equations can be included in the yield equations.

Data Sources

Data for acreage and yield were from annual county data reported by the Texas Crop and Livestock Reporting Service (Cotton Statistics) for the years 1949-1983. R&D data identified cotton production research expenditures of the state and national levels and were from the U.S. Department of Agriculture (Inventory of Ag. Research). Rainfall and temperature data were from the U.S. Department of Commerce for the years 1949 to 1983 for each county. The observations included total monthly rainfall for each month. Daily temperature data were collected where available, but not used because many observations were missing.

Prices for fertilizer (nitrogen) were from Texas Crop and Livestock Reporting Service (Texas Agricultural ...). These data are state-wide average nitrogen costs. Data for fuel (natural gas) costs, obtained from Energas Corporation, Amarillo, Texas (Huber), were regional prices for natural gas. Data for quantity of irrigation water available (IRR) were obtained from the Texas Department of Water Resources (1981; 1982). The irrigation data were reported every four years beginning in 1959, so interpolation was used for the interim years.

Data for cotton prices and prices of competing goods were taken from various publications of the Texas Crop and Livestock Reporting Service (Texas Agricultural ...). These data were reported as prices for Crop Reporting Districts 1-North and 1-South, according to the breakdown of the counties in the Texas High Plains. Data for variable production costs per acre for both cotton and the competing crops were from Texas Agricultural Extension Service budgets since 1972. For production costs between 1962 and 1972, budgets for selected years were used (Moore et al.; Osborn et al.) and interpolation was used for the years which were missing. Data used for the government policy variables were taken from the U.S. Department of Agriculture (Commodity Credit) and McArthur (1977).

Expectations

Expectation models were developed for EP_c and EYLD. Distributed lag functions for EYLD for each individual county were not statistically significant. The alternative approach of regressing EYLD on the 3-year moving average of yield gave acceptable statistical results for irrigated yields, but all non-irrigated yields were not statistically significant. Twenty-four expected irrigated yield equations were used, one for each county except Howard, for which no statistically significant equation was obtained (see Appendix).

Expected price models for cotton were based on previous prices and loan rates. Prices reported by the Texas Crop and Livestock Reporting Service for cotton, corn, wheat, and grain sorghum were divided into the Northern and Southern Crop Reporting Districts for the High Plains counties. Counties in each district were assigned prices reported for that district. Two equations, one for each district, were developed (see Appendix). The equation for cotton price in the Northern District of the High Plains lagged the prices one year. The equation for cotton price in the Southern District lagged cotton price three years. These equations gave a price for cotton for each year which was compared to the loan rates for cotton in the same year. In comparing the equation prices with the loan rates, the greater of the two was defined as the expected price.

Estimation Procedures

All equations were first estimated using OLS procedures, which assumes independence of the error terms. If this assumption is not valid, then the statistical tests of the estimated parameters are not valid and other procedures must be utilized. The equations were tested for autocorrelation using a Durbin-Watson test. If autocorrelation was present, the ALS procedure was used. If no autocorrelation was found, SUR was used to check for correlation of residuals across equations.

ALS is a statistical technique which corrects for first-order autocorrelation by introducing a lag into the estimation procedure to adjust for the correlated error terms and minimum variance of error terms is obtained. The new estimated equation gives statistical tests which are reliable, and the coefficient estimates are more efficient.

Another problem related to independence of the error terms which was a consideration in this study was that of correlation of error terms between separate equations. It was expected that the error terms for the irrigated and non-irrigated yields, and the non-irrigated and irrigated acreage harvested might be correlated because the various yield and acreage equations contain some of the same variables. If the error terms of the related equations are correlated, OLS does not give efficient coefficient estimates. The SUR technique corrects this problem (Zellner).

Both ALS and SUR increase efficiency in the parameter estimates. However, ALS and SUR cannot be used together in the estimation procedure. When a choice between ALS and SUR was necessary, ALS was chosen. While SUR provides more efficient estimators, autocorrelation invalidates the statistical tests. ALS took precedence over SUR when autocorrelation was present because valid statistical tests were judged to be more important than efficient estimators without valid tests. When there was no evidence of autocorrelation or correlation of residuals across equations, OLS was the appropriate technique.

Analysis of Yield Trends

The purpose of the study was to explain the decline in cotton yields since 1966. Trends in the independent variables which were significant in the estimated equations were examined for the years 1966 to the present. Trend coefficients for independent variables were applied to the yield equations to obtain the pounds per acre increase or decrease in cotton yield explained by the trends in the independent variables. These predicted trends were compared to the actual trends in yields to evaluate the decline in yield explained by the estimated equations.

Findings

Data for R&D expenditures were available only for years 1966-1983, and with a six-year lag only 13 data observations were left for estimating the effects of R&D. Consequently, the R&D variable was not significant and was therefore deleted from the model. In the yield equation, the expected price of cotton was highly correlated with several of the independent variables and was deleted from the model. Also, all variables in the equations which were not statistically significant were deleted from the model so that the results presented below include only variables which are statistically significant.

The most serious problem with the estimated yield equations was the lack of significance of the acreage variable. This imposed limitations on the analysis because of the manner in which the model was structured. These limitations are discussed in more detail below.

Estimated Equations

Tables 1 through 5 show the estimated yield equations for each of the subregions. In all tables, the numbers in parentheses indicate the probability level at which the estimated parameter is statistically significant. The level of significance used to retain variables in the equation was .10.

Autocorrelation was found in the OLS estimates for the Central High Plains and the Southwestern High Plains irrigated cotton yield equations, so the ALS procedure was used. SUR was used for the Northern, Southern, and Western High Plains subregions. The most prominent significant variable throughout the yield equations was fertilizer price (lnPn). It had a significant effect on yields in all but two equations. Pn had a negative effect even on non-irrigated yields in the Northern, Central, and Southwestern High Plains; a one dollar per ton increase in the average fertilizer price decreased Northern High Plains yields by 1.15 pounds per acre and by less than one pound per acre in the other two subregions. For irrigated cotton, a one dollar per ton increase in the fertilizer price decreased yields by 1.91 pounds per acre in the Central High Plains, 1.06 pounds per acre in the Southern High Plains, 1.35 pounds per acre in the Southwestern High Plains, and 0.70 pound per acre in the Western High Plains.

Table 1. Estimated Non-Irrigated and Irrigated Cotton Yields, Northern High Plains.

Dependent Variable	Independent Variables: Constant	lnPSR[1]	lnFSR[2]	lnPn[3]	lnIRR[4]	Estimation Procedure	Statistical Tests: R^2	DW[9]
YLDd[5]	571.78 (.0078)	71.59 (.0336)	56.76 (.0556)	-115.79 (.0152)	--	SUR[7]	.42[8]	--
YLDi[6]	-1594.89 (.0045)	--	--	--	571.07 (.0006)			--

[1]lnPSR = natural log of preseason (Jan.-May) rainfall in inches.

[2]lnFSR = natural log of fall season (previous Sept.-Dec.) rainfall in inches.

[3]lnPn = natural log of price of ammonium nitrate, dollars/ton.

[4]lnIRR = natural log of available water, volume of water in storage/acre.

[5]YLDd = non-irrigated cotton yield, lbs/acre.

[6]YLDi = irrigated cotton yield, lbs/acre.

[7]SUR = seemingly unrelated regression.

[8]Only one R^2 is reported when SUR is the estimation procedure.

[9]Durbin-Watson test statistic (not used with SUR).

Table 2. Estimated Non-Irrigated and Irrigated Cotton Yields, Central High Plains.

Dependent Variable	Independent Variables: Constant	lnPSR	lnFSR	lnPn	GSR[1]	Estimation Procedure	Statistical Tests: R^2	DW
YLDd	271.70 (.1910)	106.79 (.0152)	41.43 (.1131)	-90.39 (.0437)	18.99 (.0008)	OLS[2]	.47	1.60
YLDi	1347.50 (.0003)	--	--	--	-192.48 (.0121)	ALS[3]	.20	--

[1]GSR = total growing season (June-Aug.) rainfall.

[2]OLS = ordinary least squares estimation procedure.

[3]ALS = autoregressive least squares procedure.

Table 3. Estimated Non-Irrigated and Irrigated Cotton Yields, Southern High Plains.

Dependent Variable	Independent Variables: Constant	lnPSR	lnFSR	lnPn	GSR	Estimation Procedure	Statistical Tests: R^2	DW
YLDd	-51.02 (.3809)	82.20 (.0111)	56.19 (.0224)	--	18.05 (.0013)	SUR	.44	--
YLDi	904.69 (.0001)	--	51.76 (.0281)	-106.91 (.0127)	--			--

Table 4. Estimated Non-Irrigated and Irrigated Cotton Yields, Southwestern High Plains.

Dependent Variable	Independent Variables: Constant	lnFSR	lnPn	GSR	Estimation Procedure	Statistical Tests: R^2	DW
YLDd	354.00 (.0168)	51.76 (.0024)	-74.10 (.0201)	20.32 (.0001)	OLS	.62	1.67
YLDi	1003.30 (.0109)	50.10 (.0124)	-135.27 (.1006)	--	ALS	.28	--

Table 5. Estimated Non-Irrigated and Irrigated Cotton Yields, Western High Plains.

Dependent Variable	Independent Variables: Constant	lnPSR	lnIRR	lnPn	GSR	Estimation Procedure	Statistical Test: R^2	DW
YLDd	90.83 (.0800)	60.97 (.0256)	--	--	8.40 (.0176)	SUR	.40	--
YLDi	-448.30 (.2890)	--	344.60 (.0039)	-70.61 (.0986)	--			--

Table 6. Estimated Non-Irrigated and Irrigated Acreage Harvested, Northern High Plains.

Dependent Variable	Independent Variables: Constant	MQ[1]	DP[2]	PL2[3]	WHCT[4]	PCwi[5]	Estimation Procedure	Statistical Tests: R^2	DW
ACd[6]	44.31 (.0001)	25.62 (.0002)	15.39 (.0136)	15.91 (.0482)	--	--	SUR	.54	--
AC_i[7]	204.33 (.0014)	--	--	--	1,748.57 (.0087)	1.47 (.0090)			--

[1]MQ = years with acreage controls in government program, MQ = 1 if year 1950, 1954-70; MQ = 0, otherwise.

[2]DP = years with direct payment in government program; DP = 1 if year 1966-73; DP = 0, otherwise.

[3]PL2 = years with payment limitation of $20,000 in effect ; PL2 = 1 if year 1974-77; PL2 = 0, otherwise.

[4]WHCT = wheat - cotton price ratio, in $/bu ÷ ¢/lb.

[5]PCwi = variable production costs for irrigated wheat, in $/ac.

[6]ACd = non-irrigated cotton acres harvested, thousands.

[7]ACi = irrigated cotton acres harvested, thousands.

The R^2 statistic, which indicates the proportion of variation in yield explained by the independent variables, for most of the equations was relatively low. The only equation which explained more than 50% of the variation in yield was for non-irrigated yield in the Southwestern High Plains. The low R^2s are probably a result of data limitations. For example, data on production practices such as rotations were not available on a county or region basis. Likewise, insect infestations and problems with disease may have a negative effect on yields but could not be analyzed because there were no data.

However, the estimated equations indicate that both economic and physical/environmental variables have affected both non-irrigated and irrigated cotton yields in the Texas High Plains, which follows the general hypothesis of this research. Yet, some major variables hypothesized to affect yield were not significant, most especially the acreage variable. It was expected that the acreage equations would provide greater insight into the effect of the economic and policy variables on yields. However, the acreage variable was not significant in any of the ten yield equations and the hypothesized connection cannot be shown to exist. This reduced the capacity of the model to produce implications regarding effects of economic and policy variables.

Although acreage was not a significant variable in the yield equations, the estimated acreage equations are important for understanding factors which influence acreage decisions. Tables 6-10 show the estimated non-irrigated and irrigated acreage equations, which demonstrate that both economic and policy variables have a significant effect on acreage harvested. The Northern High Plains was the only subregion for which the SUR procedure was used. OLS, ALS, or a combination of both were used for the other subregions. The most common significant variable across acreage equations was the government diversion payment. It was significant in four of the seven equations estimated. In the non-irrigated acreage harvested equations, DP accounted for an increase of 361,522 acres harvested per year in the Southern High Plains, but only 15,393 acres in the Northern High Plains. In irrigated acreage, DP accounted for a decrease of 105,898 acres harvested in the Central High Plains, the only subregion for which DP was significant. Cotton price and relative prices with respect to cotton also were dominant variables in the acreage equations. However, three subregions had no significant variables in the estimated irrigated acreage equations.

Explanation of Yield Trends

Trends in statistically significant independent variables in yield equations for each subregion were examined to determine how much of the decline is explained by the estimated yield relationships. Table 11 shows actual and predicted yield declines in the five subregions for both irrigated and non-irrigated yields. Fertilizer price (Pn) was the only variable which both (1) had an effect on yields across the High Plains and (2) exhibited a trend over time. Preseason rainfall (PSR) was found to have a significant trend for the years 1966-1982, but only in the Northern High Plains. The trend equations for fertilizer price in all subregions and preseason rainfall in the Northern High Plains are shown in Table 12. Other variables had significant effects on yields (Tables 1-5), but no significant trends in those variables for the years

Table 7. Estimated Non-Irrigated and Irrigated Acreage Harvested, Central High Plains.

Dependent Variable	Independent Variables: Constant	lnEPc[1]	PP[2]	MQ	DP	Estimation Procedure	Statistical Tests: R^2	DW
ACd	633.23 (.1910)	235.01 (.0152)	-66.73 (.1131)			OLS	.67	1.55
ACi	592.48 (.0001)	--	--	-80.46 (.0086)	705.90 (.0047)	ALS	.42	--

[1]lnEPc = natural log of cotton price, ¢/lb.

[2]PP = years with two-price system in effect; PP = 1 if year 1956-64; PP = 0, otherwise.

Table 8. Estimated Non-Irrigated and Irrigated Acreage Harvested, Southern High Plains.

Dependent Variable	Independent Variables: Constant	lnEPc	DP	Estimation Procedure	Statistical Tests: R^2	DW
ACd	-2,267.45 (.0001)	767.24 (.0001)	361.52 (.0001)	OLS	.63	1.54
ACi_I	No significant variables					

Table 9. Estimated Non-Irrigated and Irrigated Acreage Harvested, Southwestern High Plains.

Dependent Variable	Independent Variables: Constant	lnPc	PP	Estimation Procedure	Statistical Tests: R^2	DW
ACd	1,054.43 (.0001)	370.93 (.0001)	76.457 (.0280)	ALS	.76	--
ACi	No significant variables					

Table 10. Estimated Non-Irrigated and Irrigated Acreage Harvested, Western High Plains.

Dependent Variable	Independent Variables: Constant	MQ	PP	PL2	Estimation Procedure	Statistical Test: R^2	DW
ACd	319.82 (.0001)	-172.53 (.0001)	-112.07 (.0038)	-169.27 (.0023)	ALS	.57	1.95
ACi	No significant variables						

1966-1982 were found. Program provisions (acreage controls, two-price provisions, diversion payments, and skip row allowances), cotton and competing good prices, and production costs have affected cotton acreage planted and harvested. Thus, these economic and policy variables affect the region's production, but not yields.

The percent error of the estimated trend in Table 11 was computed by subtracting the predicted yield trend from the actual yield trend and dividing by the actual yield trend; i.e., the absolute value of [(actual yield trend - predicted yield trend) ÷ actual yield trend]. Three subregions had equations which did not explain any of the decline in cotton yields. The average percentage error for the yield decline was 38% for irrigated cotton and 52% for non-irrigated cotton.

The finding that acreage had no significant effect on yields differs with other yield studies (Starbird and Hazera; Evans and Bell). The differences may be due to the fact that this study examines the Texas High Plains cotton yields by subregions and is more disaggregated than the other studies which looked at the Southwest cotton producing area as one unit. This analysis raises questions about the validity of the marginal land argument--that yields decline as acreage expands into poorer lands--for the High Plains. A reason that acreage does not affect yields in the Texas High Plains may be that soils are more homogeneous, and therefore, planting more acres of cotton does not decrease cotton yields. In any event, this result limits the ability of this analysis in explanation of declining cotton yields in the Texas High Plains.

Table 11. Actual and Predicted Yield Declines, Non-Irrigated and Irrigated Yields, Texas High Plains Subregions, 1966-1982.

Subregion	Actual Yield Decline		Predicted Yield Decline		Percent Error	
	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated
	lbs/acre/yr					
Northern	-3.13	-2.95	0	-5.70	100	93
Southern	-9.50	-4.97	-7.997	0	16	100
Central	-9.71	-9.48	-14.398	-6.76	48	29
Southwestern	-12.09	-7.57	-10.118	-5.543	16	27
Western	-6.03	-1.63	-5.282	0	12	100

Table 12. Trends in Independent Variables for the Years 1966-1982.

Dependent Variable	Independent Variables		Statistical Tests	
	Constant	TIME	R^2	Pr of greater t [1]
lnPSR	-1.49	.041	.206	.0385
lnPn	-.874	.075	.744	.0001

[1] Significance level of the trend variable.

Summary and Conclusions

Since 1966, annual cotton yields in the Texas High Plains have declined at a rate of about 10 pounds per acre per year. The purpose of this study was to determine which major variables affect cotton yields and what effect the variables have had on Texas High Plains cotton yield declines. Past research aided in determining some variables which may have an effect on yields, such as climate, government policies, cotton and competing good prices, and production costs, acreage, and technology. The data set was constructed from county-level data from 25 High Plains counties and aggregated to the subregion level.

The Texas High Plains region was divided into five subregions based on production practices and resource situations. Non-irrigated and irrigated yield and acreage equations were derived to capture the effects of both economic and policy variables on cotton yields. Twenty equations were analyzed, five each for non-irrigated yields, irrigated yields, non-irrigated acreage, and irrigated acreage. Because not all years in the time series contained data for every variable analyzed and years where data was missing were omitted from the analysis, only seventeen equations were estimated. Three irrigated acreage equations had no significant variables.

A small proportion of the decline in cotton yields in the Texas High Plains in the last 20 years has been explained by this analysis. However, some specific factors which have affected yields were identified and their effects on yield trends determined. Both economic and physical/environmental variables have impacted yields, but specific environmental effects on yield trends were not found. Fertilizer price, an economic variable, was the only variable in the model which consistently explained a substantial amount of the declining yield trends, although pre-season rainfall affected the yield trend in the Northern High Plains. More research is needed, but with a different approach. Future studies should examine factors expected to explain declining yields through field experiments over a period of years and/or crop-specific production function estimation rather than through aggregated data.

In this study, acreage had no direct impact on cotton yields in any of the five Texas High Plains subregions studied. The explanation offered is that soil types in the High Plains are much more homogeneous than in other areas, so the marginal land concept may not be valid in the Texas High Plains.

The general conclusion from this study is that input costs, represented by fertilizer prices, have had a significant effect on declining yields. The rising fertilizer prices suggest that adjustments are being made in input levels, but that does not necessarily imply that these adjustments were optimal. Some yield response analyses, perhaps utilizing production functions, may be needed to explore that question. A final conclusion from this analysis is that secondary county-level data are not appropriate for determining what factors have caused declining yields in the Texas High Plains.

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Appendix

Price Expectations Model

Cotton price expectations for the Southern High Plains Crop Reporting District (Andrews, Bailey, Cochran, Crosby, Dawson, Gaines, Glasscock, Hockley, Howard, Lamb, Lubbock, Lynn, Martin, Midland, Terry, and Yoakum Counties) are shown below; numbers in parentheses indicate the level at which the estimated parameter is statistically significant.

$$Pc_t = \underset{(1379)}{9.405} + \underset{(.0007)}{0.697}\, Pc_{t-1} + \underset{(.0560)}{0.464}\, Pc_{t-2} - \underset{(.0533)}{0.493}\, Pc_{t-3}$$

$R^2 = .487$

where $Pc_{(t-k)}$ = price of cotton, year t-k, k=0,1,2,3.

Price expectations for the Northern High Plains Crop Reporting District (Armstrong, Briscoe, Castro, Deaf Smith, Floyd, Hale, Parmer, Randall, and Swisher Counties) are below.

$$Pc_t = \underset{(.0091)}{13.553} + \underset{(.0003)}{0.568}\, Pc_{t-1}$$

$R^2 = .332$

Yield Expectations Models

Expected yield equations for twenty-four High Plains counties; numbers in parentheses indicated level at which the estimated parameter is statistically significant.

Andrews $\quad YLD_i = \underset{(.1305)}{173.400} + \underset{(.0890)}{0.502}\, TIMA$[1] $\quad R^2 = .144$

[1] TIMA = three-year moving average for irrigated cotton yield.

Armstrong	YLD_i = 548.168 - 0.605 TIMA	R^2 = .146
	(.0700) (.3947)	
Bailey	YLD_i = 279.324 + 0.359 TIMA	R^2 = .085
	(.0064) (.1109)	
Briscoe	YLD_i = 202.889 + 0.560 TIMA	R^2 = .212
	(.0500) (.0136)	
Castro	YLD_i = 199.544 + 0.541 TIMA	R^2 = .164
	(.0749) (.0325)	
Cochran	YLD_i = 205.433 + 0.463 TIMA	R^2 = .116
	(.1118) (.1304)	
Crosby	YLD_i = 180.227 + 0.624 TIMA	R^2 = .196
	(.1296) (.0125)	
Dawson	YLD_i = 599.859 - 0.173 TIMA	R^2 = .010
	(.0099) (.6621)	
Deaf Smith	YLD_i = 199.832 + 0.463 TIMA	R^2 = .093
	(.0749) (.1134)	
Floyd	YLD_i = 194.391 + 0.598t TIMA	R^2 = .149
	(.1671) (.0318)	
Gaines	YLD_i = 136.891 + 0.6616 TIMA	R^2 = .289
	(.2289) (.0119)	
Glasscock	YLD_i = 297.847 + 0.4818 TIMA	R^2 = .120
	(.1340) (.1232)	
Hale	YLD_i = 197.897 + 0.584 TIMA	R^2 = .192
	(.0753) (.0137)	
Hockley	YLD_i = 177.166 + 0.577 TIMA	R^2 = .173
	(.0898) (.0197)	

Lamb	$YLD_i = 216.165 + 0.514\ TIMA$	$R^2 = .156$
	(.0357) (.0277)	
Lubbock	$YLD_i = 178.451 + 0.629\ TIMA$	$R^2 = .205$
	(.1301) (.0104)	
Lynn	$YLD_i = 239.780 + 0.494\ TIMA$	$R^2 = .092$
	(.0974) (.0968)	
Martin	$YLD_i = 690.052 - 0.349\ TIMA$	$R^2 = .018$
	(.0034) (.3740)	
Midland	$YLD_i = 582.325 - 0.2236\ TIMA$	$R^2 = .018$
	(.0046) (.5517)	
Parmer	$YLD_i = 282.492 + 0.4151\ TIMA$	$R^2 = .116$
	(.0100) (.0608)	
Randall	$YLD_i = 282.386 - 0.2386\ TIMA$	$R^2 = .425$
	(.1726) (.5478)	
Swisher	$YLD_i = 165.659 + 0.615\ TIMA$	$R^2 = .232$
	(.0740) (.0061)	
Terry	$YLD_i = 101.238 + 0.7893\ TIMA$	$R^2 = .457$
	(.2123) (.0001)	
Yoakum	$YLD_i = 136.489 + 0.6411\ TIMA$	$R^2 = .298$
	(.1949) (.0105)	

Table A.1. Mean Values of Variables Which Vary Across Subregions.

Subregion	PCwi	lnPSR	lnFSR	GSR	lnAW
	Variables				
Northern	61.17	1.52	1.37	--	3.56
Central	--	1.80	1.50	7.60	--
Southern	--	1.59	1.46	5.98	--
Southwestern	--	--	1.37	6.59	--
Western	--	1.47	--	7.69	3.61

Subregion	ACd	ACi	YLDd	YLDi
	Variables			
Northern	25,392	152,628	216	427
Central	14,477	522,172	256	478
Southern	383,113	120,791	269	491
Southwestern	165,074	190,192	222	459
Western	182,201	347,949	221	422

Table A.2. Mean Values of Variables Which Are Constant Across Subregions.

Variable	Mean Value
lnPc	3.37
MQ	.50
DP	.22
PL2	.11
WHCT	.07
PP	.25
lnPn	4.54