Economic Evaluation of Plant Stress Impacts in the Texas North Plains Region

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Since the turn of the century, technological innovation in production agriculture has given rise to far-reaching changes in the techniques used to produce agricultural commodities in the United States. The transition from horsepower to mechanical power, the widespread use of chemicals, and the development of new and improved seed varieties have resulted in substantial and continuing increases in agricultural productivity. "Revolutions" in agricultural production, such as those mentioned above, have brought about significant shifts in the aggregate supplies of most agricultural commodities. Shifting supplies have had meaningful social and economic impacts in society at large, as well as in the agricultural community. Common to innovation in most American industries, widespread expectations are for technological progress to continue to play a key role in the production of agricultural commodities.

Biotechnology is a rapidly evolving technology, generally expected to make positive impacts on agricultural productivity. Broadly defined, biotechnology includes "any technique that uses living organisms or processes to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses" (Office of Technology Assessment, 1992). Common techniques such as traditional plant breeding and fermentation are part of the broader implication. However, popular use of the term more commonly refers to technologies identified with genetic engineering.

Biotechnology techniques can be used to enhance the ability of plants to counter insects and disease and to tolerate stressful enviromental conditions. The importance of these techniques may first be realized in the amount of time required to develop improved crops. Biotechnology allows for shorter development periods. Researchers can isolate genes that regulate specific crop traits much more quickly than with traditional crop breeding methods. However, the success of new biotechnology, like many innovative technologies, depends largely upon consumer and producer acceptance.

Agricultural productivity is determined by a number of relationships between crop plants and the diverse environments in which they are grown. A crop plant's environment includes all the conditions surrounding and affecting its development. Included within an environment are biotic and abiotic factors which regulate or help determine the crop varieties that may be grown. Factors may be added to the environment to make production possible or to increase productivity of a plant in a given environment. Among applied factors are nutrient levels in the form of fertilizer, irrigation water, and other agricultural inputs. Other unapplied factors include rainfall, insects, soil type, and atmospheric temperatures. Depending upon their intensity, some environmental factors (usually unapplied factors) may be classified as stresses to plants.

A stress situation is an environmental condition affecting plant development in such a way that plants realize a level of growth below the level possible if the environment were characterized by less severe stress. Biotic factors causing stress to crop plants include: insects, weeds, and pathogens. Abiotic factors affecting productivity include: excessively high and low temperatures, water deficit and excess, physical and chemical properties of the soil, electromagnetic energy, growth regulators and pesticides, air pollution, and mechanical damage resulting from among other forces wind, hail, and dust.

Assuming that demand for food will continue to increase as a consequence of the growing world population, increased supplies can only be produced by either expanding production into areas not presently suitable for agriculture, or by raising yields on crop land currently used for production (Heinrichs). Coordinated with traditional plant breeding methods, biotechnology allows researchers to develop and change plant characteristics. Plant species can be modified to have increased resistance to biotic stresses, such as insect infestation, and to better tolerate abiotic stresses, such as extreme temperatures. Yields could be raised on currently producing crop land and production could be introduced into areas previously unsuitable for agriculture. By designing plants with the capacity to counter stressful conditions, researchers may positively affect average production levels and/or reduce production variability. In the particular case of unfavorable climatic growing conditions, it is important to determine the bounds of the current losses, so that realistic expectations can be made about biotechnological developments.

The Specific Situation

Each year environmental stresses prompt significant reductions in crop yields which result in lower than expected producer returns across the United States. Generally regarded as having serious effects on returns to agricultural crop production are weather patterns and conditions during a crop's growing season. Unfavorable and unanticipated weather conditions can lead to economically important reductions in crop yields. In particular, water and temperature stresses are the source of common and significant losses in yields.

Although plant productivity is reduced by stress, significant increases in costs of production also result from efforts to minimize the effects of stress (Heinrichs). In many cases, plant stress reduces economic returns to agricultural production by increasing the cost of production. Decreased total revenue resulting from a reduction in yield and increased cost of production resulting from attempts at controlling damage from stress can result in decreased farm profitability.

Texas farms produce a significant portion of the total production of many major field crops in the United States. In 1993, Texas lead the nation in production of cotton, producing about a third of the country's total cotton crop. Likewise, Texas produced more grain sorghum than any other state, totaling about a third of the total production. Texas placed fourth in the production of winter wheat and tenth in the production of corn in 1993, resulting in 7 percent and 3.4 percent shares of national production, respectively (United States Department of Agriculture).

Upland cotton, grain sorghum, winter wheat, and corn are the primary field crops produced in the Texas Northern Plains Region (TNPR), a 55 county area including Texas Crop Reporting Districts 1-N, 1-S, and 2-N (Figure 1). Production of these crops in the region makes up most of Texas's production. Cotton production for 1993 in the TNPR was 3.8 million bales which was 23 percent of total national cotton production. Regional production of grain sorghum was 56 million bushels, representing 10 percent of grain sorghum production in the United States. Of the 2.4 billion bushels of all wheat produced in the nation, the TNPR produced 70 million bushels. TNPR production of corn in 1993 was 131 million bushels, or approximately 2 percent of corn production in the United States (United States Department of Agriculture).

Semi-arid climatic conditions in the TNPR cause the area to be subject to frequent and unanticipated periods of deficient precipitation and extreme temperatures. The average annual rainfall at county locations in the region ranges from about 15 inches in the southern counties to about 29 inches in the

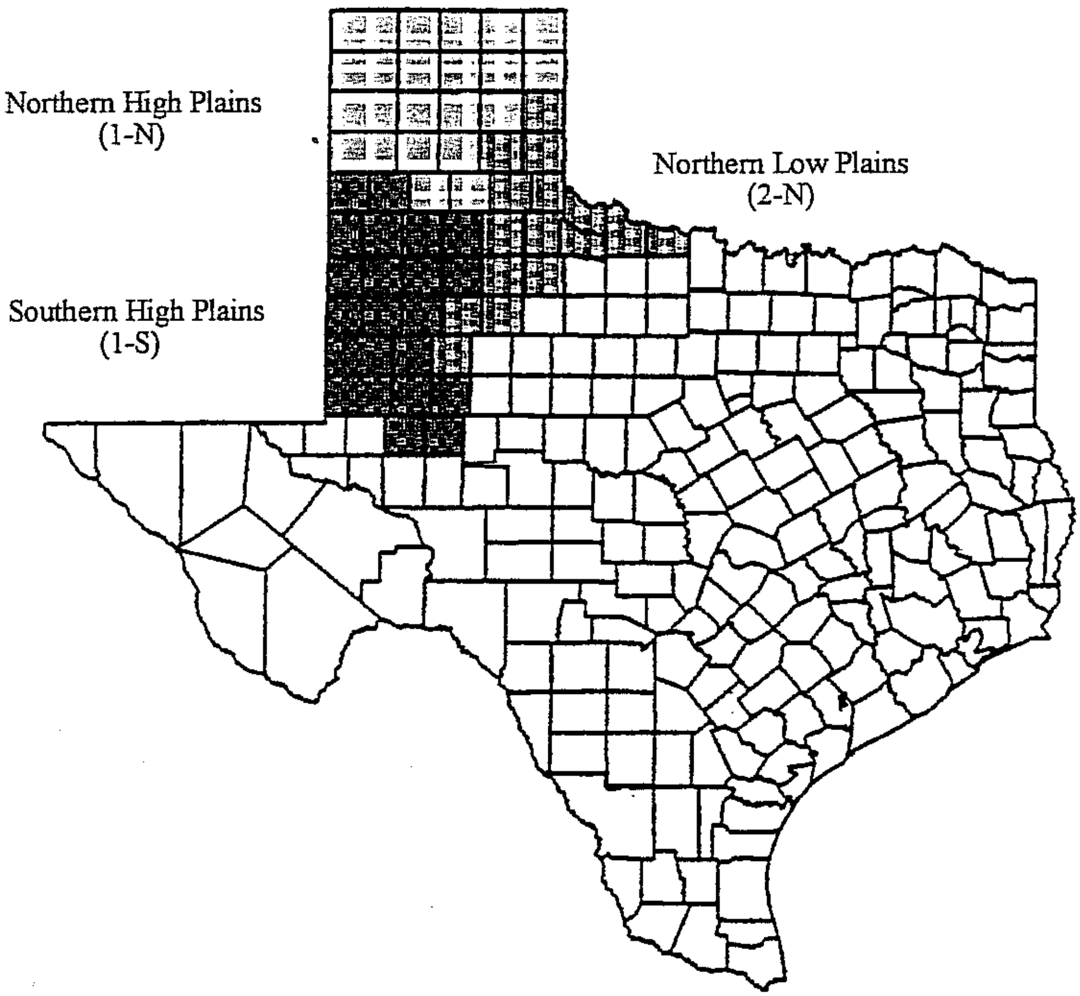

Figure 1. Texas North Plains Region, district boundaries.

extreme eastern counties. However, the dispersion around the mean is significant. Areas have received annual rainfall as little as 8 inches to as much as 45 inches (United States Department of Commerce, precipitation). Likewise, temperatures across the region during the summer growing season can range from below 20 degrees Fahrenheit in the spring to above 120 degrees in the heat of summer (United States Department of Commerce, temperatures). Plant stress resulting from unfavorable variation in precipitation and temperatures reduces realized crop yields from potential levels. Crop yield differentials, the difference between realized crop yields and expected crop yields, ultimately result in lower than expected farm revenues.

Estimates do not exist of the magnitude of reduced production and its economic value from plant stress on principal crops in the TNPR. The estimation of reduced crop production and of the economic value of that production as a result of adverse growing conditions in the TNPR, can aid in recognizing the potential benefits from biotechnology. A high economic value of reduced production would signal an urgent need for mitigation of plant stress through biotechnology.

The general objective of this study is to analyze and evaluate the economic consequences to producers of crop yield variability resulting from plant stress. The specific objectives are to: (a) determine the impacts of precipitation and thermal stress on crop yields in the TNPR, and (b) determine the impacts of precipitation and thermal stress on the profitability of crop production in the TNPR.

Review of Literature

Each crop season, reported crop yields of individual producers, counties, and states fall below producer expectations in many areas of the United States. The shortfall in yield is generally the result of plant stress. Stress may result from among other conditions, insect pest infestation, drought, severe temperatures, and crop diseases. Impacts on crop yields from stress conditions have been estimated by several researchers using different procedures. Estimation of yield losses due to thermal and precipitation stress on crops in the TNPR was made after developing a procedure to facilitate the estimation. The estimation process used in each of the studies in this section was considered in developing the estimation procedure used for this study.

Masud, et al. determined the impact of bollworms on cotton yield in a 20 county region of the Texas High Plains from 1979 to 1981. Using autoregressive procedures, they estimated cotton yield response models. The data used in the estimations were collected from a survey of farmers and secondary data sources. The authors found that bollworms did not have a serious effect on cotton yields when insecticides were applied for pest control.

However, when no insecticides were used, analysis indicated a significant decrease in yield. The study considered the development of bollworm resistance to insecticides. They concluded that the comparative economic position of cotton production in the region could be threatened if insecticide resistance were to develop among insect pests. The estimation procedure used to determine the impact of bollworm infestations involved specification of yield response models.

Thompson used a crop/weather model to determine the impact of weather variability on corn yield from 1891 to 1983. Five states (Illinois, Indiana, Iowa, Missouri, and Ohio) producing over 50 percent of the corn in the nation were included in the study. He employed multiple curvilinear regression analysis of corn yields in a subset of the study period, 1930 and 1983. The variables included in the regressions were 3 time trends and 6 weather factors. The weather factors were preseason precipitation (September through June), June temperature, July rainfall, July temperature, August rainfall, and August temperature. Corn yield was found to be increasing during the period from 1930 to 1960, and the increase accelerated during the period from 1960 to 1972. However, in 1972 the rate of increase slowed, attributed to increased weather variability and a decreased acceleration in the use of fertilizer. Thompson found that the highest corn yields were associated with normal preseason precipitation, normal June temperatures, below normal July and August temperatures, and above normal rainfall in July and August.

Kaylen and Koroma estimated the distribution of U.S. corn yields using a model incorporating a stochastic trend and weather variables. Lagged prediction errors, historical weather data, and the corn yield model were used to develop the distribution of 1989 corn yields. This distribution was developed conditionally upon weather data available prior to the 1989 planting season. The value of this study lies in its development of a model using historical weather information to estimate the empirical distribution of corn yields.

Methods and Procedures

An econometric analysis of production and weather related data was conducted to estimate economic losses from thermal and precipitation stress. Commodity prices received by farmers along with the quantified yield losses were used to determine the economic impacts. Values of the economic losses from precipitation and thermal stress were determined for each of 4 major crops grown in the TNPR. A loss estimate was made for each of 4 crops: cotton, sorghum, wheat, and corn, in each of the 55 counties included in the region (Figure 2). The 4 crops included in the analysis were selected because of their relative economic importance to the region. Cotton, sorghum, and wheat are produced under both dryland and irrigated practices in the TNPR. Corn is presently grown under both practices; however, few counties in the region have

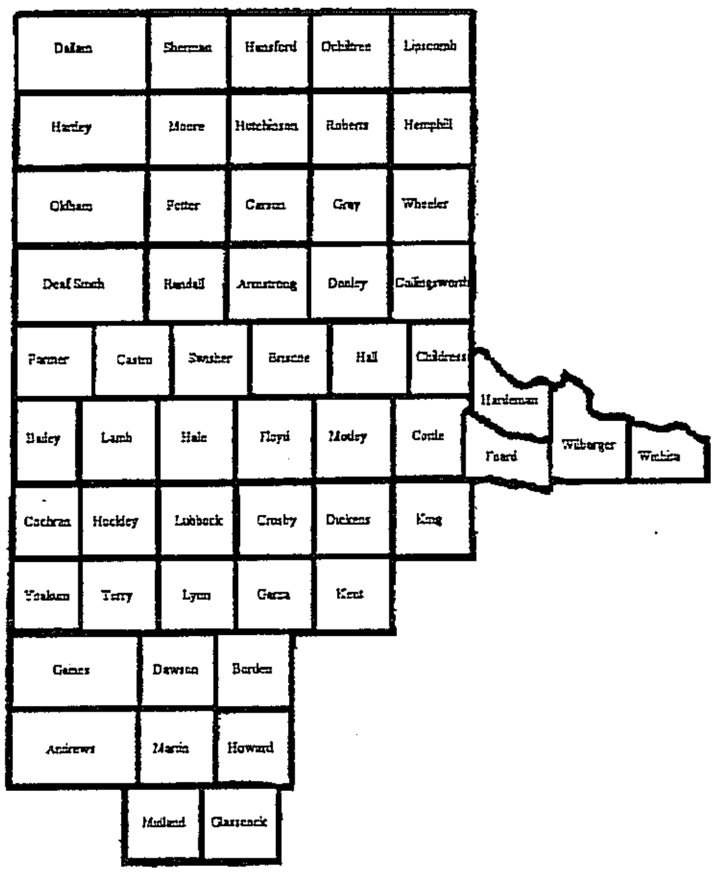

Figure 2. Texas North Plains Region, county names.

only recently begun the production of dryland corn. Therefore, corn was not separated into dryland and irrigated production.

Separate estimates were made for each of the other 3 crops in each county. In counties having both irrigated and dryland production of a crop, estimates were made for each crop and production practice. For example, because no corn is grown in Dawson County and sorghum and wheat are only produced under dryland conditions, estimates of losses were only made for irrigated and dryland cotton, dryland sorghum, and dryland wheat. In contrast, in counties where all 4 crops are grown using both practices, except for dryland corn, 7 loss estimates were determined.

The county-level estimates for each crop were aggregated across counties to generate estimates for each of the 3 crop reporting districts within the TNPR. The crop reporting districts were aggregated to determine an estimate for each crop for the entire TNPR. The county-level estimates were aggregated across crops to assess the estimated total loss for each county. The totals from the county-level estimates were aggregated at both the crop reporting district and the TNPR levels. The economic loss estimates can be described as merely the estimated crop yield loss on a per acre basis multiplied by the number of acres planted to the crop and the appropriate commodity prices received by farmers.

The estimated crop yield losses for each county and crop were made on an annual basis. Each estimate was arrived at by taking an arithmetic average of the calculated annual crop yield losses during the sample period. The annual estimated losses in crop yield from precipitation and thermal stress were calculated using annual crop yield data series spanning the 22 year period between 1972 and 1993. Estimated losses were calculated as the difference between expected crop yields and actual crop yields. The calculated loss estimates will subsequently be referred to as crop yield differentials or simply differentials. Specifically, crop yield differentials were calculated as:

$$Differential_t = Actual\ Crop\ Yield_t - Expected\ Crop\ Yield_t, \qquad (1)$$

where $Differential_t$ is the crop yield differential at time t resulting from precipitation and thermal stress.

Calculation of the crop yield differential required finding the difference between the actual crop yield and the expected crop yield. The actual crop yields were taken from USDA County Crop Statistics. Next, estimations of expected crop yields were made by using ordinary least squares regression. Expected crop yield for each county, crop, and practice combination was estimated by following 3 steps. First, several regression equations relating crop yield to growing season precipitation and daily temperatures were estimated for each county, crop, and practice combination. Next, a selection process was used to choose the most appropriate functional form. Finally, mean values of the independent variables were substituted into the regression equations to derive annual expected crop yield levels for particular county, crop, and practice combinations.

The regression equations were of the following general form:

$$YIELD_t = f(PREC_t, GDU_t, TREND), \qquad (2)$$

where $YIELD_t$ is the actual crop yield, $PREC_t$ is the amount of total precipitation received during the particular crop's growing season, GDU_t is the number of growing degree units during the same growing season, and *TREND* is an incremental variable that captures trends in crop yield levels through time. The variable for precipitation was calculated as the sum across the growing season of monthly precipitation observations collected by the National Climatic Data Center (United States Department of Commerce, precipitation). The growing seasons for each crop are: cotton, May-October; sorghum, May-September; wheat, September-June; and corn, April-September. The growing season for each crop was assumed to hold across counties in the study. The growing seasons are not precisely the same across the wide range of counties in this study, however the selected growing seasons broadly include the general growing season for the TNPR for each crop. For the sake of simplicity and directness, the same growing seasons were used for the entirety of the study.

Also, because of the nature of the winter wheat growing season, beginning in September and terminating in June of the following year, the wheat sample data used in this study begin with the 1973 crop.

The GDU_t variable represents the number of growing degree units during the specified growing seasons. The GDU_t variable is calculated as the sum of daily growing degree units during the growing season. This variable was calculated using daily high and low temperatures obtained from the National Climatic Data Center (United States Department of Commerce, temperatures). The growing degree units for a given day were calculated using the following formulas (Lascano):

Cotton	$GDU = (\text{High} - \text{Low})/2 - 60$	(3)
Wheat	$GDU = (\text{High} - \text{Low})/2 - 32$	(4)
Sorghum	$GDU = (\text{High} - \text{Low})/2 - 50$	(5)
Corn	$GDU = (\min[\text{High}, 90] - \text{Low})/2 - 50.$	(6)

The daily growing degree units for cotton, wheat, and sorghum were calculated by subtracting the daily low temperature from the daily high temperature, dividing the difference by two, and subtracting the constant at the end of the formula. However, the daily growing degree units for corn was calculated a bit differently. Instead of subtracting the daily low temperature from the daily high temperature, the daily low was subtracted from the minimum of the daily high or 90. The rest of the procedure was identical to that for the other 3 crops. The *TREND* variable had a value of 1 for 1972 and increased by 1 each year. Consequently, the *TREND* variable took a value of 22 for the 1993 observation. *TREND* was designed to capture trends in the crop yield levels resulting from improved technologies or production practices.

Fourteen regressions of differing functional forms were estimated for each county, crop, and practice combination. Each combination was tested for a trend pattern in the data. Two sets of 7 functional forms were identical except for the inclusion of the *TREND* variable. Several of the functional forms included quadratic specifications of $PREC_t$ and GDU_t. An interaction term between $PREC_t$ and GDU_t was included in some of the functional forms.

The regression form with the best fit for each crop reporting district (not the best fit for each county) was selected. The form exhibiting the best fit for a specific crop in a specific crop reporting district was made by first grouping the 14 regressions from every county in the crop reporting district. The regressions were then ranked in descending order of the adjusted coefficients of multiple determination (adjusted R-squared). The regression form occurring most frequently in a previously specified upper percentile of the regression ranking was selected as the most appropriate functional form for the particular crop reporting district.

The estimated regression equation for each county in the crop reporting district that coincided with the form selected for the district was used to estimate the county level expected yield. Long-run mean values (from the sample period, 1972 through 1993) for $PREC_t$ and GDU_t were substituted into each county equation. If the appropriate regression form contained the *TREND* variable, the incremental substitution was made, precisely as the variable was defined in the original regressions. That is, the *TREND* variable used for calculating the 1972 expected crop yield level was 1 and the *TREND* variable used for calculating the 1993 expected crop yield level was 22.

The calculations from the regressions with the named values substituted provided the expected crop yield levels for each year by county and practice. The expected crop yields were subtracted from the actual crop yields for each year to develop the annual crop yield differentials. Obviously, the crop yield differentials could take on any value, positive, negative, or zero, depending upon the precipitation and temperatures during the growing season. Because of the definition of crop yield differential, negative crop yield differentials demonstrate a yield loss from the expected or normal yield level. Therefore, only those crop yield differentials having negative values were considered in determining crop yield losses from stress.

Negative crop yield differentials were multiplied by county acreages to calculate estimated lost production for each county, crop, and practice combination. County acreages of each crop came from USDA County Crop Statistics. The crop acreages used to calculate lost production are the "acres harvested" in the given county. Perhaps a better acreage value would be "acres planted for harvest" because the stress conditions likely reduce the acres harvested to the level reported. However, complete data for "acres planted for harvest" are not available.

Lost production of a particular county, crop, and practice combination for each of the 22 years was multiplied by a price reflecting the average price received by producers in the area. The prices were taken from the Texas Agricultural Extension Service Basis Handbook. Because of the spatial differences in prices of grains throughout the TNPR, 3 generally accepted price reporting areas were used for sorghum, wheat, and corn. Prices are given for the area North of the Canadian River which runs across the midsection of the Texas Northern High Plains (Texas crop reporting district 1-N). Calculations using this price series were for the counties north of the Canadian River and the counties through which the Canadian River flows. Prices are given for the triangle area from Plainview to Canyon to Farwell. Calculations using this price series were for all counties on a map that lie within the plane perpendicular to Randall County (Canyon) and the plane perpendicular to Hale County (Plainview). Prices are also given for the area south of the line from Plainview to Muleshoe. All of the counties not covered by the other 2 price series were included in the area covered with this series. The cotton price for the entire region was the price of cotton at Lubbock.

The price series taken from the Basis Handbook were only available for 1977 through 1989. Clearly, the series does not match the production series. To estimate prices for 1972-1976 and 1990-1993 the appropriate price series were extrapolated to the missing years. The extrapolated prices resulted from regression of the particular series (1977-1989) on a Texas state price series. The regression produced a relationship between the area price and the state price. Because the state price series was known for the entire sample period, the relationship was assumed to hold for the missing years. Prices were calculated for the missing years using the regression equations.

The appropriate price series was multiplied by the lost production to determine the yearly nominal value of lost production for every county, crop, and practice combination. The nominal value of lost production was deflated to 1993 real U.S. dollars. The price deflator selected was the Index of Prices Received reported by the USDA for cotton, feed grains (sorghum and corn), and food grains (wheat). Annual losses for the period 1972-1993 expressed in 1993 real value were averaged to come up with the estimate of annual economic loss due to precipitation and thermal stress. The county estimates were aggregated to develop aggregate economic loss estimates.

Results

Statistical and economic analyses were conducted to estimate the value of lost production resulting from thermal and precipitation stress in the 4 most important crops (cotton, sorghum, wheat, and corn) in the 55 counties of the TNPR for 1972-1993. This region includes the following crop reporting districts: the Northern High Plains (Crop Reporting District 1-N), the Southern High Plains (Crop Reporting District 1-S), and the Northern Low Plains (Crop Reporting District 2-N). Overall, the TNPR is made up of 55 counties.

The results of the economic impact analysis show that the farm level expected economic losses in the TNPR due to thermal and precipitation stress are estimated to be slightly over $139 million per year (Table 1). This represents about 5.8 percent of the value of the state's production of the 4 crops. It is important to point out that a significant proportion of these losses, over 62 percent ($87 million), is expected to occur in cotton production, while just over 11 percent ($16 million), 16 percent ($23 million), and 8 percent ($11 million) are attributed to sorghum, wheat, and corn, respectively. Also, it is important to point out that the Southern High Plains (Crop Reporting District 1-S), due to the relatively high concentration of cotton production, is expected to experience the highest sub-regional impact at approximately $65 million per year. The other districts are expected to have annual losses of $56 million for the Northern High

Table 1. Expected regional and district losses, in 1993 dollars.

	Irr Sorghum	Dry Sorghum	Irr Cotton	Dry Cotton	Corn	Irr Wheat	Dry Wheat	All Crops
Northern High Plains	7,168,709	2,709,766	14,657,351	2,463,388	9,645,124	10,786,435	8,124,315	55,555,087
Southern High Plains	2,419,505	3,923,206	21,610,897	33,833,974	1,788,526	617,301	636,507	64,829,916
Northern Low Plains	0	443,820	1,345,277	13,664,373	0	44,680	3,223,049	18,721,199
TNPR	9,588,215	7,076,792	37,613,524	49,961,735	11,433,649	11,448,416	11,983,870	139,106,202

Plains (Crop Reporting District 1-N) and $19 million for the Northern Low Plains (Crop Reporting District 2-N). Tables 2 through 5 depict the breakdown of estimated losses by crop (irrigated and dryland) for the entire region and by district for the period of the study.

Inspection of Table 2 reveals a significantly higher loss in 1980 than in any other year in the sample period. Greater losses in 1980 are explained by the fact that many areas experienced the lowest precipitation during the summer growing season of all the years included in the sample period. However, if estimated losses for 1980 are removed from the total, the annual farm level expected economic loss would be about $109 million.

The agricultural crop production industry significantly impacts the broader Texas economy. In 1993, Texas production of the 4 crops in this study yielded cash receipts of about $2.2 billion (Texas Department of Agriculture). To derive an estimate of the annual total impact on the Texas economy, Type 2 multipliers of the Texas Input-Output model for irrigated and dryland crops (Texas Comptroller of Public Accounts), which include the economic impacts of household expenditures, were applied to the annual expected economic losses (Table 6). The overall state impact of thermal and precipitation stress in the TNPR is estimated to be slightly over $468 million per year (approximately 6.3 percent of the value of the economy-wide impact of the 4 crops considered).

Table 2. Estimated losses for the Texas North Plains Region, in 1993 dollars.

	Irr Sorghum	Dry Sorghum	Irr Cotton	Dry Cotton	Corn	Irr Wheat	Dry Wheat	All Crops
1972	591,084	83,303	0	34,908	121,724			
1973	347,867	267,133	0	239,247	606,443	3,448,745	56,858	4,966,293
1974	22,821,204	26,151,688	29,271,962	35,012,263	23,370,485	95,087,309	40,001,481	271,716,392
1975	6,313,126	3,747,341	42,973,328	15,816,001	10,388,977	8,099,350	10,568,369	97,906,493
1976	25,211,590	8,593,586	29,272,437	10,897,957	5,278,414	10,089,075	11,060,857	100,403,917
1977	11,356,680	4,544,595	0	2,772,819	45,911,015	2,303,895	4,581,308	71,470,311
1978	21,185,928	5,859,893	26,299,245	128,036,579	23,806,970	12,351,859	20,864,527	238,405,001
1979	4,039,970	1,220,811	95,159,665	3,756,872	3,827,614	1,527,316	370,095	109,902,341
1980	38,567,702	26,331,558	162,389,674	444,421,705	65,919,213	22,300,094	9,078,214	769,008,159
1981	8,770,118	3,869,959	29,749,567	19,572,121	632,331	5,111,224	44,498,718	112,204,038
1982	10,246,974	6,513,680	83,116,026	55,200,165	7,855,795	4,892,603	18,527,513	186,352,756
1983	22,987,123	22,381,849	67,168,507	85,614,761	6,515,871	116,396	205,855	204,990,361
1984	6,192,124	14,478,827	35,716,777	64,005,147	1,207,233	618,442	13,586,856	135,805,405
1985	10,086,228	6,512,628	71,133,322	21,530,900	3,458,715	123,713	854,178	113,699,683
1986	3,848,785	1,379,183	44,668,339	50,523,272	263,255	5,915,793	14,170,863	120,769,490
1987	1,351,791	362,223	4,067,258	0	341,607	3,939,086	3,047,731	13,109,697
1988	1,330,704	540,121	2,370,712	7,575,672	3,589,981	16,562,391	12,918,909	44,888,491
1989	8,184,382	4,680,451	34,510,615	65,778,830	7,606,289	34,256,688	33,921,488	188,938,742
1990	2,312,456	7,770,749	378,989	15,263,688	12,216,564	3,585,854	3,057,845	44,586,144
1991	509,457	1,111,532	56,912,804	61,895,682	13,277,367	3,905,110	4,619,000	142,230,952
1992	988,908	355,327	8,800,934	1,793,743	261,941	1,587,531	2,322,177	16,110,560
1993	3,696,526	8,932,988	3,537,379	9,415,842	15,082,477	4,594,265	3,348,439	48,607,917

Table 3. Estimated losses for the Northern High Plains (Crop Reporting District 1-N), in 1993 dollars.

	Irr Sorghum	Dry Sorghum	Irr Cotton	Dry Cotton	Corn	Irr Wheat	Dry Wheat	All Crops
1972	12,244	0	0	455	121,724			
1973	324,066	231,375	0	0	0	3,448,745	0	4,004,186
1974	14,049,147	7,306,295	14,537,081	1,431,592	18,378,796	93,188,377	29,481,258	178,372,546
1975	6,200,259	2,373,495	17,367,286	992,674	8,158,073	7,153,291	10,515,892	52,760,971
1976	19,096,133	1,461,895	14,521,239	679,554	3,444,930	9,409,091	5,210,301	53,823,142
1977	9,821,435	894,237	0	0	42,384,620	2,118,856	3,036,036	58,255,185
1978	17,798,641	1,203,795	5,918,298	9,486,735	19,690,800	12,165,023	14,118,635	80,381,926
1979	3,832,717	878,933	56,762,998	1,974,119	3,803,029	721,846	37,032	68,010,673
1980	31,467,232	11,112,404	30,138,961	17,428,809	54,525,871	21,348,843	5,201,452	171,223,571
1981	7,855,708	3,356,974	25,093,496	2,414,757	238,494	4,725,368	32,972,072	76,656,869
1982	3,791,924	2,638,666	32,228,445	4,520,720	6,382,397	4,610,878	16,175,511	70,348,541
1983	16,130,956	7,953,334	35,743,291	4,839,330	4,906,272	39,989	36,025	69,649,195
1984	4,734,120	10,191,013	2,267,721	1,247,721	802,022	108,466	6,596,485	25,947,547
1985	6,531,443	2,073,165	30,622,670	2,861,625	2,667,201	13,799	324,329	45,094,230
1986	1,179,045	495,296	4,164,148	621,883	51,124	4,024,545	11,627,351	22,163,392
1987	1,114,168	61,323	4,067,258	0	296,237	2,898,786	1,543,250	9,981,022
1988	678,156	177,319	2,321,547	0	3,589,981	15,882,090	12,072,648	34,721,741
1989	7,610,686	2,502,070	23,345,040	3,495,961	5,642,633	32,203,271	12,494,299	87,293,960
1990	1,843,093	3,301,513	193,572	648,687	11,237,110	3,073,057	2,811,950	23,108,982
1991	0	264,782	17,226,924	377,869	10,526,990	3,409,682	3,190,634	34,996,881
1992	988,908	291,386	5,941,740	1,172,051	261,941	1,587,531	969,168	11,212,725
1993	2,651,527	845,584	0	0	15,082,477	4,383,598	2,196,280	25,159,466

Table 4. Estimated losses for the Southern High Plains (Crop Reporting District 1-S), in 1993 dollars.

	Irr Sorghum	Dry Sorghum	Irr Cotton	Dry Cotton	Corn	Irr Wheat	Dry Wheat	All Crops
1972	578,840	0	0	0	0			
1973	23,801	35,758	0	239,247	606,443	0	56,858	962,107
1974	8,772,058	16,928,161	13,433,463	23,017,696	4,991,689	1,762,018	1,477,390	70,382,475
1975	112,867	1,274,503	25,053,813	14,415,555	2,230,905	840,951	916	43,929,510
1976	6,115,458	6,463,438	11,238,770	2,014,009	1,833,484	679,984	1,135,603	29,480,747
1977	1,535,244	3,451,888	0	979,569	3,526,394	185,038	115,266	9,793,399
1978	3,387,288	3,931,887	20,329,330	97,877,098	4,116,170	134,584	1,145,479	130,921,835
1979	207,253	125,124	38,000,624	1,464,975	24,585	805,470	331,739	40,959,771
1980	7,100,470	13,918,786	121,570,514	300,140,727	11,393,342	925,527	946,122	455,995,487
1981	914,410	347,753	2,669,734	579,715	393,837	195,011	709,418	5,809,879
1982	6,455,050	3,653,475	48,828,177	34,140,769	1,473,398	281,725	1,113,787	95,946,383
1983	6,856,166	13,372,900	28,626,932	44,904,989	1,609,599	76,407	7,449	95,454,443
1984	1,458,003	2,808,838	31,696,923	46,520,319	405,212	444,196	2,573,235	85,906,726
1985	3,554,785	4,229,590	40,462,304	17,818,505	791,514	109,915	91,089	67,057,701
1986	2,669,740	589,352	39,953,160	38,659,036	212,131	1,891,248	350,273	84,324,940
1987	237,624	292,342	0	0	45,371	994,413	403,007	1,972,757
1988	652,547	262,375	12,644	0	0	605,150	627,284	2,160,000
1989	573,696	1,886,128	8,796,370	46,014,409	1,963,655	1,820,099	1,560,461	62,614,818
1990	469,363	4,142,677	185,416	13,503,460	979,454	508,936	22,933	19,812,238
1991	509,457	825,589	38,355,863	55,365,521	2,750,377	494,060	540,591	98,841,458
1992	0	0	2,688,308	288,460	0	0	0	2,976,768
1993	1,044,999	7,769,969	3,537,379	6,403,359	0	208,595	157,751	19,122,052

Table 5. Estimated losses for the Northern Low Plains (Crop Reporting District 2-N), in 1993 dollars.

	Irr Sorghum	Dry Sorghum	Irr Cotton	Dry Cotton	Corn	Irr Wheat	Dry Wheat	All Crops
1972		83,303	0	34,452				
1973		0	0	0		0	0	0
1974		1,917,231	1,301,418	10,562,975		136,915	9,042,833	22,961,371
1975		99,343	552,229	407,772		105,108	51,561	1,216,013
1976		668,253	3,512,428	8,204,395		0	4,714,952	17,100,028
1977		198,470	0	1,793,249		0	1,430,006	3,421,726
1978		724,211	51,618	20,672,746		52,251	5,600,413	27,101,240
1979		216,753	396,043	317,777		0	1,323	931,897
1980		1,300,368	10,680,200	126,852,169		25,724	2,930,640	141,789,101
1981	No	165,232	1,986,336	16,577,649	No	190,844	10,817,229	29,737,291
1982	Production	221,538	2,059,403	16,538,676	Production	0	1,238,215	20,057,833
1983		1,055,616	2,798,284	35,870,442		0	162,381	39,886,723
1984		1,478,975	1,752,132	16,237,108		65,780	4,417,136	23,951,132
1985		209,873	48,349	850,770		0	438,759	1,547,751
1986		294,535	551,031	11,242,354		0	2,193,239	14,281,158
1987		8,558	0	0		45,887	1,101,474	1,155,918
1988		100,428	36,521	7,575,672		75,152	218,977	8,006,750
1989		292,253	2,369,205	16,268,460		233,318	19,866,728	39,029,965
1990		326,560	0	1,111,542		3,861	222,961	1,664,924
1991		21,160	1,330,017	6,152,292		1,368	887,775	8,392,613
1992		63,940	170,886	333,231		0	1,353,010	1,921,067
1993		317,436	0	3,012,484		2,072	994,408	4,326,399

Table 6. Expected Texas economy-wide impact, in 1993 dollars.

	Irr Sorghum	Dry Sorghum	Irr Cotton	Dry Cotton	Corn	Irr Wheat	Dry Wheat	All Crops
Northern High Plains	23,902,520	9,217,131	48,871,784	8,379,089	32,159,591	35,965,048	27,634,442	186,129,606
Southern High Plains	8,067,321	13,344,586	72,056,888	115,084,535	5,963,454	2,058,258	2,165,047	218,740,089
Northern Low Plains	0	1,509,630	4,485,538	46,478,669	0	148,976	10,963,036	63,585,849
TNPR	31,969,841	24,071,347	125,414,210	169,942,294	38,123,045	38,172,282	40,762,524	468,455,544

Summary and Implications

The general objective of this study was to analyze and evaluate the economic consequences to producers of crop yield variability resulting from plant stress caused by drought and unfavorable temperature extremes. Economic losses due to plant stress in 4 major crops grown in the Texas North Plains Region were estimated using econometric analyses of production and weather-related data. The results of the economic impact analysis show that the farm level expected economic losses in the TNPR due to thermal and precipitation stress are estimated to be slightly over $139 million per year. Over 60 percent of the expected economic losses are in cotton, a crop having significant economic importance to the TNPR. The Type 2 multipliers of the Texas Input-Output model were used to estimate the Texas economy-wide expected impact of thermal and precipitation stress at about $468 million per year.

The magnitude of expected farm level losses and the impact of the expected losses on the Texas economy emphasize potential benefits from biotechnological research in the TNPR. Significant economic benefits could be gained through the development of biotechnologies that mitigate thermal and precipitation stress. Only biological research will determine the actual yield gains from stress mitigation, however, probable yield gains in crop plants genetically designed to tolerate drought conditions and extreme temperatures are expected to lead to higher producer profitability. Given that over 20 percent of cotton production and 10 percent of sorghum production in the United States takes place in the TNPR, the significance of the expected economic losses from these 2 crops could reveal important economic potential, especially for genetically engineered cotton and sorghum varieties.

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