B-1650
November 1990

Optimal Cropping Strategies Considering Risk: *Texas Trans-Pecos*

The Texas Agricultural Experiment Station, Charles J. Arntzen, Director, The Texas A&M University System, College Station, Texas

[Blank Page in Original Bulletin]

Optimal Cropping Strategies Considering Risk: Texas Trans-Pecos

John R. Ellis, Assistant Professor
Agricultural Economics
Washington State University

Ronald D. Lacewell, Professor
Agricultural Economics
Texas A&M University

Jaroy Moore, Professor
Soil Physics
Texas Agricultural Experiment Station - Pecos, Texas

James Richardson, Professor
Agricultural Economics
Texas A&M University

[Blank Page in Original Bulletin]

Table of Contents

[Blank Page in Original Bulletin]

Executive Summary

High production costs and several years of poor output prices have placed most Texas Trans-Pecos agricultural producers in poor financial health. Many are operating with small or negative net worth, prompting most commercial lenders to abandon the area. Currently, surviving producers rely heavily on government farm programs including the commodity loan and target prices programs and operating loans from the Farmer's Home Administration. Reductions in government price and income support levels within the 1985 farm bill will likely lessen profit potential even further.

This analysis examines alternative paths of adjustment for the remaining producers in the region. This study was designed to identify the mixture of crops or irrigation levels, given the high cost of irrigation water and declining government support, that would provide the best chance of reducing current high debt loads and help ensure survival of the firm.

Two simulation models were employed in answering the question posed above. Recent advances in biophysical modelling offer the opportunity to examine a variety of production questions without resorting to expensive and time-consuming field trials. The EPIC (Erosion Productivity Impact Calculator) generalized crop growth model, originally developed by the U.S. Department of Agriculture (Williams et al.,1984a), was used to develop yield distributions for selected row crops and various irrigation schemes for cotton. EPIC is designed to reflect numerous aspects of the crop production process including weather, hydrology, sedimentation, nutrient cycling, plant growth, tillage, soil temperature, and irrigation effects. Detailed soil, yield, and historical weather information were combined to calibrate EPIC crop parameters for the Trans-Pecos.

A second simulation model, known as FLIPSIM (Firm Level Policy Simulation Model) and developed by Richardson and Nixon, was also employed within this study. FLIPSIM is a FORTRAN-based simulation model, which may be used to reflect annual production, farm policy, marketing, financial management, and income tax considerations within a multi-year framework. FLIPSIM has an imbedded single year linear and quadratic programming model, which can be used to formulate optimal annual cropping plans based upon changing price and yield expectations. FLIPSIM may be used to track key financial variables including debt, net worth, annual income, government payments, and ending equity for up to 10 years. Conditions for continued economic survival can also be specified, thereby allowing one to calculate probabilities of firm survival by performing numerous multi-year simulations.

Research Organization

The importance of cotton within the region prompted an emphasis on irrigation levels for that crop. Twelve furrow- and 13 sprinkler-irrigation schemes for various levels of farm program cotton yield were examined. These alternatives included furrow-irrigation schemes with a preplant irrigation and alternatively, schemes in which the seed are planted before any irrigation and then irrigated to get germination (postplant irrigations only). Varying numbers of additional postplant irrigations may then be applied.

Budgets developed for the various irrigation schemes, plus EPIC simulated yields, were used to generate distributions of whole-farm net returns assuming an all cotton crop mix. Generalized stochastic dominance techniques (Meyer) were then employed to rank the various schemes. The latter step also entails eliciting utility of net returns points from several producers and estimating Pratt risk coefficients. Once determined, the dominant cotton irrigation schemes were combined with the remaining noncotton crops (barley, forage sorghum, red top cane, and grain sorghum) in several 3-year rotation schemes. EPIC simulations for these rotations revealed only small impacts upon cotton yields. Because there was very little effect of crop rotation upon cotton yield, plus the assumed short relevant time horizon of producers with high debt loads, the analysis was based on a single year quadratic programming model with FLIPSIM to generate cropping plans in each year of simulation. Strong rotational effects may have necessitated use of a multi-year planning model.

Conditions on a 1,600-acre representative farm with 720 acres of cotton base and 360 acres of small grain base were then simulated using FLIPSIM. Five possible cotton irrigation schemes plus four noncotton crops were included as cropping alternatives. Survival of the farm firm was liberally defined as maintaining a debt-to-equity ratio below 90 percent. Fifty, 5-year simulations for numerous scenarios concerning water availability, farm program yield, tenure arrangement, and starting debt were performed. Resulting probabilities of survival were calculated based upon the number of simulations that proceeded for the full 5-year period.

Similar calculations were made concerning the probability of realizing a 5 percent return on beginning equity.

Results

Stochastic dominance analysis of furrow-irrigated cotton schemes indicated a preference for the 10-acre-inch preplant schemes over the 8-acre-inch preplant schemes or the water-up schemes. Ranking of sprinkler-irrigation schemes, consisting of two 3-acre-inch preplant irrigations plus varying postplant irrigations, showed a preference for more water per application as the base cotton yield increased. With an 800-pound base yield, 18 postplant acre-inches applied in 2-acre-inch increments was preferred. Application rates of 2.4 and 3.0 acre-inches dominated for the 1,000- and 1,200-pound base yield cases. These schemes applied 24 and 30 postplant acre-inches of water, respectively. Rankings for the sprinkler schemes indicated a preference for a number of applications rather than a given rate. Each of the top schemes has 9 or 10 postplant applications in addition to the preplant irrigations.

Whole-farm simulation results covered a variety of scenarios and indicated the importance of water availability in the area. The furrow-irrigation analysis was based on varying water availability conditions (four, six, or nine 700-gpm-wells) and conditions of medium and high starting debt. The medium debt scenario assumed that 50 percent (70 percent) of the value of long (intermediate) term assets was still outstanding. Asset percentages outstanding in the high starting debt scenario were 60 and 80 percent, respectively, for the long and intermediate debt classifications. Cropping pattern effects included a mixture of cotton irrigation schemes plus minor acreages of barley and forage sorghum in the four 700-gpm-well scenarios. Water resource limitations in this scenario resulted in a mixture of irrigation schemes, a conclusion not possible using stochastic dominance analysis alone. Greater water availability in the six- and nine-well scenarios prompted selection of a single cotton irrigation scheme and increased forage sorghum acreages. Barley production remained almost nonexistent because of relative price disadvantage.

Cropping pattern results for the 1,000-pound base, yield-sprinkler scenarios showed similar results. Limited water supplies in the three-well (1,000 gpm/well) scenario resulted in use of two irrigation schemes. Increased water supplies in the five- and seven-well scenarios lessened or removed the necessity of mixing cotton irrigation schemes. The apparent preference for a given number of irrigation applications indicated in the preliminary stochastic dominance analysis did not appear in the quadratic programming results. In some cases, schemes that ranked as low as third for a given base yield level had the highest crop acreage in the quadratic programming cropping plan.

Firm survival and economic indicator results for the various scenarios reflected the importance of water availability as well as beginning debt. For furrow-irrigated farms with four 700-gpm-wells, a 750-pound base cotton yield, and a medium starting debt position,the probability of survival was estimated as 100 percent. This value fell to 58 percent for producers in the high starting debt situation. Probabilities of success (realizing a 5 percent return on beginning equity) were 10 and 2 percent for the two scenarios, respectively. Sprinkler-irrigation results were similar. Probabilities of success and survival generally increased with increased water supplies. Despite the high probabilities of survival reported above, producer net worth declined in all cases over the simulated 5-year period. Average declines, across the various furrow-irrigated scenarios examined, range from 13 to 94 percent with similar values applying for the sprinkler runs.

Conclusions

Results of this analysis indicate that highly leveraged producers in the Texas Trans-Pecos will very likely not survive the reductions in target prices embodied in the 1985 and proposed for the 1990 farm bill. For those that attempt to do so, their chances are increased by use of more water-intensive, cotton irrigation schemes (i.e., preplant schemes with 10-acre-inches vs. 8 acre-inches, or the heavier sprinkler schemes). Even with cotton target prices in the $0.70 to $0.80 range, the analysis predicts continued declines in farm net worth for medium- and highly leveraged producers. Several consecutive years of above-average prices and yields would likely be required to remove the current debt load and assure a sound agricultural economy in Texas Trans-Pecos.

Acknowledgements

Special thanks go to David Bessler and J. Rod Martin who gave freely of their expertise concerning numerous facets of this study. Their contributions added greatly to the depth and scope of this effort.

Numerous other individuals contributed valuable time and energy. James (Jimmy) Williams of the U.S. Department of Agriculture, Blacklands Research Center at Temple, spent many hours explaining various aspects of the EPIC crop growth model. Dan Taylor and Alan Jones, also at Temple, gave freely of their time as well. Rich Patterson and Charles Stichler (Texas Agricultural Extension Service, Ft. Stockton) aided greatly in interviewing area producers and determining relevant cropping alternatives. Special thanks go to the numerous farmers that participated. They each took time out from busy schedules. We hope that results presented here will, in some way, repay them for their time. Lastly, the authors express their deep gratitude to Ed Rister, John Stoll, and Wyatt Harman for their in-depth review and many helpful comments.

Optimal Cropping Strategies Considering Risk: Texas Trans-Pecos

John R. Ellis, Ronald D. Lacewell, Jaroy Moore, and James Richardson

Introduction

Over the last decade and a half, the Trans-Pecos region of Texas has experienced major changes in input prices, crop prices, and technology. Economic conditions vary considerably from those prevailing at the time of the last major analysis by Condra, and input recommendations made in the ECONOCOT program (Texas Agricultural Extension Service, 1977) are in need of reassessment. The majority of producers in the region are experiencing serious financial stress (Hoermann) and are attempting to survive in one of the more costly-production regions of the country (U.S. Department of Agriculture, 1985, 1964). As the health of the national farm economy has declined, producers have come to rely more heavily on the farm program for survival. The 1985 farm bill, however, mandates decreased support for crops traditionally grown in the region (Knutson et al).

Recent advances in biophysical simulation hold much promise in helping the agricultural economists examine input use decisions. Application of models, which accurately predict yield for varying irrigation and fertilizer levels under alternative weather conditions, permits one to examine production problems in depth while also considering the influence of farm programs. Application of such models allows a reasonable reflection of the multitude of factors that affect the agricultural producer's decision process. Some of those factors include resource constraints, financial condition of the farm firm, government farm program features, and the goals and preferences of the producer.

Objectives

The overall objective of this study is to evaluate economic risk implications of alternative production strategies in the region. Irrigation water is a major limiting factor of production, prompting an emphasis in the analysis upon both optimal levels of application and timing under stochastic weather conditions. Specific objectives of the research are:

1) To examine the risk implications of alternative cropping strategies upon per-acre net returns.
2) To develop whole-farm crop production plans when considering declining government price supports.
3) To determine probabilities of farm survival in a stochastic production/price environment for the cropping pattern plans developed in objective two.

Study Area

The Texas Trans-Pecos region is located in the western portion of the state and consists of over 18 million acres of rangeland, desert, desert mountains, and irrigated cropland (Fig. 1). A relatively sparse population, approximately 600,000 (Dallas Morning News), relies upon petroleum, agriculture, and tourism as the mainstays of the currently struggling economy. Approximately 85 percent of the land area is farms and ranches, but a much smaller percentage is currently under cultivation (U.S. Department of Commerce, 1984). Major agricultural products include cattle, cotton, small grains, hay, vegetables, and cantaloupe. Receipts from crops marketed in 1984 totaled more than $87 million, or 2.4 percent of the state's total (Texas Crop and Livestock Reporting Service). Historically, agricultural production in this region has centered in two counties, Reeves and Pecos; and these two areas are the focus of the present study. Selected historical acreages for the 10 counties comprising the Trans-Pecos region and the two counties serving as the study area appear in Table 1. The value of 1984 crop production in Reeves and Pecos counties totaled $23 million.

Groundwater supplies provide the majority of irrigation water in the region. Ninety-three percent of

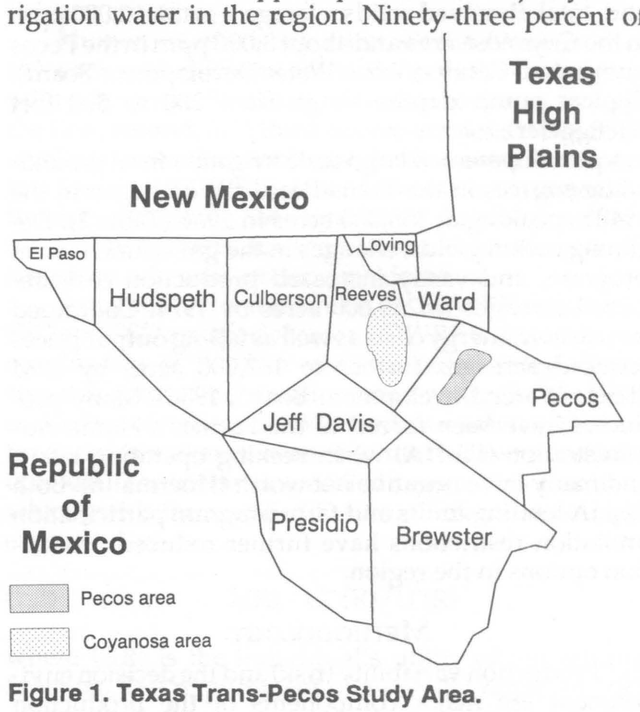

Figure 1. Texas Trans-Pecos Study Area.

Table 1. Selected Historical Crop Acreages; Texas Trans-Pecos.

Year	Cotton	Grain Sorghum	Forage Crops	Alfalfa	Wheat	Other	Pecan Grains	Vegetables	Total Irrigated Acres[a]
				Pecos County					
1969	16,001	11,054	13,519	1,700	6,000	4,600	650	2,500	55,043
1974	10,053	5,890	14,494	4,480	5,200	8,938	1,000	800	51,795
1979	4,814	697	1,573	3,512	1,825	7,548	2,121	3,431	27,291
1984	11,116	1,235	1,863	6,096	1,571	2,246	1,879	2,612	31,231
				Reeves County					
1969	44,033	6,500	14,594	782	7,788	5,550	0	1,700	82,035
1974	40,070	5,320	12,722	4,620	1,800	10,793	0	1,180	78,180
1979	10,179	601	1,263	6,174	4,368	3,391	330	2,289	36,502
1984	13,065	218	1,672	3,435	157	4,965	362	504	27,061
				Trans-Pecos[b]					
1969	116,366	38,274	36,412	17,615	15,015	15,725	1,277	7,157	253,118
1974	106,282	20,687	33,124	41,75	7,665	28,016	3,295	6,499	252,636
1979	76,646	10,056	4,579	46,144	11,839	18,224	8,827	15,824	209,447
1984	60,180	9,996	6,305	38,642	13,355	8,326	9,249	11,048	162,391

[a]Sum of individual acreages may not agree with total due to crops grown but not shown.

[b]Includes irrigated acreages for Brewster, Culberson, El Paso, Hudspeth, Jeff Davis, Loving, Pecos, Presidio, Reeves, and Ward counties. Sources: (1.) Texas Water Development Board, *Inventories of Irrigation in Texas 1958, 1964, 1969, and 1974.* Report 196, Austin, Texas. 1975 . (2.) Texas Water Development Board, *Surveys of Irrigation in Texas 1958, 1964, 1969, 1974, 1979, and 1984.* Report 294, Austin, Texas. 1986.

the irrigation water used in Pecos and Reeves counties in 1984 came from groundwater sources (Texas Water Development Board). Water quality varies across farms and, total dissolved solids average less than 2,000 ppm in the Coyanosa area and about 3,000 ppm in the Pecos pump area (Condra; Texas Water Development Board). Typical pump depths range from 200 to 500 feet (Henggeler).

Development of large-scale irrigation from groundwater sources in the Trans-Pecos region began in the 1940's, peaking at 356,000 acres in 1964 (Table 2). Declining cotton yields, changes in the government farm program, and vastly increased production costs reduced acreages to 252,000 acres by 1974. Continued increases in energy costs as well as falling output prices reduced acreages further to 162,000 acres by 1984 (Texas Water Development Board, 1986). Many producers have been forced to the Farmer's Home Administration (FmHA) when seeking operating loans, and many have negative net worth (Hoermann). Both FmHA lending limits and farm program participation limitation restrictions have further reduced production options in the region.

Methodology

Production variability (risk) and the decision environment are major components of the production problem under investigation. Two computer simulation models were employed, both of which incorporate some aspect of risk analysis. A desire to examine possible cotton irrigation strategies prompted use of the EPIC (Erosion Productivity Impact Calculator) generalized crop growth model. This model is capable of estimating yield distributions for a variety of crops and reflecting the agronomic benefits associated with various rotations. The heavy reliance of Trans-Pecos producers on government farm programs and a desire to reflect the decision environment faced by todays' agricultural producer prompted use of the FLIPSIM (Firm Level Policy Simulation Model) computer model.

Risk Analysis

Price and yield variability are the two major sources of risk faced by agricultural producers. Government farm programs mitigate a portion of the price risk, although marketing tools such as forward contracting or commodities futures contracts may also be used. Producers generally attempt to reduce production risk via their chosen production practices and risk management tools such as crop insurance.

Within this analysis, two major risk analysis techniques were employed. A quadratic programming (QP) planning model within FLIPSIM determined the annual crop mix (including combination of cotton irriga-

Table 2. Historical Irrigation Summary; Texas Trans-Pecos.

Year	Acres Irrigated	Acre-Feet[a] (on-farm use)	Acre-Feet (per acre)	Wells	Trans-Pecos Irrigated Acres
			Pecos County		
1958	117,413	345,266	2.94	636	0
1964	119,313	367,455	3.08	1,166	0
1969	55,043	201,748	3.66	912	0
1974	51,795	183,669	3.54	911	0
1979	27,291	94,462	3.46	915	3,097
1984	31,232	90,022	2.88	850	3,794
			Reeves County		
1958	96,000	358,568	3.83	850	0
1964	118,200	414,217	3.50	975	0
1969	82,035	334,392	4.08	1,010	640
1974	78,170	319,785	4.09	995	1,100
1979	36,502	127,469	3.49	975	11,370
1984	27,061	89,688	3.31	935	7,774
			Total Trans-Pecos		
1958	319,365	1,067,801	3.34	2,467	1,755
1964	356,185	1,101,237	3.09	3,273	2,507
1969	253,118	961,732	2.80	3,056	2,302
1974	252,636	932,108	3.69	3,107	4,442
1979	209,447	662,962	3.17	3,182	42,634
1984	162,391	544,563	3.35	3,022	22,897

[a]May include both surface and groundwater use.
Source: Texas Water Development Board. *Surveys of Irrigation in Texas 1958, 1964, 1974, 1979 and 1984.* Report 294, Austin, Texas 1986.

tion schemes). QP is a popular risk analysis tool (Freund; Anderson et al.) and is one of the many that rely on the premise that decision makers choose from among various alternatives by maximizing their expected well-being or utility. The technique assumes that utility is a quadratic function of expected returns.

(1.1) $$U(R) = R'X = \lambda X'\Sigma X$$

Where X = the vector of activities, R = expected monetary returns for each activity, Σ = covariance matrix for net returns, and λ = the Pratt risk aversion coefficient (Pratt). Lambda is used to reflect the relative weight of the variance and covariance of expected returns within the decision makers' utility function. Equation (1.1) is usually maximized subject to constraints on water labor, land, and capital.

Quadratic programming assumes either negative exponential or quadratic utility. In many cases one does not know the specific utility functional form. For such cases or those cases in which there is limited information on producer attitudes toward risk, efficiency criteria may be used to select efficient subsets of investment alternatives. The efficient subset contains the preferred choices of the individual whose preferences conform to the restrictions associated with the given efficiency criterion.

Numerous efficiency criteria exist (Anderson et al.), each with different restrictions on the underlying utility function. Stochastic dominance forms include the first, second, and third degree versions (FSD, SSD, and TSD) as well as stochastic dominance with respect to a function (SDWRF). Use of these criteria generally involve comparing the cumulative distribution functions of net returns for the various alternatives (e.g., irrigation schemes) under consideration.

Attention is focused here on SDWRF, of which, FSD and SSD are special cases. SDWRF is the most discriminatory of the four versions noted (Meyer), yet requires greater information concerning the decision maker's preferences. SDWRF orders uncertain choices for decision makers whose absolute risk aversion function $\lambda(R)$ lies within a specified range. This function, which yields the so-called Pratt coefficient at a point, is expressed as

(1.2) $$\lambda(R) - U''(R)/U'(R)$$

where U(R) is the individual's utility of net returns function. The requirement of a specific range on $\lambda(R)$

allows the greater discriminatory power of SDWRF. Interested readers are referred to the reference section (Anderson et al.; Barry; Markowitz) for further details concerning use of these techniques.

Crop Growth Method - EPIC

EPIC is a generalized crop growth model developed by the U.S. Department of Agriculture (Williams et al., 1984a and 1984b) and was originally designed to evaluate the impacts of alternative management schemes on both crop yield and soil erosion. The model consists of several major components designed to reflect weather, hydrology, sedimentation, nutrient cycling, plant growth, tillage, soil temperature, and irrigation.

Major points favoring use of the EPIC model include reflection of the impacts of alternative irrigation and fertilization schemes as well as that of varying crop rotations on yield over time. This latter facet is somewhat unique since most crop growth models focus on a single crop in a single year, trading general applicability for supposed increased accuracy. Primary EPIC output variables of interest in this study include crop yield, plant water, and nitrogen stress, as well as estimates of wind and water erosion. Potential disadvantages include the required calibration effort, the restriction to a user-determined but pre-set management scheme (independent of weather conditions), and the data-intensive nature of the model.

The flexibility of EPIC in estimating yields for several crops, as well as the ability to generate crop yield distributions over a large variety of management schemes, prompted its use within the current study. Extensive calibration efforts were required, both to gain familiarity with the model and to specify crop parameters for Texas Trans-Pecos and range of input variables pertinent to that region. A detailed description of the applications of EPIC is presented by Ellis.

Firm Simulation - FLIPSIM

The Firm Level Policy Simulation Model (FLIPSIM) is a FORTRAN-based model developed by Richardson and Nixon. A wide variety of agricultural policy options may be reflected using FLIPSIM, although the basic farm programs (Glaser; Knutson et al.) involving target prices, nonrecourse loans, and Findley loans (marketing loans in the case of cotton) are the main options emphasized here. In addition to provisions of the current (1985) farm bill, the model was used to reflect numerous other aspects of the decision environment facing the agricultural producer. These include equipment replacement, qualification for financing, annual case withdrawals for family living expenses, and income taxes under current tax laws.

The FLIPSIM model operates recursively, simulating the annual production, farm policy, marketing, financial management, and income tax aspects of a farm firm over a multiple-year planning horizon. Periods ranging from 1 to 10 years may be reflected with FLIPSIM tracking such key variables as debt, net worth, annual income, government payments, and ending equity. Conditions for continued economic survival may also be specified, resulting in the ability when making stochastic runs to estimate the probability of firm survival over the chosen planning horizon.

The annual quadratic programming planning model with FLIPSIM may be used to determine annual crop mix based on expected returns over variable costs. Expected net returns per acre are calculated by subtracting the expected nonlabor, noninterest variable production costs per acre from expected cash receipts. Government payments are included, if applicable, in expected cash receipts. Expected variable costs are the sum of per acre input costs inflated for annual increases in production costs.

Research Organizations

Several phases of analysis were required within this research effort. These steps are outlined in Figure 2. Step 1 entailed interviews with producers and agricultural experts in the region. Results of those interviews were used to develop the cultural practices and irrigation alternatives to be evaluated by EPIC (step 2). Collection of detailed information concerning major soils in the area (Hallmark et al.) and weather data (U.S. Department of Commerce, 1966-1985) was also required (step 3). Step 4 required collection of variety test data for cotton and expert opinions concerning the mean and range of yields for several other crops.

Once obtained, the data noted above measured in calibrating EPIC for crop production in the Texas Trans-Pecos. Williams and Jones, two of the original developers of EPIC, suggested allowable ranges for selected crop growth parameters. Their input was critical in the calibration effort for cotton, barley, grain sorghum, red top cane, and forage sorghum.

Several agricultural producers were also interviewed in an effort to elicit information concerning their attitudes toward risk. The modified Ramsey technique of elicitation (Ramaratnam; Lin et al.) was used to obtain data points relating utility to whole-farm net returns. Utility of net returns functions and corresponding Pratt risk coefficients (Pratt) were then estimated assuming negative exponential, quadratic, and Fourier functional forms. The latter form is flexible (Gallant), allowing reflection of a wider range of decision behavior than the negative exponential or quadratic forms. The rest of step 6 entailed the development of crop enterprise budgets for various crops and water availability situations.

Two major factors prompted consideration of only cotton at this juncture of the analysis. First, current acreages of other row crops are relatively minor. Second, Raskin and Cochran caution that Pratt risk coefficients should be used within the context in which they were elicited. Utility is usually elicited for net returns at the whole-farm level, yet crop enterprise budgets are generated on an acreage basis. Raskin and Cochran suggest multiplying per-acre returns by farm size if a whole-farm Pratt range is known. For multi-product farms such scaling of returns requires some assumption of crop mix. Given the minor role of other row crops and the primary interest in cotton irrigation

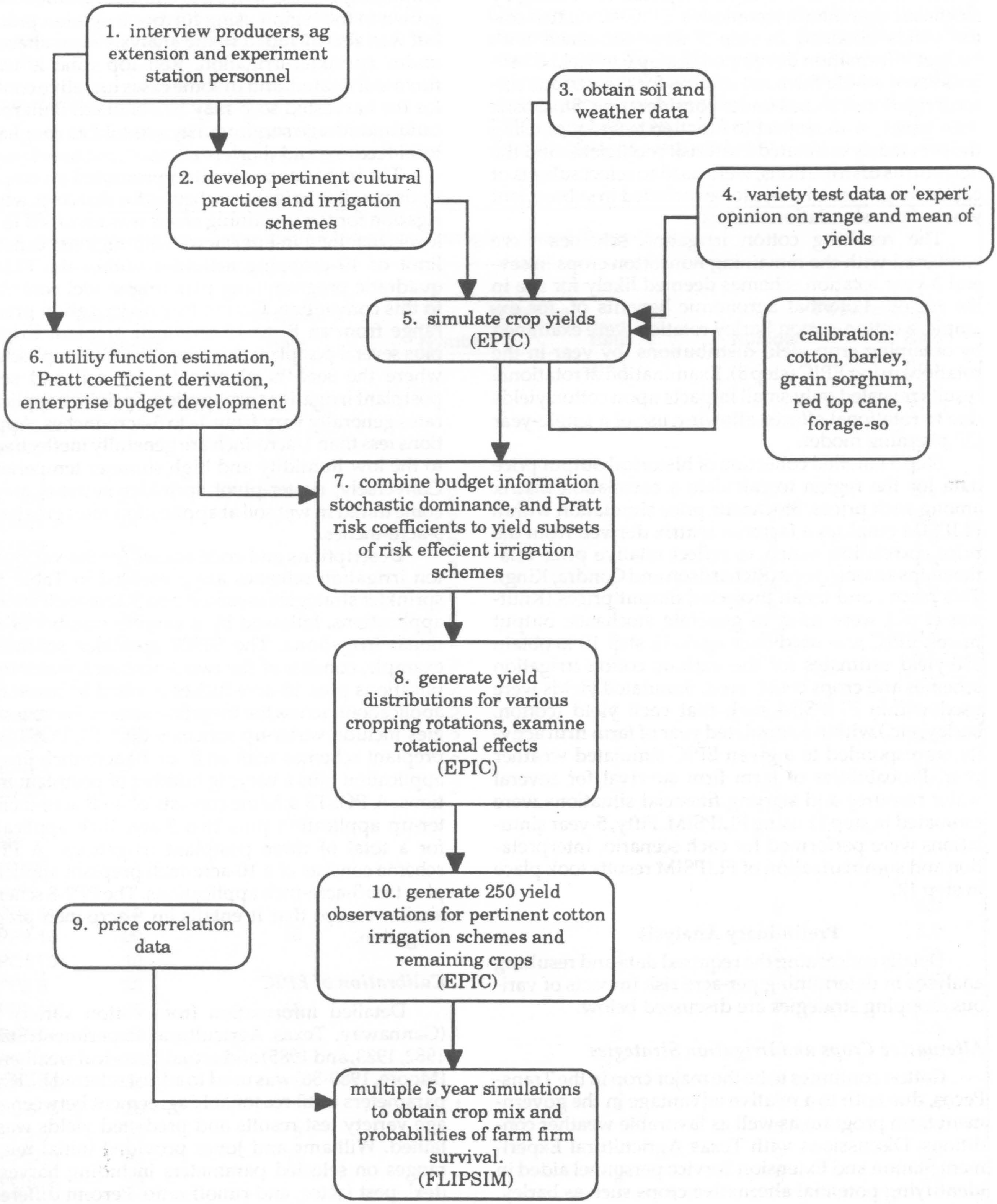

Figure 2. Progression of research approach.

schemes, only cotton was considered in generating whole-farm net returns to be subjected to ranking by stochastic dominance techniques. EPIC-simulated cotton yields obtained in step 5 were combined with budget information developed in step 6 to yield distributions of whole-farm net returns for the various cotton irrigation schemes under consideration. Stochastic dominance, with respect to function techniques using the previously estimated Pratt risk coefficients and the net returns distributions, were used to select subsets of cotton irrigation schemes to be included in subsequent whole-farm simulation analyses.

The resulting cotton irrigation schemes were combined with the remaining noncotton crops in several 3-year rotation schemes deemed likely for use in the region. Potential agronomic benefits of, for example, a cotton-cotton-barley rotation were examined by obtaining crop yield distributions (by year in the rotation) using EPIC (step 8). Examination of rotational results revealed only small impacts upon cotton yields due to rotational effects, allowing use of a single-year QP planning model.

Step 9 entailed collection of historical output price data for the region to calculate a correlation matrix among such prices. Stochastic price simulation within FLIPSIM employs a factored matrix derived from the price correlation matrix to reflect relative price relationships among crops (Richardson and Condra; King). This matrix and mean projected output prices (Knutson et al.) were used to generate stochastic output prices. EPIC was used once again in step 10 to obtain 250-yield estimates for the various cotton irrigation schemes and crops considered. Simulated yields were used within FLIPSIM such that each yield (cotton, barley, etc.) within a simulated year of farm firm activity corresponded to a given EPIC-simulated weather year. Probabilities of farm firm survival for several water resource and starting financial situations were estimated in step 11 using FLIPSIM. Fifty, 5-year simulations were performed for each scenario. Interpretation and summarization of FLIPSIM results took place in step 12.

Preliminary Analysis

Details concerning the required data and resulting analyses in determining per-acre risk impacts of various cropping strategies are discussed below.

Alternative Crops and Irrigation Strategies

Cotton continues to be the major crop in the Trans-Pecos, due both to a relative advantage in the government farm program as well as favorable weather conditions. Discussions with Texas Agricultural Experiment Station and Extension Service personnel aided in identifying potential alternative crops such as barley, grain sorghum, red top cane, and forage sorghum. Sprinkler-irrigated barley, accompanied with stocker cattle grazing, is grown as a winter crop. Spring barley is normally furrow-irrigated. Grain sorghum is usually grown in the region using furrow-irrigation practices, but was also included in the analysis as an alternative under sprinkler-irrigation. Red top cane is usually furrow-irrigated, and in some cases lucrative contracts for the harvested seed may be obtained. Both red top cane and forage sorghum hay are sold as roughage to local feedlots and dairies.

The importance of cotton prompted an emphasis upon possible irrigation schemes for that crop, while irrigation for the remaining crops was assumed to be at levels obtained in interviews with regional experts. A limit of 10 cropping activities within the FLIPSIM quadratic programming planning model contributed to this convention. Cotton furrow-irrigation practices range from an 8- to 10-acre-inch preplant irrigation plus several postplant irrigations to "water-up" schemes where the seed is planted in dry soil and several postplant irrigations are applied. Sprinkler application rates generally vary from 1- to 3-acre-inches. Applications less than 1-acre-inch are generally ineffective due to the low humidity and high summer temperatures. Conversely, center-pivot sprinkler systems may become mired in wet soil at application rates greater than 3-acre-inches.

Descriptions and code names for the various cotton irrigation schemes are presented in Table 3. All sprinkler strategies assumed two 3-acre-inch water-up applications, followed by a varying number of additional irrigations. The S1807 sprinkler scheme, for example, consists of the two 3-acre-inch water-up applications plus 18-acre-inches applied in seven equal applications across the irrigation season. Furrow strategies include water-up schemes (POST3, POST6) and preplant schemes with an 8- or 10-acre-inch preplant application plus a varying number of postplant irrigations. A POST3 scheme consists of an 8-acre-inch water-up application plus two 5-acre-inch applications for a total of three postplant irrigations. A PP2-10 scheme consists of a 10-acre-inch preplant application plus two 5-acre-inch applications. The PP2-8 scheme is similar except that it entails an 8-acre-inch preplant irrigation.

Calibration of EPIC

Detailed information from cotton variety tests (Gannaway, Texas Agricultural Experiment Station, 1982, 1983, and 1985) and actual historical weather data (Moore, 1980-86) was used to adjust selected EPIC crop parameters until reasonable agreement between average variety test results and predicted yields was obtained. Williams and Jones provided initial relevant ranges on selected parameters including harvest index[1], pest factor, and runoff ratio. Percent differences between average variety test yields and EPIC predicted yields range from -12.3 to +2.8 percent for

[1]Harvest index is the fraction of aboveground biomass which is harvested.

cotton. Extensive regional variety test data for grain sorghum, barley, forage sorghum, and red top cane did not exist, prompting calibration using mean yield data elicited from experts in the area. Selected final EPIC crop growth parameters appear in Table A1 of the Appendix.

Simulated Yields

Prior to calculation of net return budgets, EPIC was employed to estimate average yield values for the various cotton irrigation schemes. Estimation of those yields was a two-step process. Nitrogen (N) fertilization levels were first calculated using the automatic fertilization option within EPIC. A stress level trigger of 5 percent was assumed, promoting the application of N whenever the EPIC N stress index rose above that value. Average μN and standard deviation σN values for the amount of N applied were calculated using 25 EPIC runs. Nitrogen levels assumed for the final irrigation simulations were set at $\mu N + \sigma N$ to ensure that N

Table 3. Description of Alternative Cotton Irrigation Strategies; Texas Trans-Pecos.

	Total Acre-Inches Applied	Preplant Rate (in.)	Water-up Number	Water-up Rate (in.)	Postplant Number	Postplant Rate (in.)
Sprinkler Schemes[a]						
S1806	24		2	3	6	3.0
S1807	24		2	3	7	2.6
S1809	24		2	3	9	2.0
S1812	24		2	3	12	1.5
S1818	24		2	3	18	1.0
S2408	30		2	3	8	3.0
S2410	30		2	3	10	2.4
S2412	30		2	3	16	2.0
S2416	30		2	3	10	1.5
S3010	36		2	3	12	3.0
S3012	36		2	3	12	2.5
S3015	36		2	3	20	2.0
S3020	36		2	3	20	1.5
Furrow Schemes[b]						
PP2-8	18	8			2	5.0
PP2-10	20	10			2	5.0
POST3	18		1	8	2	5.0
PP3-8	23	8			3	5.0
PP3-10	25	10			3	5.0
POST4	23		1	8	3	5.0
PP4-8	28	8			4	5.0
PP4-10	30	10			4	5.0
POST5	28		1	8	4	5.0
PP5-8	33	8			5	5.0
PP5-10	35	10			5	5.0
POST6	33		1	8	5	5.0

[a]Sprinkler scheme mnemonics SXXYY imply two, 3-inch, water-up irrigations XX acre-inches applied in YY positions.

[b]Furrow scheme mnemonics PPX-Y imply a preplant irrigation of Y acre-inches plus X postplant irrigation of 5-acre-inches. A POSTZ scheme implies an 8-acre-inch water-up plus Z-1, 5-acre-inch, postplant irrigations.

stress on the plant did not confound interpretation of irrigation results. Applied N levels, as well as summary statistics for the final furrow and sprinkler simulations, appear in Table 4. Simulation-determined N levels were at or below levels common in the region.

Furrow yield results corresponded fairly well with prior expectations in terms of absolute and relative magnitude. Yields for the schemes may be considered in subgroups of three. For example, the POST3, PP2-8, and PP2-10 schemes apply an almost identical amount of total water. Within that subgroup, and similar groups as well, average yield for the water-up scheme (POST3 in our example) lies somewhat between that for the 8-inch and 10-inch preplant schemes. Interviews with producers revealed some preference for the water-up schemes. Using maximum expected yield as a criterion, the 10-inch preplant scheme showed a higher yield than a corresponding postplant irrigation-only

Table 4. Simulated Cotton Yield Summary Data, Furrow- and Sprinkler-Irrigation; Texas Trans-Pecos.

	Mean Yield/Acre (lbs)	Std. Dev. (lbs)	c.v.[a]	Skewness	Min. (lbs)	Max. (lbs)	Nitrogen (lbs)
Furrow Schemes[b]							
POST3	525	94	.1790	.8056	388	752	70
POST4	656	115	.1753	.5177	478	896	94
POST5	776	120	.1546	.4220	611	996	114
POST6	916	120	.1310	.4568	731	1151	139
PP2-8	505	93	.1842	.8137	377	718	82
PP2-10	555	97	.1748	.7926	422	780	90
PP3-8	636	103	.1619	.7328	506	870	108
PP3-10	690	106	.1536	.7226	557	932	121
PP4-8	780	117	.1500	.7031	641	1050	133
PP4-10	840	118	.1405	.7158	701	1114	146
PP5-8	901	149	.1654	.0411	664	1151	152
PP5-10	966	146	.1511	-.0280	716	1213	166
Sprinkler Schemes[c]							
S1806	799	127	.1630	.3948	611	1022	140
S1807	790	129	.1633	.4423	615	1035	141
S1809	794	124	.1562	.5708	634	1044	138
S1812	789	126	.1597	.7229	639	1074	134
S1818	759	122	.1607	.6128	591	1009	130
S2408	1018	130	.1277	.2565	810	1292	164
S2410	1020	126	.1235	.2796	821	1260	166
S2412	1017	128	.1258	.4886	825	1271	165
S2416	991	135	.1362	.5450	810	1281	162
S3010	1233	87	.0706	-.1908	1056	1416	192
S3012	1232	89	.0722	-.2787	1045	1421	189
S3015	1218	91	.0747	-.0155	1035	1423	190
S3020	1205	100	.0830	.0151	1031	1421	190

[a]Coefficient of variation risk measure: (std. dev./mean).

[b]Furrow scheme mnemonics PPX-Y imply a preplant irrigation of Y acre-inches plus X postplant irrigations of 5-acre-inches. A POSTZ scheme implies an 8-acre-inch water-up plus Z-1, postplant irrigation of 5-acre-inches. Yield values are based on 25 observations and assuming a 24% turnout (lint/harvested biomass) ratio.

[c]Sprinkler scheme mnemonics SXXYY imply two 3-inch, water-up irrigations plus XX acre-inches applied in YY applications. Yield values are based on 25 observations and assuming a 24% turnout (lint/harvested biomass) ratio.

strategy. Final conclusions on this point, however, may not be drawn until economic criteria are applied. Cost of water, resource availability (especially timing), and distribution of yield may alter such a conclusion.

Similar results apply for sprinkler-irrigation, although average yields in this case exceeded actual yields. This applies especially for the water intensive S30 schemes[2]. Two possible explanations may be inferred: 1) the S30 schemes lie outside in terms of total applied water, the data used to calibrate EPIC for sprinkler irrigations; and 2) the pest factor may not be constant. Calibration of EPIC for sprinkler cotton covered irrigation applications ranging from 18 to 24 inches. and hail and insect damage may be increasing functions (percentage-wise) of yield or plant population.

For the S18 schemes, average yield varied little for application rates between 1.5 inches (S1812) and 2.57 inches (S1807). A similar plateau of constant yields occurs for application rates between 2 and 3 inches. Application rates apparently make little difference in average yield when operating within these "windows" of optimality. As with the furrow case, constraints on water availability or distributions of yields could determine an alternative preferred strategy.

Yield risk conclusions drawn from the data in Table 4 is mixed. Standard deviations of yield generally increase with increased water application (i.e., going from a POST3 to POST4 scheme). Yield variance, however, decreases with increased water application when going from the S24 to the S30 sprinkler schemes. An alternative measure of yield risk is the coefficient of variation. This measure declines unambiguously as total applied water increases. Yield variance, as a percentage of mean, falls indicating less risk as total water applied increases.

Enterprise Budget Development

Extensive interviews with area producers revealed detailed information concerning equipment complement size and composition. Tillage and irrigation operations were then summarized for the cotton irrigation schemes and remaining crops. Three farm sizes (960, 1,600, and 2,500 acres) were assumed to apply in the region based on producer interviews and U.S. Agricultural Census data (U.S. Department of Commerce, 1984). The Microcomputer Budget Management System, or MBMS, (Texas Agricultural Extension Service, 1986) was used to develop crop enterprise budgets for each cotton irrigation scheme and crop by farm size. Individual budgets were calculated assuming two well sizes (700 and 1,000 gpm) for furrow-irrigated farms and one well size (1,000 gpm) for farms using center-pivot sprinklers.

Comparative per acre returns to land, management, and risk for the various cropping alternatives are summarized for the 960-acre farm equipment complement in Table 5. Yields used in the budgeting process were the average of 25 individual EPIC simulations for each crop irrigation scheme. Assumed output prices and selected input prices appear in footnote *a* of Table 5 and in Table A3 of the Appendix. Expected returns (above variable and fixed costs) continue to favor cotton over the small grains. The summary also indicates greater returns for the more water-intensive cotton irrigation schemes. Red top cane returns also appear attractive, assuming that contracts for sale of the

Table 5. Summary of Projected Per Acre Returns to Land, Management, and Risk[a]; Texas Trans-Pecos.

Furrow Crop/Irrig. Scheme[b]	$/Acre	Sprinkler Crop/Irrig. Scheme[c]	$/Acre
Cotton		Cotton	
POST3	71.99	S1806-S1818	171.18
POST4	115.01	S2408-S2416	258.24
POST5	152.31	S3010-S3020	337.62
POST6	200.63		
PP2-8	55.66		
PP3-8	104.89		
PP4-8	151.15		
PP5-8	186.31		
PP2-10	75.09		
PP3-10	127.03		
PP4-10	177.81		
PP5-10	217.20		
Sorghum	-26.89	Sorghum	-16.80
Barley	-53.21	Barley	-61.34
Forage Sorghum	65.00	Forage Sorghum	76.36
Red Top Cane	265.96		

[a]Crop enterprise budget returns calculated assuming the following prices: lint ($.55/lb), cotton ($105/ton), grain sorghum ($3.21/cwt), barley ($1.90/bu), forage/red hay ($64/ton), and red top cane seed ($10.40/cwt). Furrow returns based on well costs for a 700 gpm well using 7.5/kwh electricity. Sprinkler costs based on a 1,000 gpm well yield.

[b]Furrow scheme mnemonics PPX-Y imply a preplant irrigation of acres-inches plus X postplant irrigations of 5-acre-inches. A POSTZ scheme implies an 8-acre-inch water-up plus Z-1 postplant irrigations of 5-acre-inches.

[c]Sprinkler scheme mnemonics SXXYY imply two 3-inch water-up irrigations plus XX acre-inches applied in YY applications.

[2]The S30 schemes have two 6-acre-inch water-up applications plus 30 additional acre-inches applied across the irrigation season. A key to irrigation scheme mnemonics appears in Table 3.

seed are available to alleviate price risk. Implications for the 960-acre farm were similiar for the 1,600 and 2,500 acre farms.

Probability distributions of whole-farm net returns to management and risk were calculated using EPIC-generated yields (as summarized in Table 4) and the previously developed cotton budgets. A 79.4-cent per pound price and a $110 per ton cottonseed price were employed. The lint price included 55 cents for market or returns from the loan program, and 24.4 cents per pound for deficiency payments. Producers were assumed to have access to 960 acres with 432 acres of cotton base acreage. A 25-percent set aside requirement reduced the 432 acres to 324 permitted or allowed acres available for cotton production. Thus, producers were assumed to farm only a third of their actual acreage, a situation not uncommon in the area given the relatively high cost of inputs, low prices for small grains, and limited availability of operating capital. Several farm program yield (FPY) levels were assumed to apply depending on the average yield for the irrigation scheme under consideration.

Summary statistics for the returns distributions appear in Table 6. For the sprinkler-irrigated schemes, average net returns appeared to be maximized for schemes having 8 to 10 applications. For example, within the S18 alternatives, the S1809 scheme has the highest average net return with a value of $36,712. (Note: As one applies more water [e.g., moves from the S18 to S24 to S30 schemes] the coefficient of variation of net returns declines.) Greater water application levels lead to more stable returns.

Generally, similar conclusions apply to the furrow-irrigated schemes. As one applies more water in going from the POST3 to POST6 schemes the coefficient of variation declines. This trend does not apply, however, for the two preplant (8- and 10-inch) schemes. The coefficient of variation of net returns is a minimum for the four postplant application rate, yet increased slightly when more water is applied in the five postplant scheme.

Once calculated, the net return distributions were ranked using stochastic dominance with respect to a function technique. This preliminary screening was

Table 6. Summary of Whole-Farm Returns to Management and Risk[a]; Texas Trans-Pecos.

Irrigation Scheme[b]	Farm Program Yield (lbs)	Returns to Management and Risk ($) Mean	Min.	Max.	Std. Dev.	c.v.[c]
S1806	800	34,381	8,830	71,339	19,262	.5603
S1807	800	36,008	9,481	73,292	19,572	.5436
S1809	800	36,712	12,411	74,595	18,884	.5144
S1812	800	35,982	13,062	79,145	19,204	.5337
S1818	800	31,294	5,899	69,386	18,470	.5902
S2408	1,000	50,555	18,975	92,227	19,715	.3899
S2410	1,000	50,919	20,602	87,344	19,113	.3753
S2412	1,000	50,476	21,253	88,972	19,392	.3842
S2416	1,000	46,531	18,975	90,560	20,436	.4392
S3010	1,200	63,813	37,508	92,855	13,421	.2103
S3012	1,200	63,423	34,252	92,854	13,635	.2150
S3015	1,200	61,730	34,252	92,854	13,943	.2259
S3020	1,200	61,105	34,578	93,831	15,210	.2489
PP2-8	550	12,560	-6,909	44,856	14,199	1.1306
PP3-8	660	27,310	7,580	62,927	15,657	.5733
PP4-8	800	33,938	12,711	74,894	17,794	.5243
PP5-8	930	38,594	2,690	76,595	22,642	.5864
PP2-10	550	15,992	-4,178	50,139	14,748	.9222
PP3-10	660	31,245	10,984	67,899	16,133	.5164
PP4-10	800	38,496	17,413	80,195	17,867	.4641
PP5-10	930	43,991	6,029	81,562	22,161	.5038
POST3	550	16,066	-4,796	50,530	14,340	.8926
POST4	660	29,057	1,997	65,465	17,544	.6038
POST5	800	34,540	9,471	68,074	18,198	.5269
POST6	930	41,748	13,567	77,379	18,276	.4378

[a]Calculations based on a 960-acre cotton farm with 432 acres of cotton program acreage. Prices assumed include $0.55/lb lint, $110/ton cottonseed, 7.5/kwh electricity, and $24/acre land charge.

[b]Sprinkler scheme mnemonics SXXYY imply 2-inch water-up irrigations plus XX acre-inches applied in YY applications. Furrow scheme mnemonics PPX-Y imply a preplant irrigation of Y acre-inches plus X postplant irrigations of 5-acre-inches. A POSTZ scheme implies an 8-acre-inch water-up plus Z-1 postplant irrigations of 5-acre-inches.

[c]Coefficient of variation risk measure: (std. dev./mean).

used to reduce the number of cotton irrigation strategies considered. Assumed Pratt intervals included a risk neutral interval (-.00001, .00001) and two risk averse intervals ([.01, .0002] and [.001, .002]). Results portrayed in Table 7 indicate several points. First, relative rankings were invariant across the assumed Pratt intervals and farm program yield values. For the furrow schemes, more water is almost universally preferred. Only for the lowest base yield (550 lbs) is the water-up POST3 scheme preferred to its more water-intensive PP2-10 counterpart. In all cases, the 10-inch preplant dominates the 8-inch preplant schemes.

Sprinkler scheme rankings place a 2-inch application rate (S1809) first for the lowest base yield. As base yield increases, however, the preferred application rate increases. A 2.4-inch application rate dominates for the S24 schemes. Rankings for the sprinkler schemes may also indicate a preference for number of applications, rather than a given rate. Each of the top schemes had 9 or 10 postplant applications. Once chosen, the subset of alternatives selected via stochastic dominance techniques must face the additional test of resource feasibility. A producer may prefer the net returns distribution associated with a water-intensive scheme. Limited water or labor supplies or financial constraints may, however, preclude consideration of that particular scheme. Given this possible resource constraint, five irrigation schemes were chosen for three assumed farm program yields using each of the two types of irrigation. These cotton irrigation alternatives (Table 8) were chosen by: 1) taking the three most preferred schemes with average yields near the assumed farm program yield, and; 2) combining those schemes with the two top-ranked schemes from the adjacent farm program yield classification(s). The altered QP planning model within FLIPSIM selected the optimal annual crop mix from among the five designated cotton schemes plus the noncotton crop alternatives.

Whole-Farm Analysis

The previously described research focuses primarily on acreage-based issues. Examination of the optimal choice of cotton irrigation schemes and the potential impact on farm-firm survival is a natural extension. Given the declines in government target prices, what are the expected impacts on a whole-farm bases? The FLIPSIM policy simulation model provided an excellent means of reflecting the numerous factors acting in such a situation.

Whole-Farm Scenarios

Producers in Texas Trans-Pecos face a variety of financial and resource constraints, and the performance of farm firms in the region is definitely affected by accrued debt. Starting debt was assumed to have two possible values. These were referred to as medium and high debt as shown in Table 9. Differing levels of outstanding intermediate and long-term debt characterize the different debt scenarios.

Additional factors affecting farm-firm performance were water availability and cotton farm program yield. Details concerning the number of wells, starting debt levels, and assumed farm program yield are shown in Tables 10 and 11 for the furrow and sprinkler analysis. Furrow-irrigated farms were assumed to use 700 gpm irrigation wells, while sprinkler systems had access to 1,000 gpm wells. Two possible tenure arrangements were also assumed: full ownership and a mixed own/cash lease scenario. Farm program acreages for

Table 7. Stochastic Dominance Rankings of Alternative Cotton Irrigation Schemes[a]; Texas Trans-Pecos.

	Farm Program Yield (lbs)					
Ranking	550	660	800	930	1000	1200
Furrow Schemes						
1	POST3	PP3-10	PP4-10	PP5-10		
2	PP2-10	POST4	POST5	POST6		
3	PP2-8	PP3-8	PP4-8	PP5-8		
Sprinkler Schemes						
1			S1809		S2410	S3010
2			S1807		S2408	S3012
3			S1812		S2412	S3015
4			S1806		S2416	S3020
5			S1818			

[a]Pratt coefficient ranges of (-.00001, .00001), (.0001, .0002), and (.001, .002) were employed, although relative rankings did not vary across those ranges nor across the three farm sizes investigated. Relative rankings were invariant to assumed farm program yield as well.

Table 8. Cotton Irrigation Schemes Selected for Inclusion in Whole-Farm Model; Texas Trans-Pecos.

	Farm Program Yield (lbs)					
	550	750	800	930	1000	1200
Furrow Schemes Considered[a]	POST3 POST4 PP2-8 PP2-10 PP3-10	POST4 POST5 PP3-10 PP4-8 PP4-10		POST5 POST6 PP4-10 PP5-8 PP5-10		
Sprinkler Schemes Considered[b]			S1807 S1809 S1812 S2408 S2410		S2408 S2410 S2412 S1809 S3010	S3010 S3012 S3015 S2408 S2410

[a]Furrow scheme mnemonics PPX-Y imply a preplant irrigation of Y acre-inches plus X postplant irrigations of 5-acre-inches. A POSTZ scheme implies an 8-acre-inch water-up plus Z-1 postplant irrigation of 5-acre-inches.

[b]Sprinkler scheme mnemonics SXXYY imply two 3-inch water-up irrigations plus XX acre-inches applied in YY applications.

Table 9. Beginning Debt Specifications; Texas Trans-Pecos[a]

	Debt Scenario[b]	
	Medium	High
Outstanding long-term debt	.50	.60
Outstanding intermediate-term debt	.70	.80

[a]Developed from FmHA data. Debt levels are not inclusive of all producers in the Texas Trans-Pecos, but are generally representative.

[b]Debt ratios expressed are long- or intermediate-term debts divided by the value of long or intermediate-term assets.

the 1,600-acre farm assume 720 acres for cotton and 360 acres of small grain base.

Scenario names consist of five parts. The first letter defines furrow- or sprinkler- (F or S) irrigated scenarios. The second column of the name lists the number of wells for that scenario, with well numbers chosen to cover a reasonable range of water availability conditions. The third column conveys the land tenure specification O for owner and L for the own/lease case. Owned land was valued at $300 per acre.

Cash lease costs vary from $40 to $90 per acre of allowed cotton acreage (Hoermann), prompting assumption of a cash lease cost of $60 per allowed cotton acre. The relative proportion of cotton acreage to total farmland reduced the $60 value to a net cost of $20.25 per leased acre. Medium or high starting debt levels are noted by M or H in column 5. The final designation (columns 5-8) is the assumed cotton farm program yield in pounds of lint.

Six broad scenarios were originally analyzed, three for furrow (500-lb, 750-lb, and 930-lb farm program yield) and three similar scenarios for sprinkler. Only the 750-lb furrow and 1,000-lb sprinkler cases, however, are examined here. Results for the remaining scenarios may be found in Ellis' work.

FLIPSIM Assumptions

Numerous additional assumptions were required prior to simulating the activity of the 1,600 acre farm firm. A 5-year time horizon was chosen and expected target and market prices determined from Knutson et al., and projections from historical data (Table A2). Effective loan rates listed reflect the possible use of Findley loan provisions for small grains and the marketing loan for cotton. Projected cottonseed prices reflect the historical relationship between lint and seed prices. Expected forage hay prices reflect a trend line calculation from past observations. Grazing fees on barley were assumed to be $27/acre, inflated 3 percent per year. Red top cane was not considered in the whole-farm analysis because of the specialized nature of seed contracts. Input prices (Table A3) were inflated 4 percent per year.

Table 10. Farm Characteristics for Furrow Irrigation Scenarios[a], Texas Trans-Pecos.

Cotton Farm Program Yield																	
550 lbs						750 lbs						930 lbs					
		Tenure						Tenure						Tenure			
Scenario	No.		Own/	Debt		Scenario	No.		Own/	Debt		Scenario	No.		Own/	Debt	
Name	Wells	Own	Lease	Med.	High	Name	Wells	Own	Lease	Med.	High	Name	Wells	Own	Lease	Med.	High
F4OM550	4	X		X		F4OM750	4	X		X		F6OM930	6	X		X	
F4OH550	4	X			X	F4OH750	4	X			X	F6OH930	6	X			X
F6OM550	6	X		X		F6OM750	6	X		X		F9OM930	9	X		X	
F6OH550	6	X			X	F6OH750	6	X			X	F9OH930	9	X			X
						F9OM750	9	X		X							
						F9OH750	9	X			X						
						F4LM750	4		X	X							
						F4LH750	4		X		X						
						F6LM750	6		X	X							
						F6LH750	6		X		X						

[a]Scenario naming convention: col 1 - F = furrow, S = sprinkler.
col 2 - number of wells.
col 3 - tenure, O = own, L = own/lease, (960 acres own, 640 acres lease).
col 4 - debt level, M = med, H = High.
col 5 to 7 - farm program yield for cotton.

Table 11. Farm Characteristics for Sprinkler Irrigation Scenarios[a], Texas Trans-Pecos.

Cotton Farm Program Yield																	
800 lbs						1,000 lbs						1,200 lbs					
		Tenure		Debt				Tenure		Debt				Tenure		Debt	
Scenario Name	No. Wells	Own	Own/ Lease	Med.	High	Scenario Name	No. Wells	Own	Own/ Lease	Med.	High	Scenario Name	No. Wells	Own	Own/ Lease	Med.	High
S3OM800	3	X		X		S3OM1000	3	X		X		S6OM1200	6	X		X	
S3OH800	3	X			X	S3OH1000	3	X			X	S6OH1200	6	X			X
S5OM800	5	X		X		S5OM1000	5	X		X		S9OM1200	9	X		X	
S5OH800	5	X			X	S5OH1000	5	X			X	S9OH1200	9	X			X
						S7OM1000	7	X		X							
						S7OH1000	7	X			X						

[a]Scenario naming convention: col 1 - F = furrow, S - sprinkler.
col 2 - number of wells.
col 3 - tenure, O = own, L = own/lease.
col 4 - debt level, M = med, H = high.
col 5 to 8 - farm program yield for cotton.

The QP planning model within FLIPSIM included annual constraints for labor and numerous biweekly constraints limiting groundwater availability. Land constraints imposed farm program limits on cotton and small grain acreage as well as set aside requirements. The $50,000 limit on deficiency payments was assumed ineffective. A fixed net return (over variable cost) covariance matrix based on estimated net returns for the 1982-1986 period was employed to reflect potential variation in net returns across alternative irrigation schemes and crops. Five observations were included in calculation of the covariance matrix due to limited historical price data and the assumption of a limited relevant historical period.

Lambda, the Pratt coefficient of risk, was set at .00002 for the QP planning model. This value implies a slight aversion to risk, a result common in past risk studies (Anderson; King). The .00002 value is also representative of the values found in examining the Pratt coefficients derived from utility elicitation of several Trans-Pecos producers (Ellis). The negative exponential, quadratic, and Fourier functional forms yielded fairly similar Pratt estimates for the range of net returns under consideration.

Optimal Cropping Patterns

Optimal crop mix varied significantly with water availability and FPY, although results only for the 750-pound furrow and 1,000-pound cotton farm program yield sprinkler scenarios appear here (Tables 12 and 13). Results for alternative levels of farm program yield appear in Ellis. Furrow acreage results for the 750-pound FPY scenario indicate significant impacts on crop mix and preferred irrigation schemes due to limited water supplies. The impact of the assumed irrigation windows are most evident in the four-irrigation well scenario. Restricted water supplies and timing effects force the selection of the three separate irrigation schemes (POST4, PP3-10, and PP4-10) for cotton. The more water-intensive PP4-10 scheme, however, was the most preferred of the three. This preference apparently strengthened as target price declined. Over time, declining acreages for the less water intensive POST4 and PP3-10 strategies support this contention. Total cotton acreage declines as increasing input prices and declining target prices prompt putting more water on limited acreage. Barley production is positive at 161 acres in 1987, but continued expected weak prices for small grains precluded production in later years. Small increases in forage hay prices resulted in small acreages in the latter years. Total cropped acreages also decline because of the absence of small grain production.

Greater water supplies in the six-well scenario result in selection of a single cotton irrigation strategy. All of the farm's allowed cotton acreage used the PP4-10 irrigation plan. Timing aspects for irrigation apparently were no longer a limiting factor. Barley production continued in its weak posture, and the remainder of the increased water supplies were used for 128 acres of forage sorghum production in each of the 5 years considered. Total cropped acreages remained stable after 1988.

Further increases in water supplies (9 wells) allow increased barley production in the first 2 years and a single year of grain sorghum production. Total cropped acres generally decline over time, but are highly dependent on the assumed trend in forage hay prices and inflationary pressure on input prices.

Examination of results for the 550- and 930-pound cotton farm program yield scenarios (not shown) yield similar conclusions: 1) limited water supplies may force a mixture of irrigation schemes; 2) for the relative output prices assumed, small grain production prospects continue to be unfavorable; and 3) forage sorghum appears to be a viable production alternative, especially if water supplies are adequate.

Table 12. Optimal Crop Mix for Furrow Irrigation, 750-lb Base Cotton Yield[a]; Texas Trans-Pecos.

Crop/Scheme[b]	1987	1988	1989	1990	1991
	(acres)				
(4 Wells)[c]					
Cotton:					
POST4	117	94	94	30	30
PP3-10	88	65	65	0	0
PP4-10	335	381	381	445	440
Barley	161	0	0	0	0
Forage Sorghum	23	0	0	1	6
(6 Wells)					
Cotton:					
PP4-10	540	540	540	540	540
Barley	86	0	0	0	0
Forage Sorghum	128	128	128	128	128
(9 Wells)					
Cotton:					
PP4-10	540	540	540	540	540
Barley	287	109	0	0	0
Forage Sorghum	234	218	222	244	201
Sorghum	0	132	0	0	0

[a]Optimal cropping mix includes alternative irrigation strategies for cotton as well as acreages for noncotton crops. Base yield refers to the proven cotton yield for government farm programs.

[b]Furrow scheme mnemonics PPX-Y imply a preplant irrigation of Y acre-inches plus X postplant irrigations of 5-acre-inches. A POSTZ scheme implies an 8-acre-inch water-up plus Z-1 postplant irrigation of 5-acre-inches.

[c]Furrow irrigation scenarios assumed 700 gpm irrigation wells.

Table 13. Optimal Crop Mix for Sprinkler Irrigation, 1,000-lb Base Cotton Yield[a], Texas Trans-Pecos.

Crop/Scheme[b]	1987	1988	1989	1990	1991
	(acres)				
(3 Wells)[c]					
Cotton:					
S2412	507	507	507	398	252
S3010	33	33	33	106	203
(5 Wells)					
Cotton:					
S2412	72	0	0	0	0
S3010	468	540	540	540	540
Forage Sorghum	102	78	78	78	78
(7 Wells)					
Cotton:					
S3010	540	540	540	540	540
Forage Sorghum	206	204	209	215	172
Sorghum	120	122	117	0	0

[a]Optimal cropping mix includes alternative irrigation strategies for cotton as well as acreages for noncotton crops. Base yield refers to the proven cotton yield for government farm programs.

[b]Sprinkler scheme mnemonics SXXYY imply two 3-inch water-up irrigations plus XX acre-inches applied in YY applications.

[c]Sprinkler irrigation scenarios assumed 1,000 gpm irrigation wells.

Results for the sprinkler scenarios are presented in Table 12. Limited water supplies in the three-well scenario resulted in a mixture of the S2412 and S3010 schemes. The apparent preference for a given number of irrigation applications indicated in the preliminary stochastic dominance analysis did not appear in the quadratic programming results. Total cropped acreages decline slightly over time.

Limited water and the relative profitability of cotton resulted in production of only that crop in the three-well scenario. Cotton acreages were highest for the S2412 alternative, although stochastic dominance rankings (Table 7) for the 800-pound cotton base yield case placed the S2412 scheme third behind the S2410 and S2408 alternatives. Resource constraints resulted in selection of a significantly different irrigation scheme than that chosen with stochastic dominance.

Increased water supplies in the five- and seven-well scenarios resulted in greater acreages of both forage sorghum and the more water-intensive cotton strategies similar to the furrow scenarios. The seven-well scenario had enough water to support grain sorghum production. Acreages for that crop declined, however, as target prices declined over time.

Several observations arise from the preceding results. First, limited water availability resulted in a choice of schemes, some of which were deemed inferior when using stochastic dominance techniques. Second, as target prices declined, producers had an incentive to shift cotton production to the more water-intensive irrigation alternatives. Declining output prices, increasing input costs, and a desire to maintain farm program base acreage can be expected to prompt such a strategy. Interpretation of these results should be tempered, however, by recalling that farm program payment limitations are assumed ineffective. If, however, program payment limitations are effective and the variable cost of production exceeded the loan rate or world market price, producer incentives would be to target production for their established farm program yield. Significant production above the FPY would have to be sold at a loss at market price or the loan rate.

Additional acreage results of note include the continued poor performance of small grains and the attractiveness of forage sorghum as a cropping alternative given adequate water supplies. One might question whether total cropped acreages would decline as projected. This question applies especially in the case of center-pivot sprinkler systems. In either case, it is likely that the land would no longer be cropped. This phenomenon has occurred commonly in the past (Tables 1 and 2). Sprinkler systems, although representing a large capital asset, would simply not be replaced. Reductions in sprinkler-irrigated acres in such instances might not proceed as rapidly as portrayed here, but would eventually occur nonetheless.

Firm Survival

FLIPSIM tracks numerous variables pertaining to the survival and relative financial health of the farm firm. Stochastic simulation results in a distribution of values for many of those variables. Discussion in this section focuses on mean values for selected measures of financial health as well as estimates of the probabilities of survival and success.

Results pertaining to FLIPSIM simulations for the furrow-irrigated scenarios with a cotton farm program yield of 1,000 pounds per acre appear in Table 13. Probabilities of survival and success for the various scenarios are listed as well as starting net worth and debt. The average present value of ending net worth (assuming a 5 percent discount rate) is presented for comparison with its initial value. Average values for ending debt (nominal) as well as annual average cash receipts, net cash income[3], and government payments are presented in Table 14 as well.

Under the liberal condition for firm survival (maintaining 10 percent equity), the majority of representa-

[3]Net cash income consists of total cash receipts less total cash expenses. Total cash expenses do not, however, include principal payments or family living expenses.

Table 14. Estimated Effects of Varying Water Availability and Starting Debt on Farm Firm Health.

		Scenarios[a]									
Measure	Unit	F4OM750	F4OH750	F6OM750	F6OH750	F9OM750	F9OH750	F4LM750	F4LH750	F6LM750	F6LH750
Probability of Survival	%	100.	56.	100.	86.	100.	80.	100.	60.	100.	86.
Probability of Success	%	10.	2.	36.	12.	36.	14.	18.	8.	62.	30.
Beginning Net Worth	$1,000	349.	224.	350.	225.	351.	225.	253.	167.	254.	167.
p.v. Ending Net Worth[b]	$1,000	236.	-17.	287.	93.	287.	86.	173.	20.	222.	87.
(Percent Change)	%	-32.	-94.	-18.	-59.	-18.	-62.	-32.	-88.	-13.	-48.
Beginning Debt	$1,000	326.	452.	328.	453.	329.	453.	218.	318.	232.	319.
Ending Debt	$1,000	341.	572.	283.	519.	293.	532.	230.	393.	181.	346.
Annual Cash Receipts	$1,000	350.	349.	433.	433.	491.	491.	350.	349.	491.	491.
Annual Net Cash Income	$1,000	2.7	-21.8	19.3	-5.3	19.4	-5.4	6.1	-10.8	23.6	6.7
Annual Govt. Payments	$1,000	61.	61.	62.	62.	67.	67.	61.	61.	67.	67.

[a]Scenario naming convention: col 1 - F = furrow, S = sprinkler.
col 2 - number of wells.
col 3 - tenure, O = own, L = own/lease (960 acres own, 640 acres lease).
col 4 - debt level, M = med., H = high.
col 5 to 7 - farm program yield for cotton.

[b]Present values (p.v.) calculated using a 5% interest rate.

tive farms would still be in operation in 1991. Estimated probabilities of survival range from 56 percent for the four-well owned high-debt (F4OH750) scenario to 100 percent for all of the scenarios with so-called medium starting debt levels. Probabilities of success (earning a 5 percent return on beginning net worth), however, are much less likely. Among wholly owned scenarios, the six- and nine-well medium-debt scenarios have the greatest chance of success. Their chances of a reasonable return, however, were surpassed by the high probability of success (62 percent) experienced by the five-well lease/own medium-debt (F6LM750) scenario.

Values for beginning and present value of average ending net worth portend continued erosion of producer equity with percent declines ranging from 13 to 94 percent. Firms in the medium starting debt classification fare somewhat better, yet still experience significant declines in net worth over the 5-year period. Several factors contribute to such declines. Increasing production costs, static land values, and reductions in government farm program target prices force producers to borrow against owned land to continue production, reducing equity in the process. Outstanding debt values also increase. Government payments exceed net cash income in all cases, indicating a strong reliance on the price and income support programs. Average net cash income values are negative in most cases, even before extraction of living expenses and principal payments.

In terms of resource scenarios, producers in the six-well medium-debt situation (F6OM750) appear to have a relative advantage over their four- and nine-well counterparts. Restricted water supplies in the four-well case (F4OM750) resulted in an average annual net cash income of $2,700 and ending debt of $341,000. Conversely, the F6OM750 operation has an average annual net cash income of $19,300 and ending debt of only $283,000. Additional water availability for the nine-well owner (F6OM750) results in essentially the same net cash income and $10,000 more average debt.

Producers often view the water resource question in terms of how many acres to crop given a fixed water supply. The answer to such queries is a function of crop mix water requirements, output prices, and input prices. For the six 700-gpm well scenario, the 685 average cropped acres (Table 12) indicate a needed capacity of 6.1 gpm per cropped acre. This value increases slightly to 7.35 gpm per cropped acre for the none-well scenario. Net cash income values for the two scenarios (six- and nine-well) allow for land payments and repairs and maintenance on wells. Given the relative economic advantage of the six-well scenario with relatively good net cash income and lower ending debt, the optimal capacity ratio is likely around the 6.1 gpm per cropped acre value.

Tenure arrangement also matters in the area as producers in the lease/own scenarios fare better than their wholly owned counterparts. Probabilities of success and survival for the lease/own situations exceed those for the owned scenarios. Declines in net worth are less as well. Comparative results across tenure situations could change, however, if cash lease costs vary significantly from the effective rate of $20.25 per leased acre assumed here.

Results for producers using sprinkler irrigation are summarized in Table 15. Probabilities of survival and success improve slightly over those occurring for the 750-pounds FPY furrow-irrigated case. Net worth continues to decline, even with the admittedly high simulated yields associated with sprinkler irrigation. Increased assets (i.e., sprinkler systems) result in greater starting debt levels than for furrow irrigation. Debt loads continue to increase, fueled by liberal loan policies and growing demand accompanying falling target prices. Ending debt and average net cash income values do, however, show a slight advantage for producers in the five- or seven-well owned medium-debt classifications.

Summary and Conclusions

Provisions of the current government farm program are designed to reduce income support levels (i.e., target prices) during the 1986-1990 period. Impacts of reduced deficiency payments upon a high cost production area such as Texas Trans-Pecos could be dramatic. Agricultural producers in the region rely heavily on government farm program payments, and changes in those programs could imply major adjustments in production. Potential responses include alteration of irrigation practices, changes in crop mix (possibly to nonprogram crops), and idling of acreages.

Objectives of this study include an appraisal of potential cropping strategies at both the acre and whole-farm levels of analysis. Yield and price risk effects were accounted for explicitly due to the large role such factors play in the ultimate success or failure of agricultural firms in the region.

Preliminary Risk Analysis Results

Traditional enterprise budgeting techniques demonstrated greater expected returns for more water-intensive cotton irrigation schemes. Forage sorghum and red top cane provided reasonable nonprogram cropping alternatives and small grains were deemed inferior due to insufficient market returns and farm program support.

Use of stochastic dominance techniques with distributions of whole-farm net returns for various cotton irrigation alternatives demonstrated a general preference for the more water-intensive schemes. Rankings for furrow irrigation generally identified in the 10-acre-inch preplant schemes as preferable to the water-up and 8-inch preplant schemes applying approximately the same amount of water. Only in the low farm program yield (550 lbs) case did the water-up scheme (POST3 in this case) dominate the 10-inch preplant alternative.

Sprinkler rankings appeared to prefer a number of applications rather than a particular application rate. Preferred sprinkler schemes each had 9 or 10 postplant applications. Five cotton-irrigation schemes, chosen

Table 15. Estimated Effects of Varying Water Availability and Starting Debt on Farm Firm Health, Sprinkler Irrigation, 1,000-lb Base Cotton Yield; Texas Trans-Pecos.

		Scenario[a]					
Measure	**Unit**	**S3OM1000**	**S3OH1000**	**S5OM1000**	**S5OH1000**	**S7OM1000**	**S7OH1000**
Probability of Survival	%	100.	24.	100.	62.	100.	62.
Probability of Success	%	10.	4.	36.	8.	42.	14.
Beginning Net Worth	$1,000	378.	239.	379.	239.	381.	240.
p.v. Ending Net Worth[b]	$1,000	222.	-48.	287.	-48.	291.	-49.
(Percent Change)	%	-41.	-120.	-24.	-120.	-24.	-120.
Beginning Debt	$1,000	370.	510.	371.	511.	374.	515.
Ending Debt	$1,000	483.	710.	407.	656.	405.	657.
Annual Cash Receipts	$1,000	438.	439.	560.	560.	630.	629.
Annual Net Cash Income	$1,000	-1.7	-24.9	18.4	-7.4	20.	-5.9
Annual Govt. Payments	$1,000	79.	82.	81.	82.	86.	87.

[a]Scenario naming convention: col 1 - F = furrow, S = sprinkler.
col 2 - number of wells.
col 3 - tenure, O = own, L = own/lease, (960 acres own, 640 acres lease).
col 4 - debt level, M = med, H = high.
col 5 to 8 - farm program yield.

[b]Present values (p.v.) calculated using a 5% interest rate.

from among the top-ranked schemes at or near a particular farm program yield, were combined with non-cotton crops for consideration in the whole-farm simulation analysis.

Whole-Farm Results

Optimal cropping patterns identified via application of the quadratic programming model within FLIPSIM provided insight into irrigation management. Multiple irrigation schemes were chosen when water supplies were limited, indicating that timing of application becomes more important under those conditions. Furthermore, restricted water availability resulted in the selection of non-optimal, in terms of stochastic dominance rankings, irrigation schemes. Inclusion of resource feasibility constraints not accounted for in stochastic dominance analysis resulted in a different set of preferred activities, and in general, the more water-intensive alternatives were preferred. The 10-inch preplant and water-up furrow-irrigation schemes were chosen over the 8-inch preplant strategies. Low water supplies resulted in a mixture of 2- and 3-inch sprinkler application rates, but moved toward the 3-inch rate with more adequate water supplies. Declining target prices and relatively high production costs resulted in negligible barley and grain sorghum production, while forage sorghum production became profitable once cotton base acreage water requirements were met.

Significant firm survival results include the small chances of economic success and moderate to high chances of survival. The "quality" or length of that survival may be questionable given the analysis' indicated erosion of net worth, negative net cash income, and increased levels of debt. Few of the scenarios examined offered a reasonable hope of reducing the significant debt levels many Trans-Pecos producers now hold.

Results indicate that producers with moderate starting debt have a greater chance of surviving oncoming reductions in farm program income support (target price) levels. Producers with mixed own/cash lease operations also may have a greater change of survival. In all cases, producers in the region will continue to depend heavily upon government farm programs.

Resources related results indicate that returns will be maximized if water and land are combined in ratios of 6 or 7 gpm per cropped acre. Even these optimal rates will not, however, offset the adverse effects of high starting debt levels as evidenced by declining net worth in all but the most optimistic scenarios.

Conclusions

Producers in the Trans-Pecos will continue to struggle given the assumptions made in this analysis. Current projected prices (market and government) simply will not allow producers to overcome current debt loads. Significantly higher market prices over an extended period could aid greatly in that effort, but do not appear likely.

References

Anderson, J.R. "Simulation: Methodology and Application in Agricultural Economics." Review of Marketing and Agricultural Economics. 42(1974):3-55.

Barry, P.J. and D.R. Willman. "A Risk Programming Analysis of Forward Contracting with Credit Constraints." Amer. J. Agric. Econ. 53(1976):62-70.

Condra, G.D. "An Economic Feasibility Study of Irrigated Crop Production in the Pecos Valley of Texas." Texas Water Resources Institute TR-101, Texas Agricultural Experiment Station, 1979.

Dallas Morning News. Texas Almanac and Industrial Guide, *1986 and 1987*. Dallas: A.H. Belo Corporation, 1985.

Ellis, J.R., R.D. Lacewell, and D.R. Reneau. "Estimated Economic Impact From Adoption of Water-Related Agricultural Technology." West. J. Agric. Econ. 10(1985):307-21.

Ellis, J.R. "Risk Efficient Cropping Strategies and Farm Survival: Texas Trans Pecos" Ph.D. dissertation, Texas A&M University, 2987.

Freund, R.J. "The Introduction of Risk Into a Prgramming Model." Econometrica 24(1956):253-63.

Gallant, A.R. "The Fourier Flexible Form." Amer. J. Agric. Econ. 66(1984):204-08.

Gannaway, J. Cotton Improvement Specialist, Texas Agricultural Research and Extension Center, personal communication. Lubock, Texas, October 1986.

Glaser, L.K. Provisions of the Food Security Act of 1985. U.S. Dept. of Agriculture, Economics Research Service, Agricultural Information Bulletin No. 498, 1986.

Hallmark, A.M., L.T. West, L.P. Wilding, and L.R. Drees. "Characterization Data for Selected Texas Soils," Texas Agricultural Experiment Station MP-1583, 1986.

Henggeler, J. Unpublished irrigation plant efficiency tests, Pecos County, 1975-1982. Texas Agricultural Extension Service, Ft. Stockton, Texas.

Hoermann, J. Director, Farmers' Home Administration Office, personal communication. Ft. Stockton, Texas, 1985.

Hoermann, J. Director, Farmers' Home Administration Office, personal communication. Ft. Stockton, Texas, 1985.

King, R.P. "Operational Techniques for Applied Decision Analysis Under Uncertainty." Ph.D. dissertation, Michigan State University, 1979.

Knutson, R.D., E.G. Smith, J.W. Richardson, J.B. Penson, Jr., D. W. Hughes, M.S. Paggi, R.D. Yonkers, and D. T. Chen. Policy Alternatives for Modifying the 1985 Farm Bill. B-1561, Texas Agricultural Experiment Station, College Station, Texas, 1987.

Lin, Wm., G.W. Dean, and C.V. Moore. "An Empirical Test of Utility vs. Profit Maximization in Agricultural Production." Amer. J. Agric. Econ. 56(1974):497-508.

Markowitz, H.M. Portifolio Selection-Efficient Diversification of Investments. New York: John Wiley and Sons, 1959.

Meyer, J. "Choice Among Distribution." J. Econ. Theory 13(1977):325-36.

Moore, J. "Historical Weather Data for Texas Agricultural Experiment Station. Pecos, Texas, 1980-86." Unpublished.

Pratt, J.W. "Risk Aversion in the Small and the Large." Econometrica 32(1959):122-36.

Ramaratnam, S.S. "Texas Coastal Bend Grain Sorghum Producer's Fertilizer Decisions Under Uncertainty." Ph.D. dissertation, Texas A&M University, 1985.

Raskin, R. and M.J. Cochran. "Interpretations and Transformations of Scale for the Pratt-Arrow Absolute Risk Aversion Coefficient: Implications for Generalized Stochastic Dominance." West J. Agric. Econ. 11(1986):204-10.

Richardson, J.W. and C.J. Nixon. "Description of FLIPSIM V: A General Firm Level Policy Simulation Model". B-1528. Texas Agricultural Experiment Station, College Station, Texas, 1986.

Richardson, J.W. and G.D. Condra. "Farm Size Evaluation in the El Paso Valley: A Survival/Success Approach." Amer. J. Agric. Econ. 63(1981):430-37.

Texas Agricultural Experiment Station. "Cotton Variety Tests in the Trans-Pecos Area of Texas, 1981." TR-82, El Paso and Pecos, Texas, 1982.

Texas Agricultural Experiment Station. "Cotton Variety Tests in the Trans-Pecos Area of Texas, 1982." TR-83-1, El Paso and Pecos,Texas, 1983.Texas Agricultural Experiment Station. "Cotton Variety Tests in the Trans-Pecos Area of Texas, 1984." Lubbock and Halfway, Texas, 1985.

Texas Agricultural Extension Service. "Drip Irrigated Cotton Symposium." Midland, Texas, February 18-19, 1986.

Texas Agricultural Extension Service. "Texas ECONOCOT System." Texas A&M University System, Ft. Stockton, Texas, 1977.

Texas Crop and Livestock Reporting Service. "1984 Texas Agricultural Cash Receipts and Price Statistics." Austin, Texas, 1985.

Texas Water Development Board. "Surveys of Irrigation in Texas, 1958, 1964, 1969, and 1984." Report No. 294. Austin, Texas, 1986.

U.S. Department of Agriculture. "Economic Indicators of the Farm Sector, Costs of Production, 1984." EDIFS 4-1, Econ. Res. Serv., 1985.

U. S. Department of Agriculture. "Costs of Producing Upland Cotton in the United States." Econ. Res. Serv., Agric. Econ. Rept. 99, Washington, DC, 1964.

U.S. Department of Commerce. "1982 Census of Agriculture, Texas State and County Data." Vol. 1, Part 43, U.S. Govt. Printing Office, Washington, DC, 1984.

U. S. Department of Commerce. "Climatological Data, Texas." U.S. Govt. Printing Office, Washington, DC, 1966-1985.

Williams, J.R., C.A. Jones, and P.T. Dyke. "A Modelling Approach to Determining the Relationship Between Erosion and Soil Productivity." Trans. ASAE (1984a):129-44.

Williams, J.R., J.W. Putnam and P.T. Dyke. "Assessing the Effects of Soil Erosion with EPIC." Proc. Natl. Symp. Erosion and Soil Prod., New Orleans, LA, December 1984b.

Williams, S.R. and C.A. Jones. Texas Agricultural Experiment Station, personal communication. Temple, Texas, 1985 and 1986.

APPENDIX

Table A1. Selected EPIC[a] Crop Parameters; Texas Trans-Pecos.

	Barley	Cotton	Grain Sorghum	Red Top Cane	Forage Sorghum
Biomass/energy	30.0	20.0	40.0	28.0	32.0
Harvest index	.42	.55	.33	.34	.33
Optimal temp. for plant growth	15.0	27.5	27.5	27.5	27.5
Min. temp. for plant growth	0.0	12.0	10.0	10.0	10.0
Max. leaf area index	8.0	5.0	5.0	5.0	5.0
Fraction of growing season when leaf area starts declining	.80	.85	.80	.72	.90
Leaf area development parameter 1	15.01	15.01	15.01	15.01	15.01
Leaf area development parameter 2	50.95	45.95	50.95	50.95	50.95
Leaf area decline rate factor	2.0	2.0	.5	2.0	2.0
Biomass/energy decline rate factor	10.0	2.0	2.0	10.0	10.0
Aluminum tolerance	2.0	3.0	2.0	2.0	2.0
Maximum crop height	1.2	1.0	1.5	2.5	2.5
Maximum root depth	2.0	2.0	2.0	1.5	1.5
Harvest efficiency	.95	.90	.95	.95	.95
Pest factor	.95	.80	.95	.95	.95
Fraction water in yield	.12	.01	.14	.11	.14
Nitrogen in plant at 0. growth	.0600	.0580	.0440	.0440	.0440
Nitrogen in plant at .5 growth	.0231	.0192	.0164	.0164	.0164
Nitrogen in plant at 1. growth	.0134	.0177	.0128	.0128	.0128
P in plant at 0. growth	.0084	.0081	.0060	.0060	.0060
P in plant at .5 growth	.0032	.0027	.0022	.0022	.0022
P in plant at 1. growth	.0019	.0025	.0018	.0018	.0018
Wind erosion factor (standing live)	3.39	1.138	.657	3.39	3.39
Wind erosion factor (standing dead)	3.39	.603	.657	3.39	3.39
Wind erosion factor (flat residue)	1.61	.332	.320	1.61	1.61
Crop category	5.	4.	4.	4.	4.
Potential heat units	2056.	2400.	1918.	1918.	1205.

[a]EPIC (Erosion Productivity Impact Calculator) refers to a generalized crop growth simulation model developed by the U.S. Department of Agriculture (Williams et al. 1984b).

Table A2. Projected Market, Target, and Adjusted Loan Prices; Texas Trans-Pecos, 1987-1991.

Commodity	1987	1988	1989	1990	1991
Cotton (cents/lb)					
Market	53.32	59.16	59.40	67.90	67.90
Target	79.40	77.00	74.50	72.90	72.90
Adjusted Loan	41.80	40.00	40.00	40.00	40.00
Cottonseed ($/ton)					
Market	85.31	94.66	95.04	108.64	108.64
Barley ($/ton)					
Market	1.79	1.84	1.92	2.08	2.08
Target	2.60	2.55	2.47	2.38	2.38
Adjusted Loan	1.49	1.42	1.34	1.27	1.27
Grain Sorghum ($/cwt)					
Market	3.31	3.41	3.55	3.83	3.83
Target	5.14	5.04	4.89	4.66	4.66
Adjusted Loan	3.14	2.98	2.83	2.68	2.68
Forage Hay ($/ton)					
Market	61.20	63.20	66.00	71.60	71.60
Grazing ($/acre)					
Market	27.00	27.81	28.64	29.50	30.39

Sources: Knutson et al., 1987 and projections from historical data.

Table A3. Selected 1986 Input Prices, Crop Enterprise Budget Calculations; Texas Trans-Pecos.

Item	Unit	Cost ($/unit)
Electricity	kwh	.075
Gasoline	gal	.90
Hired Labor (repair/maintenance)	hr	6.00
Hired Labor (irrigation)	hr	3.00
Insurance Rate (% of mkt. value)	%	1.00
Interest Rate (intermediate borrow)	%	10.00
Interest Rate (intermediate equity)	%	10.00
Interest Rate (oper. capital borrow)	%	10.50
Interest Rate (oper. capital equity)	%	10.50
Interest Rate (positive cash flow)	%	5.25
Interest Rate (investment capital)	%	7.50
Lube Multiplier	none	.10
Owner Labor (repair/maintenance)	hr	6.00
Owner Labor (irrigation)	hr	6.00
Personal Property Tax	%	.50
Nitrogen Fertilizer (NH3)	lb	.16
Nitrogen Fertilizer (dry)	lb	.28
Nitrogen Fertilizer (liquid)	lb	.28
Hail Insurance (cotton)	$100 valuation	11.00
Herbicide (cotton)	appl	6.00
Herbicide (sorghum)	appl	5.50
Seed (cotton)	lb	.55
Seed (barley)	lb	.15
Seed (grain sorghum)	lb	.80
Seed (forage sorghum)	lb	.44
Seed (red top cane)	lb	.30

[Blank Page in Original Bulletin]

1M—11-90