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Crop Selection and Implications for Profits and Wind Erosion in a Semi-Arid Environment

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Abstract

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A daily crop growth simulation model was applied to four dryland cropping systems to estimate the profit distributions for each of four price series under stochastic weather conditions on the Southern High Plains of Texas. Stochastic dominance with respect to a function was utilized to rank each crop rotation for different risk-averse intervals. Solutions from the model indicate that long-term average annual soil loss due to wind erosion was a function of the producer's risk aversion, price expectation, and discount rate which affect the optimal crop rotation selection.

INTRODUCTION

Sloggett (1981) estimated that approximately 15 million acres (6 million ha or 60 thousand km^2) of cropland in the U.S.A. are irrigated from aquifers which are incurring declining groundwater levels. This is primarily in the Great Plains Region where irrigation water is pumped from the Ogallala Aquifer. This aquifer underlying the Southern High Plains of Texas is exhaustible, as there is negligible recharged (Lacewell et al., 1978). Given the declining groundwater levels and associated increased pumping costs, the profitability of irrigated production in the region is eroding. As producers make the transition from irrigated to dryland crop production, numerous questions arise concerning preferred cropping practices as well as changes in the producer's profit position

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and its stability. Risk relative to crop yields and net returns are perceived to be much greater under dryland as compared to irrigated cropping systems. The transition from irrigated to dryland production will also affect resource management issues such as long-term soil erosion susceptibility.

While considerable research efforts have focused on quantifying the impact of water-based erosion on production (Heady and Vocke, 1978; Foster and Becker, 1979; English and Heady, 1980; Burt, 1981), there exists little information on the effect of wind erosion on dryland crop yields in a semi-arid environment. The purpose of this study was to identify wind erosion implications for alternative dryland crop rotations on the Southern High Plains of Texas. A simulation model consisting of physically based components for simulating plant growth, wind and water erosion, and related processes was utilized to generate stochastic yields through time for each of the four dryland crop rotations. Discounted net present value distributions were developed for each rotation under static and random output price. Stochastic dominance with respect to a function was then utilized to rank the four crop rotation strategies under each price assumption for different levels of producer risk aversion and discount rates. From these rankings of risk efficient crop rotations, erosion implications were derived.

Erosion/Crop growth simulation model

Biophysical simulation techniques have been applied to a number of agricultural problems. Mapp and Eidman (1975) utilized a soil water–crop yield simulation model to evaluate alternative irrigation strategies within a whole farm planning context. Biological crop growth simulation models have been used to generate irrigated and dryland crop yield distributions which are then used as input into another simulation model to analyze investment in irrigation systems in northern Florida (Boggess and Amerling, 1983). Specific to the assessment of soil erosion, Taylor and Young (1985) indicate that simulation models offer more flexibility as compared to programming models in representing the complex interaction through time of soil erosion on crop yields and farm income.

A daily time step crop growth simulation model known as EPIC (Erosion Productivity Impact Calculator) was calibrated and used to estimate crop yields under 20 randomly generated 50-year weather patterns. EPIC simulations have been performed on 163 test sites in the continental U.S. and Hawaii. These tests have shown that EPIC produces valid results under a variety of climatic conditions, soil characteristics, and management practices (Williams, 1984). The components of EPIC include weather simulation, hydrology, erosion–sedimentation, nutrient cycling, tillage, soil temperature, plant growth, economic accounting, and plant environment (Williams et al., 1983). The erosion component of EPIC consists of two parts. The first part is water-based erosion.

EPIC predicts three forms of annual water-based erosion. These three forms include the 'Onstad and Foster' measure based on both rainfall and runoff variables, the USLE (Universal Soil Loss Equation) based only on rainfall variables, and the MUSLE (Modified Universal Soil Loss Equation) based on irrigation water erosion. For this analysis, only the Onstad and Foster measure of water erosion was reported.

A second erosion component of EPIC predicts annual wind erosion. Wind erosion was predicted by using a modified Manhatten, Kansas, wind erosion model capable of operating on a daily time step. The input data necessary to drive the wind erosion simulator were average daily wind velocity and daily direction by month. The wind erosion model within EPIC was calibrated to monitored daily wind erosion events in the area. A discussion of the sampling technique used to estimate daily wind erosion events is described by Fryrear (1986) and Zobeck and Fryrear (1986).

For this study, the EPIC model simulated dryland crop production on an Amarillo soil type. The Amarillo or sandyland type soils accounts for approximately 52% of the cropland acres in this region (USDA, 1957). The dryland crop rotations and tillage practices simulated were based on interview information from scientists in the region (C. Wendt, B. Ott, J. Abernathy, G. Wistran and J. Gammany, Texas Agricultural Experiment Station, Lubbock, TX, personal communication, May 1984). The four dryland rotations considered were continuous cotton, cotton/sorghum, cotton/wheat/cotton, and a cotton/sorghum/wheat rotation. Twenty random weather patterns were generated for 50 years in the study area. Each of the four crop rotations were subjected to the same 20 random weather patterns. Output from each simulation gives temporal estimates of crop yield as well as erosion from wind and water. Due to the time step simulation process, crop yield in a given year is not only a function of the climatic conditions in that year, but also the soil and soil moisture conditions from the previous year. Unlike single crop simulation models, EPIC is capable of simulating multi-year/multi-crop rotations. This framework was necessary to account for wind and water erosion and the subsequent impact upon crop yields under the alternative rotations.

Discounted present values

Enterprise budgets were developed for each rotation to determine annual net returns. Net returns to land, management, and risk by year was the difference between total revenue and the variable cost of production. The variable cost for a given year was based on the 1984 Texas Agricultural Extension Service crop enterprise budgets and harvesting costs which vary depending on predicted yield. Total revenue by rotation was determined by multiplying the appropriate expected crop price by the annual predicted yield. Four sets of crop prices were used to test the sensitivity of net returns. These price sets are listed

TABLE 1

Alternative Commodity Price Series

Commodity	20-year average[a]	1984[b] actual	High[c] mean random	Low[d] mean random
Cotton				
($/lb)	0.71	0.63	0.55	0.39
($/kg)	1.56	1.39	1.21	0.86
Cottonseed				
($/ton)	96.00	74.00	91.66	65.00
(c/kg)	10.60	8.16	10.10	7.16
Grain sorghum				
($/cwt)	5.16	4.90	4.08	2.90
(c/kg)	11.38	10.80	90.00	6.40
Wheat				
($/bu)	4.28	3.30	3.31	2.10
(c/kg)	15.70	12.10	12.20	9.80

[1]20 year average of seasonal prices adjusted by the USDA parity price index.
[b]Actual price received in the area in 1984.
[c]Mean of a random correlated price distribution with the target price > mean > loan rate under U.S. farm program provisions.
[d]Mean of a random correlated price distribution with the mean < loan rate under U.S. farm program provisions.
lb, pound (avoirdupois) ≈ 0.4536 kg.
bu, 60-1b bushel of wheat, white potatoes, soybeans (international bushel for grains) ≈ 27.2155 kg
cwt, short or nett hundredweight = 100 lb ≈ 45.36 kg.
ton, short or nett ton = 2000 lb ≈ 907 kg.

in Table 1. The first set of expected commodity prices were calculated from 20 years of seasonally adjusted prices and application of the parity price index (USDA) to express the prices in terms of static 1984 U.S. dollars. The parity price index expresses the prices paid by farmers for commodities, services, interest, taxes and wage rates on a 1910–1914 basis. The second set of static commodity prices correspond to the actual prices received by producers in 1984 on the Texas High Plains (Texas Crop and Livestock Reporting Service, 1984).

Tew and Boggess (1984) indicate that several potential biases in risk of profits are introduced if output price is assumed static. The third and fourth price series constitute stochastic output price in the area. The values listed in Table 1 for these price series are the means of correlated crop price distributions from which random price deviates by year are drawn. The procedure used to develop correlated crop price distributions is described by Richardson and Condra (1981). Ten years of actual price data for each commodity in the region were used to estimate the crop price distributions. United States commodity program provisions in 1984–1985 for small grains and cotton were included in the estimation of annual stochastic net returns.

A cumulative probability density function of net present values by price series was derived for each rotation by discounting each of the 20 random 50-year streams of net returns. Four discount rates of 0, 3, 6, and 9% were used to test present value sensitivity to the discount rate by dryland rotation across different risk aversion levels.

Stochastic dominance

Producer decisions are made relative to their attitudes toward taking risk, and many will accept a reduced expected return for a reduction in the variability of returns. Stochastic dominance can take into account such attitudes to determine the alternative strategy which maximizes a producer's expected utility U (y) from uncertain discounted net returns. Stochastic dominance with respect to a function establishes both necessary and sufficient conditions for the discounted net return cumulative density function (CDF) of $F(y)$ to be preferred to the CDF of $G(y)$ by all individuals whose absolute risk aversion coefficients are between a specified lower and upper bound (King and Robison, 1981). Meyer (1974, 1977) indicates that stochastic dominance with respect to a function can be more efficient in ranking alternative strategies than first, second, or third-degree stochastic dominance when the appropriate risk aversion intervals can be specified.

Stochastic dominance with respect to a function was used to rank CDF's of discounted net returns by dryland rotation across four discount rates. Four pairs of Pratt coefficients of absolute risk aversion were selected to represent appropriate risk aversion intervals. The intervals were derived by solving a certainty equivalent formula to define a maximal risk aversion coefficient which was a function of the mean and variance of the CDF's under consideration. The scaling of the risk aversion parameter to per-area present values reduces the possibility of inaccurate rankings from stochastic dominance with respect to a function as mentioned by Raskin and Cochran (1986). The risk interval was partitioned into four classes of producers. The risk aversion intervals $(-0.0001, 0.0001)$, $(0.0001, 0.015)$, $(0.015, 0.030)$, and $(0.030, 0.45)$ represent risk-neutral, slightly risk-averse, moderately risk-averse, and extremely risk-averse producers on the Southern High Plains, respectively.

Results

Average annual crop yields and soil erosion from wind and water as predicted by EPIC are summarized in Table 2. The mean and standard deviation of yield reported by crop for each rotation are over 50 years and across the 20 random weather patterns. The positive mean cotton yield response of shifting from

TABLE 2

Predicted crop yield and soil erosion by crop rotation over a 50 year time horizon

Predicted value	Irrigation[a]	Dryland			
	CC	CC	CS	CWC	CSW
Cotton yield (lb/acre)	351.8	182.9	224.3	214.2	242.9
(SD)	(33.7)	(91.4)	(88.2)	(88.3)	(88.5)
Sorghum yield (lb/acre)			2025.4		1997.3
(SD)			(1080.9)		(1038.8)
Wheat yield (bu/acre)				14.6	12.3
(SD)				(9.9)	(7.9)
Predicted average annual soil loss (ton/acre)					
Water erosion	0.2960	0.3202	0.2946	0.1996	0.2301
min	0.1782	0.0092	0.0086	0.0036	0.0062
max	0.4647	1.301	1.221	0.8547	0.9437
Wind erosion	9.81	11.41	10.50	7.40	7.42
min	0.85	0.70	0.66	0.17	0.19
max	88.15	87.10	81.90	84.95	84.90
Total	10.10	11.73	10.79	7.60	7.65
Average eroded soil Thickness (in)[b]	3.42	3.98	3.66	2.57	2.59

[a]Irrigation timing and amount for irrigated continuous cotton based on interviews (C. Wendt, B. Ott, J. Abernathy, G. Wistran and J. Gammany, Texas Agricultural Experiment Station, Lubbock, TX, May 1984).
[b]Average eroded soil thickness over the 50-year simulation.
CC, continuous cotton; CS, cotton/sorghum; CWC, cotton/wheat/cotton; and CSW, cotton/sorghum/wheat crop rotation.
acre = 0.40468 ha ≈ 4047 m^2.
1 lb/acre ≈ 1.1208 kg/ha.
1 bu/acre ≈ 67.25 kg/ha.
1 ton/acre ≈ 2.242 t/ha; t, metric tonne = 1000 kg.
in, inch = 2.54 cm.

continuous cotton to a cotton/sorghum wheat rotation is due to potential agronomic benefits of rotations under stochastic weather conditions. This yield increase comes at the expense of a reduction in the wheat yield relative to the cotton/wheat/cotton rotation and a reduction in sorghum yield compared to the cotton/wheat/cotton rotation and a reduction in sorghum yield compared to the cotton/sorghum rotation. This has implications for the overall variance and covariance of net returns by crop rotation scheme.

Predicted soil erosion due to water ranged from 0.0036 to 1.3 tons per acre annually. Average annual water erosion by rotation varied from 0.1996 tons per acre from the cotton/wheat/cotton rotation to 0.3202 tons per acre for the continuous cotton scenario. Water erosion was relatively minor compared with estimated annual wind erosion. The average monthly wind speed in the region is 13 mph (21 km/h or 5.8 m/s) and often exceeds 40 mph (64 km/h or 18 m/s) daily in the spring (Hardin and Lacewell, 1981). Average annual wind erosion from the cotton/sorghum and continuous cotton rotations were approximately 35 times greater than water erosion. The large difference between predicted wind and water erosion rates was due to climatic and soil conditions in this semi-arid region. When wheat was introduced into the rotation, estimated annual wind erosion declined by 34% compared to the dryland continuous cotton case. Average soil loss due to wind erosion varied from 11.41 tons per acre annually for continuous cotton to 7.4 tons per acre annually for the cotton/wheat/cotton rotation. Top-soil depths were reduced by 3.98 and 2.57 inches over the 50-year horizon at these rates of annual soil loss, respectively.

As a base to compare the affect of irrigation, irrigated continuous cotton was simulated on the Amarillo soil type. Estimated annual soil erosion was only 14% less under irrigated cotton as compared to dryland continuous cotton. This translates to an eroded topsoil depth of 3.42 inches instead of 3.98 over 50 years. Irrigation typically increases surface soil moisture which reduces wind erosion susceptibility. However, irrigation is less effective at reducing wind erosion susceptibility on the coarse sand of the Amarillo soil type.

Native pasture without grazing or harvest was simulated to provide estimates of annual wind erosion in the absence of tillage. Predicted erosion rates in this case averaged 0.90 tons per acre or an eroded topsoil depth of 0.11 inches over 50 years. The maximum annual level of wind erosion predicted for native pasture was 16.13 tons per acre compared to 80 plus tons for the other cropping systems.

The sources of risk considered in this study were output price variability and variation in dryland yield due to weather. Initially, only yield variability impact on net returns was considered. The estimated nominal net return and mean and standard deviation of net present values for two static price sets are reported in Table 3. Estimated average annual net returns for the 20-year USDA adjusted price series ranged form $27.31 per acre ($67.48 per ha) for dryland cotton to $38.97 per acre ($96.30 per ha) for the cotton/sorgum rotation. This is significantly less than the estimated average annual net returns of over $63 per acre ($155.85 per ha) for irrigated cotton. The annual net returns and discounted net present values for irrigated cotton were derived under current groundwater conditions which cannot be maintained indefinitely into the future.

The first column in Table 3 summarizes the mean and standard deviation of discount rates for irrigated monoculture cotton. These figures support the earlier contention that dryland crop production entails more risk given a lower

TABLE 3

Annual net returns and discounted net present value by crop rotation under static prices over a 50-year time horizon ($ per acre)

Predicted value	Irrigation	Dryland			
	CC	CC	CS	CWC	CSW
20-year series [a]					
Average annual net return	63.07	27.31	38.97	37.33	38.26
	155.85	67.48	96.30	92.24	94.54
Net present value discount rate					
0.%	3153.4	1365.7	38.97	37.33	38.26
	(96.1)	(372.9)	96.30	92.24	94.54
3%	1869.9	773.4	1948.7	1866.9	1918.0
	(60.3)	(239.4)	(377.4)	(225.7)	(262.3)
6%	1296.3	718.9	1094.9	1042.40	1052.1
	(48.7)	(180.6)	(258.7)	(175.4)	(172.8)
9%	996.1	381.1	636.9	681.4	680.7
	(42.9)	(146.8)	(193.6)	(146.7)	(137.1)
			527.5	497.1	493.9
			(150.3)	(126.6)	((1165)
1984 price received[b]					
Average annual net return	34.98	12.69	28.48	21.19	26.20
	86.44	31.36	70.38	52.36	64.74
Net present value discount rate					
0%	1749.2	634.5	1423.9	1059.3	1310.3
	(81.4)	(315.9)	(355.9)	(188.9)	(337.0)
3%	1096.4	378.7	789.9)	604.9	718.3
	(51.7)	(203.1)	(218.4)	(146.3)	(213.2)
6%	791.3	262.1	532.2	401.3	463.5
	(41.4)	(152.6)	(179.8)	(121.8)	(164.2)
9%	625.2	201.1	369.8	295.0	335.6
	(36.5)	(123.3)	(137.0)	(104.7)	(136.2)

[a]Discounted net present values calculated using the 20-year price series adjusted by the USDA parity price index.
[b]Discounted net present values calculated using 1984 prices received on the Texas High Plains.

TABLE 4

Annual net returns and discounted net present value by crop rotation under random price over a 50-year time horizon[a] ($ per acre)

Predicted value	Irrigation	Dryland			
	CC	CC	CS	CWC	CSW
High mean random[b]					
Average annual net return	96.04	41.15	42.41	42.20	38.79
Net present value discount rate					
0%	4801.91	2057.47	2120.73	2109.87	1939.67
	(81.07)	(327.54)	(284.40)	(188.32)	(287.79)
3%	2706.53	1130.75	1167.30	1161.96	1059.16
	(52.20)	(205.51)	(181.54)	(148.38)	(189.54)
6%	1801.01	734.52	753.90	752.22	682.15
	(45.13)	(154.35)	(129.49)	(125.58)	(148.25)
9%	1343.04	535.56	543.24	545.58	492.16
	(41.93)	(127.35)	(111.74)	(109.08)	(123.70)
Low mean random[c]					
Average annual net return	67.06	24.92	35.68	29.20	33.06
Net present value discount rate					
0%	3353.32	1246.27	1783.97	1459.97	1652.85
	(82.70)	(202.82)	(2322.41)	(120.69)	(222.41)
3%	1875.63	685.78	943.95	804.25	898.40
	(46.00)	(130.74)	(139.57	(95.36)	(142.50)
6%	1240.70	446.21	628.73	521.04	577.37
	(37.32)	(100.48)	(106.36)	(80.61)	(110.15)
9%	921.36	325.95	441.79	378.27	417.71
	(34.32)	(83.95)	(83.61)	(70.27)	(91.60)

[a]Discounted net present values are derived under 1986 commodity program provisions with assumed flexible base substitution.
[b]Discounted net present values calculated using random price deviates drawn from correlated price distributions where target price > mean > loan rate.
[c]Discounted net present values calculated using random price deviates drawn from correlated price distributions where mean > loan Rate.
CC, continuous cotton; CS, cotton/sorghum; CWC, cotton/wheat/cotton; and CSW, cotton/sorghum/wheat crop rotation.

mean and larger standard deviation of net returns compared to irrigated cropping systems. At a discount rate of 6% under the 20-year average price series, the present value for irrigated continuous cotton was 152% greater than dryland continuous cotton. Likewise, the coefficient of variation was 0.04 for irrigated cotton compared to 0.35 for dryland cotton. Even under the lower 1984 static price case, the mean net present value was greater and the standard deviation less for irrigated than for dryland crop production.

The previous results indicate serious financial implications for the transition from irrigated to dryland production. Given the lower annual net return associated with dryland, the productive value of land in the region will decline as cropland shifts from irrigated to dryland cropping systems. Since land represents a major share of total assets, producers will be forced to expand their operation upon a diminishing asset base to maintain pre-transition income levels. This eroding of land value can be accelerated by further decline in output prices and/or increase in input prices.

A second source of risk considered in this analysis are variations in dryland net returns due to weather and output price evaluated within government sponsored commodity program provisions. The estimated average annual net return and discounted net present values by cropping system for both stochastic price sets are reported in Table 4. Inclusion of the U.S. cotton marketing loan under high mean random price increased the average annual net returns to cotton by 50% as compared to the 20-year static price series. Average annual net returns to cotton estimated with the low mean random price series was more than 90% greater relative to the 1984 static price set.

An extension of this analysis was to assess the resulting soil erosion implications when producers rank alternative dryland crop rotations based on their risk aversion level and the expected utility for each strategy. Stochastic dominance with respect to a function was used to rank the four dryland crop rotations under four risk aversion levels and four discount rates for each price series. The results of the stochastic dominance analysis under the static price series are presented in Table 5.

The risk neutral individual, which is equivalent to maximizing expected net returns, prefers the cotton/sorghum rotation to all other rotations for both static price sets. Under the 20-year price series, the slightly risk-averse producer would be indifferent between cotton/sorghum and the cotton/sorghum/wheat rotation for all discount rates except at the 6% discount rate where he also is indifferent to the cotton/wheat/cotton rotation. The moderately and extremely risk-averse producer would prefer the cotton/sorghum/wheat rotation to the other dryland rotations for discount rates of 0 to 9%. This rotation results in an estimated annual wind erosion rate of 7.42 tons per acre as compared to 10.79 tons per acre from the cotton/sorghum rotation. The change in preference from the cotton/sorghum to the cotton/sorghum rotation implies a potential decline of 31% in the average annual soil loss due to wind erosion.

TABLE 5

Rankings of crop rotations based on risk aversion across various discount rates for the static price series

	Rank	Discount rate			
		0%	3%	6%	9%
20-year series					
Risk-neutral	1	CS	CS	CS	CS
(−0.0001 to 0.00001)	2	CSW	CSW	CWC	CWC
	3	CWC	CWC	CSW	CSW
	4	CC	CC	CC	CC
Slightly risk-averse	1	CS/CSW	CS/CSW	CS/CSW/CWC	CS/CSW
(0.0001 to 0.015)	2				
	3	CWC	CWC		CWC
	4	CC	CC	CC	CC
Moderately risk-averse	1	CSW	CSW	CSW	CSW
	2	CWC	CS/CWC	CS	CS
(0.015 to 0.030)	3	CS		CWC	CWC
	4	CC	CC	CC	CC
Extremely risk-averse	1	CSW	CSW	CSW	CSW
	2	CWC	CS	CS	CS
(0.030 to 0.045)	3	CS	CWC	CWC	CWC
	4	CC	CC	CC	CC
1984 price received					
Risk-neutral	1	CS	CS	CS	CS
(−0.0001 to 0.0001)	2	CSW	CSW	CSW	CSW
	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC
Slightly risk-averse	1	CS	CS	CS	CS
(0.001 to 0.015)	2	CSW	CSW	CSW	CSW
	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC
Moderately risk-averse	1	CS	CS	CS	CS
	2	CSW	CSW	CSW	CSW
(0.015 to 0.030)	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC
Extremely risk-averse	1	CS	CS	CS	CS
	2	CSW	CSW	CSW	CSW
(0.030 to 0.045)	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC

Under the 1984 static price case, the producer would prefer the cotton/sorghum rotation across all discount rates and risk aversion levels considered.

The results of the stochastic dominance analysis given random price expec-

TABLE 6

Rankings of crop rotations based on risk aversion across various discount rates for the random price series

	Rank	Discount rate			
		0%	3%	6%	9%
High mean random	1	CS	CS	CS	CWC
Risk-neutral	2	CWC	CWC	CWC	CS
(−0.0001 to 0.0001)	3	CC	CC	CC	CC
	4	CSW	CSW	CSW	CSW
Slightly risk-averse	1	CS/CWC	CS/CWC	CS/CWC/CWC	CWC
(0.0001 to 0.015)	2				CS
	3	CC	CC	CC/CSW	CSW
	4	CSW	CSW		CSW
Moderately risk-averse	1	CWC	CWC	CWC	CWC
(0.015 to 0.030)	2	CS	CS	CS	CS
	3	CC	CC/CSW	CSW	CSW
	4	CSW		CC	CC
Extremely risk-averse	1	CWC	CWC	CWC	CWC
(0.030 to 0.045)	2	CS	CS	CS	CS
	3	CC	CSW	CSW	CSW
	4	CSW	CC	CC	CC
Low mean random					
Risk-neutral	1	CS	CS	CS	CS
(−0.0001 to 0.0001)	2	CSW	CSW	CSW	CSW
	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC
Slightly risk-averse	1	CS	CS	CS	CS
(0.001 to 0.015)	2	CSW	CSW	CSW	CSW
	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC
Moderately risk-averse	1	CS	CS	CS	CS
(0.015 to 0.030)	2	CSW	CSW	CSW	CSW
	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC
Extremely risk-averse	1	CS	CS	CS	CS
(0.030 to 0.045)	2	CSW	CSW	CSW	CSW
	3	CWC	CWC	CWC	CWC
	4	CC	CC	CC	CC

CC, continuous cotton; CS, cotton/sorghum; CWC, cotton/wheat/cotton; and CSW, cotton/sorghum/wheat crop rotation.

tations are presented in Table 6. In the high mean random price case, the risk neutral producer would prefer the cotton/sorghum rotation to all other dryland rotations for discount rates less than 9%. The cotton/wheat/cotton rotation dominates at a 9% discount rate. The slightly risk-averse producer would

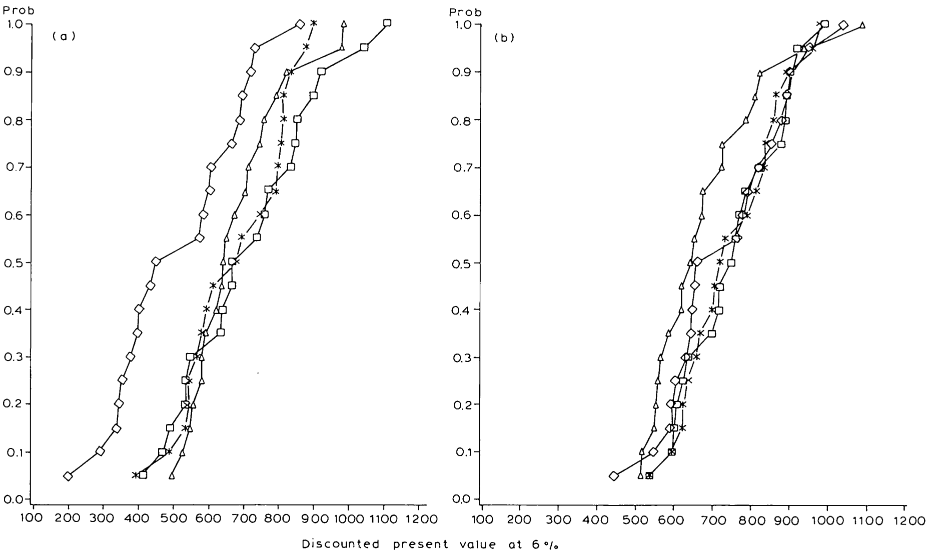

Fig. 1. CDF's of discounted net returns by dryland crop rotatio (diamond, net returns from continuous cotton; square, net returns from cotton/sorghum rotation; star, net returns from cotton/wheat rotation; triangle, net returns from cotton/sorghum/wheat rotation) (a) Static 20-year series. (b) High mean random series.

be indifferent to the cotton/sorghum and cotton/wheat/cotton rotation for discount rates less than 9%. The moderately and extremely risk-averse producer would prefer the cotton/wheat/cotton rotation to the other dryland crop options for discount rates between 0 and 9%. The ranking of dryland crop rotations given the low mean random price series is identical to the 1984 static price scenario. Again, the cotton/sorghum rotation dominates all other rotation for all discount rates and risk aversion intervals evaluated. These results indicate that lower crop price expectations, static or random, could increase annual soil erosion from 7.4 tons per acre to 10.79 tons per acre by shifting preference from the cotton/sorghum/wheat/cotton rotation to the cotton/sorghum rotation.

Illustrated in Fig. 1 are the estimated discounted net return CDF's for each dryland crop rotation at a 6% discount rate under the 20-year static price series and the high mean random price series. Continuous cotton is first-degree stochastically dominated by the other three dryland crop rotations under the static price case. Continuous cotton is not first-degree stochastically dominated under the high mean random price scenario modelled within the 1986 commodity program. These figures support the earlier finding that commodity programs in this area increase the mean discounted present value and reduces the variance of present value for each dryland crop rotation.

The 1981 and 1985 farm programs have encouraged the maintenance of cotton base yields and base acreage through lucrative differentials between the target price and the market price in the region. For example, the 1986 regionally adjusted target price is set at \$ 0.734/1b or \$ 1.81/kg compared to a projected 1986 market price of \$ 0.32/1b or \$ 0.79/kg (Law, 1986). These differentials create a short-term impediment for the adoption of less erosive dryland rotations such as cotton/wheat/cotton and cotton/sorghum/wheat since base acreage in wheat and sorghum has not been established under traditional monoculture cotton production. The government-sponsored incentive to maintain traditional cropping patterns, continuous cotton in this region, coupled with declining groundwater levels indicate that average annual wind erosion could increase by 16% as cropland reverts from irrigated to dryland cropping systems. This increase is significant if one considers the projection that 3.4 million acres (1.38 million ha or 13.8 thousand km^2) of irrigated cropland will revert to dryland in the next 50 years (Grubb, 1966). An overall implication of this analysis suggests that increased flexibility in the 1985 farm program concerning cropping patterns would substantially reduce annual rates of wind erosion in the study area.

Summary

As producers make the transition from irrigated to dryland crop production, the impact on discounted net returns and wind erosion is rather uncertain. The results of the stochastic dominance analysis and the simulation model EPIC, indicate that long-term average annual soil loss due to wind erosion is a function of crop rotation selection which depends upon the producer's discount rate, price expectations, and level of risk aversion. The results from this study indicate that under the higher static 20-year price series or the high mean random price series, as producers overall become more risk-averse, annual soil erosion from wind is reduced because of a shift in preference from the cotton/sorghum rotation to the cotton/sorghum/wheat or cotton/wheat/cotton rotation. However, under lower crop prices the cotton/sorghum rotation is preferred to all other dryland rotations. A change in the relative price of wheat, cotton and sorghum as well as a change in government commodity programs affect crop rotation preferences. An area of future research necessary to quantify regional wind erosion implications of the transition from irrigated to dryland relates to the distribution of risk preferences among producers. In conclusion, the integration of a daily time step simulation model and the stochastic dominance with respect to a function technique provides a very useful tool to evaluate alternative dryland crop rotations and the resulting wind erosion implications under randomly generated weather conditions in a semi-arid environment.

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