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Government Policy, Wind Erosion, and Economic Viability in Semi-Arid Agriculture: The Case of the Southern Texas High Plains

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ABSTRACT

The 1996 farm bill challenges agricultural producers to pursue conservation objectives while allowing flexibility and reducing subsidies. The nature of this challenge for semi-arid rainfed, wind-erosion-prone agriculture is explored via a behavioral model. Simulations of farm-firm decision making under scenarios in the southern Texas High Plains are evaluated. Results indicate that the removal of subsidies, while lowering farm incomes, does not, under most assumptions, alter cropping system choice. Alternatively, under a variety of assumptions, the imposition of an erosion tax shuts down cropping.

Key Words: conservation practices, cropping system choice, economic dynamics, FAIR Act of 1996.

The Federal Agricultural Improvement and Reform (FAIR) Act of 1996 introduces three primary changes in agricultural policy. First, income payments are divorced from acreage requirements for particular crops. This increased planting flexibility, while generally perceived as beneficial to allocative efficiency in the agricultural sector, may or may not lead to environmental improvements. Second, income transfers to farmers decline over time. Third, the environmental and conservation provision changes under FAIR, in giving priority to water quality and wildlife concerns, will decrease both the Conservation Reserve Program (CRP) and conservation cost-share payments flowing to areas that experience significant wind erosion.

The combination of these policy changes raises three primary sets of questions with respect to farm-firm decisions in wind-erosion-prone agricultural regions: (*a*) Will a reduction in subsidies and reversion to market prices result in a shift to "higher residue" alternative crops, diversified production, or to grazing in these regions, and hence in a reduction of annual rates of wind erosion? (*b*) Will a reduction in subsidies and reversion to market prices result in land going out of agricultural use? and (*c*) How might a "stick" rather than "carrot" approach to the control of erosion affect farm-firm choices and the viability of agricultural production?

This article attempts to address these questions in the context of the southern Texas High Plains. First, a behavioral model of farm-firm decision making with respect to cropping system choice and soil resource depletion over time in the semi-arid rainfed context is pre-

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sented. Next, simulation results address the first and second questions by providing information on the choice of initial cropping system, the switching time between an erosive and less erosive system, and the time to economic exhaustion of the land resource under alternative policy scenarios with and without subsidies. The third question is addressed by analyzing the effects of an erosion tax which forces farm firms to internalize environmental costs.

A Dynamic Model of Cropping System Choice and Soil Erosion

Previous analyses have developed general dynamic models of farm-level decision making with respect to soil conservation (Burt; McConnell; Miranowski; Saliba; Segarra and Taylor). The conceptual model developed here differs from this literature in several key respects. First, a discrete-time formulation was chosen both because agricultural production decisions are made on a discrete-time basis and because, while the steady-state solutions to a discrete-time model and its continuous-time analog are the same, the dynamics are typically different. Second, in order to meet the requirements on decision variables, to keep the number of decision variables to a mathematically tractable level, and to formulate a theoretical model consistent with the data available for empirical investigation, the approach employs a "cropping system" concept. A cropping system encompasses farming practices, crop choice, crop rotations, and technology. Third, the initial cropping system choice and switching and shutdown conditions are found analytically using the first-order conditions.

The model incorporates three key features of soil erosion in the semi-arid rainfed environment: (*a*) under most known crop rotations and technologies, the rate of soil erosion exceeds that of the natural rate of regeneration of soil;[1] (*b*) the choice of crop appears of greater significance for the magnitude of erosion than cultural practices; and (*c*) in addition to the across-period, on-site productivity impacts of soil erosion, there are significant within-period effects off the farm site. Additionally, the model assumes that the farm firm operates in a competitive industry, that locationally determined variable inputs and stocks are held constant across crops and hence ignored, that no durable investments exist, that farm firms cannot expand production along the extensive margin, and that the farm firm has complete knowledge about current and future prices, costs, and the effects of cropping system decisions on soil loss.

The decision variables in the control problem (X_{it}) are the proportion of total acreage allocated to each of two cropping systems—an erosive cropping system ($i = 1$) and a less erosive cropping system ($i = 2$)—in each time period. The stock of the soil resource remaining at the end of each time period (D_t) serves as the state variable. Given the locally specific conditions and level of the soil stock, once the farm firm chooses a cropping system i, per acre yield, cost, and erosion, and standard practice with respect to inputs, are determined.

The free-time, free-state, autonomous control problem for a representative one-acre farm then can be written as:

$$(1)\quad \max_{\{X_{it}\}} J = \sum_{t=1}^{\infty} \rho^t \sum_{i=1}^{2} R_{it}X_{it},$$

$$\text{s.t.:}\quad D_t = D_{t-1} - \sum_{i=1}^{2} \alpha_{it}X_{it},$$

$$D_t \geq 0 \quad \forall\, t,$$

$$X_{it} \geq 0 \quad \forall\, i,\, t, \quad \text{and}$$

$$\sum_{i=1}^{2} X_{it} \leq 1 \quad \forall\, t,$$

where ρ is the discount factor [$\rho = 1/(1 + \delta)$, with δ denoting the periodic discount rate],

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[1] While techniques for determining soil formation rates are not highly reliable, the estimates that do exist for soil types found in semi-arid regions (Lal) are much lower than estimates of annual soil loss on cropland in the southern Texas High Plains (Lee). Hence, it appears that continued cropping of the southern Texas High Plains would lead in time to exhaustion of the soil resource.

and R_{it} is the net revenue from the ith cropping system at the end of period t; $R_{it} = (P_{it}Y_{it} - C_{it})$, where P_{it} is the price per unit yield, Y_{it} is the yield per acre, and C_{it} is the cost per acre for the ith cropping system in period t. The erosion in period t can be expressed as $\Sigma_{i=1}^{2} \alpha_{it}X_{it}$, where α_{it} is the amount of soil loss in tons per acre in time period t if using the ith cropping system. It is assumed that $\alpha_{1t} > \alpha_{2t} \geq 0$, and that acreage not cropped experiences zero erosion.

The farm firm chooses the proportion of total acreage allotted to each cropping system so as to maximize the net present value of net revenues over an infinite planning horizon subject to the equation of motion for the soil stock [equation (1)] and to inequality constraints on the soil stock and proportions of acreage devoted to each cropping system. The per acre yields, costs, and erosion rates associated with each cropping system are a function of the soil stock, i.e., $Y_{it} = f(D_{t-1})$, $C_{it} = g(D_{t-1})$, and $\alpha_{it} = h(D_{t-1})$. Per acre yield increases with soil depth because soil depth proxies for numerous aspects of soil quality which are positively correlated to soil depth and which enhance crop growth. Yet, other factors which influence yields, such as plant genetics and climate, provide an upper bound on the extent to which aspects of soil quality can enhance yields; hence, yields increase with soil depth at a decreasing rate, asymptotically approaching this upper bound. Marginal costs decline with increasing soil depth as aspects of soil quality substitute for purchased variable inputs; yet, due to decreasing substitutability, one would expect these marginal costs to decline at a decreasing rate. Erosion is expected to decline with increasing soil depth as improved soil quality leads to higher yields, higher residues, and better moisture retention; soil quality cannot, however, mitigate against all soil erosion. Because the change in erosiveness may not be uniform across cropping systems as the stock and quality of the soil resource changes, the relative erosiveness of various cropping systems may change over time.

Defining $\alpha_t = \alpha_{1t} - \alpha_{2t}$ as the additional erosiveness associated with cropping system 1 relative to cropping system 2, $R_t = R_{1t} - R_{2t}$ as the net returns advantage associated with cropping system 1 relative to cropping system 2, and λ_t as the shadow price of a unit of soil depth at the end of period t, the set of necessary conditions for a solution to the optimal control problem can be summarized by equations (2)–(5):

$$(2)\qquad X_{1t}^{*} = \begin{cases} X_{1t} = 1 \\ \quad \text{only if } R_t \geq \lambda_t\alpha_t \quad \text{and} \quad R_{1t} \geq \lambda_t\alpha_{1t} \\ 0 \leq X_{1t} \leq 1 \\ \quad \text{only if } R_t = \lambda_t\alpha_t \quad \text{and} \quad R_{1t} \geq \lambda_t\alpha_{1t} \\ X_{1t} = 0 \\ \quad \text{only if } R_{1t} \leq \lambda_t\alpha_{1t} \quad \text{or} \quad R_t \leq \lambda_t\alpha_t, \end{cases}$$

$$(3)\qquad X_{2t}^{*} = \begin{cases} X_{2t} = 1 \\ \quad \text{only if } R_t \leq \lambda_t\alpha_t \quad \text{and} \quad R_{2t} \geq \lambda_t\alpha_{2t} \\ 0 \leq X_{2t} \leq 1 \\ \quad \text{only if } R_t = \lambda_t\alpha_t \quad \text{and} \quad R_{2t} \geq \lambda_t\alpha_{2t} \\ X_{2t} = 0 \\ \quad \text{only if } R_{2t} \leq \lambda_t\alpha_{2t} \quad \text{or} \quad R_t \geq \lambda_t\alpha_t, \end{cases}$$

$$(4)\qquad \lambda_t = \sum_{j=t}^{\infty} \rho^{j-(t-1)} \sum_{i=1}^{2} \left(P_{i,t+1} \frac{\partial Y_{i,j+1}}{\partial D_j} - \frac{\partial C_{i,j+1}}{\partial D_j} \right) \times X_{i,j+1} \prod_{k=t}^{j} \left(1 - \sum_{i=1}^{2} \frac{\partial \alpha_{i,k+1}}{\partial D_k} X_{i,k+1} \right),$$

$$(5)\qquad \lambda_t \geq 0, \quad \text{and} \quad D_t \geq 0,$$

$$\lambda_T D_T = 0, \quad \text{and} \quad D_0 \text{ given.}$$

Equation (2) states that the entire farm acreage will be devoted to cropping system 1 in any period t only if the net revenue advantage associated with cropping system 1 is greater than or equal to the value of the erosion disadvantage associated with cropping system 1 ($R_t \geq \lambda_t\alpha_t$), and the net revenue associated with cropping system 1 is greater than or equal to the value of the soil loss associated with cropping system 1 ($R_{1t} \geq \lambda_t\alpha_{1t}$). Equation (3) states the equivalent conditions for choosing cropping system 2. The entire acreage will be cropped, but the farm-firm manager would be indifferent between the proportion of the acreage devoted to the two cropping systems, when the revenue advantage of one cropping system relative to the other is just offset by the increased erosiveness of that cropping system relative to the other (i.e., when $R_t = \lambda_t\alpha_t$). All cropping will cease only if the per acre net revenue for each of the cropping systems is less than or equal to the per acre shadow value of the soil resource. Equation (4) states that the shadow price of the soil in period t can be expressed as an infinite sum of the present value of all future decreases in per acre net revenue, adjusted further by a multiplicative term dependent upon future increases in per acre erosion due to a deterioration in the quality of the soil resource which accompanies depletion of the soil stock. Equation (5), with T denoting the terminal time, is really a condition that $\lambda_T = 0$. Under most conditions, prior to physical exhaustion of the resource, costs will rise so high as to render continued depletion of the resource unprofitable.

The Study Area

The study area includes the eight southernmost counties in the southern Texas High Plains: Yoakum, Terry, Lynn, Gaines, Dawson, Andrews, Martin, and Howard. Dawson County, located at the center of this area, served as the representative county for much of the data. This semi-arid region receives, on average, between 12 and 18 inches of annual rainfall. Irrigation in the region peaked in the mid-1960s, experienced a decline until the late 1980s, and has since undergone a slight increase. Today, less than 9% of the cropland is irrigated. In 1992, of the region's 4,009,965 farm acres, 34% were in harvested cropland, 43% were in rangeland and pasture, and 7% were in the CRP and the Wetland Reserve Program (WRP). Of the harvested acreage in 1992, 66% was planted to cotton, 25% to sorghum, and less than 9% to other crops. CRP and WRP acreage has more than doubled since 1987 (acres rose from 136,504 to 384,428). Also, because conservation compliance provisions of the 1985 and 1990 farm bills did not have their full impact until after 1990, the 1992 figures for the allocation of harvested acreage planted to sorghum and cotton reflect a quite dramatic shift toward more sorghum and less cotton. In 1987, sorghum accounted for less than 10% of harvested acreage, while cotton represented 80% (U.S. Department of Commerce, Census of Agriculture). Sorghum's rise to 25% in 1992 is consistent with the 25% high-residue-crop rotation requirement for conservation compliance under dryland cotton systems in the region.

Simulation Inputs

First-order conditions of the theoretical model are used to simulate the economic dynamics of cropping system choice and resource depletion in the southern Texas High Plains. The information underlying the stock functions and the other data used in the simulations are described in Bunn (1995). A three-step approach was used to derive the yield and erosion stock functions. First, experts were asked to describe the form of these functions for various cropping systems over the domain of soil stock and to support their views with scientific evidence. Second, other relevant published research was used to refine and provide a check on the data series resulting from the interviews of experts. Third, appropriate analytic functions were identified and then fitted to the data generated by steps one and two.

Four primary types of cropping systems are potentially applicable to the southern Texas High Plains: (*a*) conventional tillage and monoculture, (*b*) conventional tillage and rotation of two or more crops, (*c*) reduced tillage monoculture, and (*d*) reduced tillage and rotation of two or more crops. Neither a survey of the literature relevant to the agricultural economy or cropping systems of this region, nor field work, led to a consensus as to identification of the technically and economically viable set of cropping systems for the area or a consensus as to relative yields and erosion as a function of soil depth for a particular subset of the cropping systems. Two distinct views are supported by research and expert opinion: the "pro-tillage" scenario and the "conservation rotation" scenario.

According to the pro-tillage view, the region's farmers should moldboard plow and deep plow to control erosion. Conservation tillage systems are thought to decrease yields and increase erosion. Alternatively, the conservation rotation view holds that rotation with sorghum boosts cotton yields, and that reduced tillage cotton and conservation rotation systems outperform conventional tillage cotton in both yields and revenues. Under either school of thought, the erosion stock functions are unusual in that while erosion initially rises with soil loss, at below 15 inches above the caliche layer, as plowing brings more of the caliche layer to the surface, erosion declines. Under the pro-tillage scenario, initial annual soil losses are not thought to differ markedly for cotton and sorghum, but annual soil losses rise more rapidly for sorghum than for cotton with declining soil depth, and hence surpass cotton at about 25 inches above the caliche layer. Two possible views of erosion are examined under the conservation rotation scenario. The first assumes that the pro-tillage erosion functions still apply, while the second holds that the sorghum and rotation erosion functions fall below the cotton erosion function over the entire domain of the soil stock. Bunn (1997) provides a detailed description of the pro-tillage and conservation rotation schools of thought and their corresponding stock functions. Data allowing grazing to serve as a third alternative are presented below.

On-Site Cost Data

Given the nature of the available cost data and the state of knowledge about the link between costs and the level of the soil stock, the simulations hold per acre costs of production constant at their 1990 level. The per acre cost values are derived from U.S. Department of Agriculture (USDA) *Costs of Production* estimates, with several adjustments being made to render them suitable for use in the simulations. By employing the USDA's costs of production fixed-cost expenditure estimate, which essentially totals general farm fixed costs and then allocates them to a crop based on the crop's value of production as a proportion of total value of production, the empirical analysis implicitly assumes the scale of farm operations which underlie the Southern Plains "Farm Costs and Returns Survey" data in the year upon which the estimates are based. And, since they implicitly assume existing scale of production, these fixed-cost estimates represent an upper bound to this component (roughly 25% of total cost for cotton and sorghum); if, over time, operators expanded production acreage, the per acre cost figure would fall as the fixed cost per acre fell.

The total on-site economic costs per acre include not only fixed and variable cash expenditures, but also the opportunity costs associated with use of own labor and the purchase of machinery and equipment (the value of land is endogenous to the model, and hence this cost category is excluded). Annual per acre net revenue thus represents per acre returns to management and risk, and farming continues as long as they are nonnegative. Due to the way in which the cost data were collected, two estimates for the cotton cost are employed in the simulations—one skip-row planting adjusted, and one not. The per acre costs appropriate to the southern Texas High Plains region in 1990 are $217.05 (nonskip-row adjusted) and $167.76 (skip-row adjusted) for cotton, and $151.33 for sorghum.

Off-Site Cost Data

Huszar and Piper's off-site cost estimates for the New Mexico portion of MLRA 77 were used to derive a rough estimate of the off-site costs of wind-eroded soil from a farm in the southern Texas High Plains (this region makes up the remaining two-thirds of MLRA 77). In 1990 dollars, the estimate for off-site cost per ton of eroded soil per acre is $6.77.

Price Data

The simulations employ 1990 "effective" (including government subsidy), 1990 world, and 1991 world prices (79.78, 75.32, and 63.84 cents per pound, respectively, for the combined lint-seed cotton; and 5.20, 4.16, and 4.16 cents per pound, respectively, for sorghum). Comparison of the 1990 prices with long-run means of correlated crop price distributions developed for these two crops at Texas A&M University indicate that 1990 prices do not differ markedly from the long-term average. If anything, 1990 prices were slightly higher than the recently preceding history, and prices have been lower since. In the simulation analysis, the effective price is assumed for the base case analysis, while the 1990 and 1991 world prices are employed to examine the possible effects on profitability, cropping system choice, and resource use of removing the price subsidies.

Grazing Data

Aside from lands off the caprock and some extremely uneven and rocky areas, grazing does not occur currently in the study area. Hence, the approach taken to consideration of grazing as a third system was to propose some hypothetical and generous grazing functions loosely based on what is known about these systems in contexts that are as similar as possible. Net revenue per cow unit data from the few studies (Texas Agricultural Extension Service; Connor and Taylor; Ethridge et al. 1987; Ethridge et al. 1990; and Taylor, Garza, and Brooks) conducted with regard to conditions in or near the study area were converted to net revenue per acre data. These studies indicate that per acre revenues range from substantially negative to around $25 per acre depending on the location, soil, management, and stocking rate assumptions. The $25 figure, based on a relatively wet area (22–24 inches of rainfall), could be considered an upper bound on revenues (Ethridge); even $10 per acre may be generous.

Little is known about soil erosion on rangeland in the western United States, and no studies could be located linking productivity to erosion. Studies that do exist, however, indicate that wind erosion rates for rangeland and pasture are much lower than those for dryland and irrigated crops. The wind erosion estimates for the Texas portion of MLRA 77 suggest that rangeland wind erosion is about one-seventh that of dryland cropland (USDA, Soil Conservation Service). Given the imprecision and paucity of information on rangeland erosion, a simple 1-tay perpetual rate was adopted for the purpose of simulations (as compared to initial cropland soil erosion estimates in the 4–5 tay range).

Outcomes were analyzed or simulations run for two initial per acre revenues—$10 and $25. The net revenue function was assumed to be linear and declining as soil depth declined, with net revenues going to zero as soil depth goes to zero (implicitly assuming that forage grasses cannot grow on caliche). The use of alternative monotonic, but nonlinear, functional forms for net revenues would not alter the simulation results other than to reduce profitability.

Simulation Results

The simulation analyses assume an initial soil depth of 30 inches above the caliche layer (considered an average soil depth for the region), and a discount rate of 5% (considered to be an appropriate real rate of discount for farm firms in the region). Tables 1 and 2 present simulation results for the pro-tillage (PT) and the conservation rotation (CR-I, CR-II) scenarios under the two cotton-cost assumptions: the skip-row adjusted (the low assumption) and the unadjusted (the high assumption), respectively.[2] For the pro-tillage scenario, the farm firm's cropping system choice decision is based on comparison of conventional tillage monoculture cotton to conventional tillage monoculture sorghum, since these systems dominate minimum tillage or rotation cropping system options. For the conservation rotation scenario, the farm firm chooses between monoculture cotton and a conservation rotation of 50/50 sorghum and cotton.

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[2] Given the nonconvexities in both the empirical yield and erosion functions, tests were developed to discern whether the results presented are global rather than local optima, and maxima rather than minima with regard to the farm firm's maximization of the objective function. Findings from these tests were, without exception, consistent with the hypothesis that the results are global maxima; see Bunn (1995) for a description of the methodology employed.

Table 1. Baseline, Removal of Subsidy, and Erosion Tax Results Under Low-Cotton-Cost Assumption

Price Source	Initial Crop Chosen	Initial Net Revenue per Acre ($)	Initial Soil Shadow Price ($)	Time of Switching (year)	Time of Shutdown (year)	Soil Depth at Shutdown (inches)
Baseline:						
PT[a]	Cotton	68.80	9.06	No Switch	505	11.22
CR-I[b]	Rotation	75.70	19.06	296	496	11.18
CR-II[c]	Rotation	75.70	18.79	373	NC (405)[d]	NC (19.36)[d]
World 90:						
PT	Cotton	55.58	2.85	No Switch	498	11.55
CR-I	Cotton	55.58	2.85	No Switch	498	11.55
CR-II	Cotton	55.58	2.85	No Switch	498	11.55
World 90 w/Tax:						
PT & CR	Cotton	21.88	8.55	No Switch	444	14.67
World 91:						
PT	Cotton	21.53	7.25	No Switch	456	13.94
CR-I	Rotation	28.69	15.25	337	438	13.94
CR-II	Rotation	28.69	15.04	432	NC (476)[d]	NC (16.49)[d]
World 91 w/Tax:	No Cropping					

[a] PT = the pro-tillage scenario.
[b] CR-I = the erosion status quo/conservation rotation scenario.
[c] CR-II = the erosion-reducing/conservation rotation scenario.
[d] NC denotes the simulation did not converge; hence, the time of shutdown underestimates the true value, while the soil depth at shutdown overestimates the true value (the numbers in parentheses indicate shutdown time).

The Baseline "Effective Price" Simulation Results

Under the pro-tillage scenario, with either the low- or high-cotton-cost assumptions, and the baseline effective prices, a farm firm optimally chooses to plant cotton for over 400 years and then ceases agricultural production at a soil depth of over 11 inches. Alternatively, under all erosion and cotton cost assumptions of the conservation rotation scenario, the farm firm optimally chooses the rotation system over the monoculture conventional cotton system in the initial period. The yield boost afforded cotton under the conservation rotation scenario tips the decision to the mixed system over the monoculture system. Also, under the low-cotton-cost assumption, while the rotation system is chosen in the initial period, eventually a switch to monoculture cotton occurs because sorghum yields decline more rapidly than do cotton yields with a decline in soil depth, and erosion increases more rapidly under sorghum than under cotton with a decline in soil depth. This does not occur under the high-cotton-cost assumption because the net revenue differential between the conservation rotation scenario and the monoculture cotton system widens over time and retains the rotation's dominance. Finally, under the conservation rotation scenario, as compared to the pro-tillage scenario, a combination of higher profitability and lower net erosion rates over some ranges of the domain of the soil resource stock delays the time to cessation of production and reduces the steady-state soil stock.

Policy I: Reduction or Removal of Price Subsidies

To examine the effect of the removal of price subsidies, the six baseline cropping system

Table 2. Baseline, Removal of Subsidy, and Erosion Tax Results Under High-Cotton-Cost Assumption

Price Source	Initial Crop Chosen	Initial Net Revenue per Acre ($)	Initial Soil Shadow Price ($)	Time of Switching (year)	Time of Shutdown (year)	Soil Depth at Shutdown (inches)
Baseline:						
PT[a]	Cotton	19.30	9.10	No Switch	425	15.70
CR-I[b]	Rotation	51.06	19.06	No Switch	445	13.04
CR-II[c]	Rotation	51.06	18.79	No Switch	554	13.08
World 90:						
PT	Cotton	6.29	8.55	No Switch	279	21.61
CR-I	Rotation	27.46	16.16	No Switch	397	15.99
CR-II	Rotation	27.46	15.95	No Switch	495	15.96
World 90 w/Tax:	No Cropping					
World 91:						
PT	No Cropping					
CR-I	Rotation	4.04	15.23	No Switch	158	25.53
CR-II	Rotation	4.04	15.04	No Switch	176	25.58
World 91 w/Tax:	No Cropping					

[a] PT = the pro-tillage scenario.
[b] CR-I = the erosion status quo/conservation rotation scenario.
[c] CR-II = the erosion-reducing/conservation rotation scenario.

cases and the cropping versus grazing cases were examined using world market as opposed to effective prices. The key results from this analysis using 1990 world prices are that, with low cotton costs, the monoculture cotton system will be chosen under either scenario, while under high cotton costs the pattern mirrors that of the baseline case. In all instances, cropping continues for almost as long as under effective prices. The removal of subsidies affects agricultural income levels under both scenarios, but only under the conservation rotation scenario is the cropping system choice altered. The value of the yield boost to cotton from rotation with sorghum, when evaluated at world prices, is no longer sufficient to offset the loss in revenue from having to plant half the acreage to sorghum.

World prices from 1991, which were more consistent with longer-run historical trends, also were employed in simulations. The 1991 world price for cotton was considerably below that of 1990; the world price for sorghum remained the same. When further reducing agricultural incomes, and completely shutting down cropping under the high-cotton-cost pro-tillage scenario, cropping system choice results remain as in the base case analysis. In addition, use of 1991 world market prices leads to a delay in the switching time and to a truncation of the duration of agricultural production.

Results on the Inclusion of Grazing as an Alternative System

The primary effect of including grazing in the analysis as a third, alternative system, is that it extends the time to shutdown by thousands of years.[3] It requires very generous assumptions about initial revenues for grazing sys-

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[3] Under the perpetual 1-tay erosion rate assumption for rangeland, it would take 5,160 years to fully wind erode 30 inches of topsoil.

tems, and pessimistic assumptions about cotton costs and/or prices for the grazing system to be chosen over the cotton or rotation systems initially. Assuming the pro-tillage scenario, 1990 world prices, the low cotton cost, and either a $25 or $10 initial rangeland revenue, the cotton system is chosen initially, followed by a switch to the grazing system after more than 450 years. When employing the high cotton cost, the grazing system is more profitable than monoculture cotton, and is chosen over the entire productive horizon. With 1991 world prices and the low cotton cost, a grazing system would be chosen from the outset under the $25 initial net revenue assumption. Under the conservation rotation scenario, 1990 world prices, and the low cotton cost, the cotton system continues to be chosen initially, but is followed after more than 450 years by the grazing system. Using 1991 world prices and the low cotton cost leads to the conservation rotation being chosen initially, and then followed by a switch to cotton and then to grazing. Under the high-cotton-cost assumption, use of 1990 prices leads to the rotation followed by a switch to grazing, while use of 1991 prices leads to grazing being chosen from the outset and no switch occurring.

Policy II: Imposition of a Fixed per Acre Tax to Reflect Off-Site Costs

As for the environmental externality associated with wind erosion, the public will either agree to a continuation of subsidies on environmental grounds (paying farmers not to pollute) or will demand that this sector be treated like any other mature sector of the economy and the polluters be asked to pay (Runge). As the public begins to understand that many of the recipients of the agricultural entitlements have net worths well over a million dollars and experience standards of living above that of the nonfarm population, the latter becomes increasingly likely. In a nationwide survey designed to ascertain citizens' attitudes toward government support for measures to combat soil erosion, Jordon and Elnagheeb found more support for government enforcement of erosion control through laws, including fining farmers who fail to adopt soil conservation practices, than through voluntary compliance programs or payments to farmers to assist in covering the cost of conservation practices. This provides evidence that our increasingly urban and educated public may well be moving in the direction of supporting a different approach to controlling erosion.

Employing the $6.77 per tay off-site cost estimate from above, this section explores the effect of a government-imposed production tax on farmers experiencing wind erosion. The tax, intended to force farmers to internalize the off-site costs of erosion, would be a fixed amount per acre cropped. The per acre tax rate used in the simulation exercise is the estimated off-site cost per ton multiplied by the average tons per acre per year (tay) soil loss in the initial period. Using the initial period to determine the tax seemed to be a reasonable approach considering the political context from which such a policy would have to emanate. Given the inherent weakness of the scientific information underlying specification of the stock functions, and presuming such a tax is politically feasible, farmers and their lobbyists surely would be able to block any tax rate found by averaging over future estimated "higher" values of soil loss. Since the initial soil losses are 4.98 tay and 4.25 tay for cotton and sorghum, respectively, the fixed per acre tax is $33.71 and $28.77, respectively, for the two crops. Presumably, if farmers are required to bear the burden of the off-site environmental costs of production, price subsidies would be removed as well.

Using the low-cotton-cost assumption, imposition of the tax increases total per acre cost of production from $167.76 to $201.47 and from $151.33 to $180.10, respectively, for cotton and sorghum. Using 1990 world prices, conventional monoculture cotton continues to be planted under either scenario, and the agricultural time horizon, while shortened, still extends more than 400 years. Alternatively, with the low cotton cost and 1991 world prices, or with the high cotton cost, imposition of the tax shuts down cropping.

Discussion and Policy Implications

While the study has numerous limitations, most having to do with limited or uncertain information (i.e., the data underlying the simulations are for the most part subjective or uncertain, the study ignores technological, price, cost, and climate changes over time, and the data assume perfect foresight on the part of the farm-firm operator), the simulation results provide tentative insights regarding a number of issues. First, the results point to the importance of identifying the operative cost and stock function scenario in order to accurately predict the effects on the economy or a region of lowering or removing subsidies. Data available for the southern Texas High Plains could not conclusively support one set of cost or stock function assumptions. Under some cost and yield assumptions, the removal of price subsidies shuts down the agricultural economy of the southern Texas High Plains entirely. Under other cost and yield assumptions, however, income is impacted dramatically, but the same cropping pattern is chosen for about the same number of years as would have been the case under a higher subsidy policy. Under still other assumptions, the cropping pattern would not be altered, but the time to shutdown would be significantly reduced.

Second, the simulation results show that an across-the-board removal of subsidies does pose the possibility of sufficiently altering the relative prices, or the relative net revenue to erosion ratios for those crops, to cause a change in the choice of cropping system. Yet, the only possible initial period changes are from a sorghum-cotton conservation rotation to a monoculture cotton system, or a change from either of those two systems to no cropping.

Finally, the results provide further evidence about whether greater flexibility would lead to greater or less adoption of what are considered soil-conserving practices, about the long-run prospects for the economic viability of dryland agricultural production on the southern Texas High Plains, and about the long-run outlook for wind erosion. All of these are discussed in turn below.

Changes in Cropping Mix Due to Flexibility?

With the introduction of complete flexibility under FAIR, and in particular if one believes the pro-tillage scenario, most southern Texas High Plains farmers will continue to plant a monoculture cotton system, not because of constraints imposed by commodity programs designed around historically determined base acreage, but rather because the system dominates all others. And, with removal of subsidies, that continues to be the case. This result is consistent with research on the effect of flex acres on cropping decisions (Daberkow, Langley, and Beach; Zulauf and Tweeten). These studies found for cotton both that it was the only crop for which the flexing in of Normal Flex Acres was greater than flexing out, and that, for the U.S. as a whole, a greater percentage of cotton was planted back to the same crop than any other crop (69%). Only 32% of sorghum was planted back to the same crop.

The flexible base provision of the commodity programs in the 1985 and 1990 farm bills was intended to prevent, or at least mitigate, the effect of crop base acreage allocations on discouraging the adoption of high-residue crops. In the southern Texas High Plains, the effect was just the reverse: instead of planting some of their cotton base to high-residue crops, the region's farmers took advantage of the provisions to plant cotton on the small base acreage in sorghum and other high-residue crops without losing the ability to count that acreage in their high-residue crop base. For regions in which a crop like cotton dominates the cropping system choice, flexible base provisions such as these may have led the region to produce more, not less, erosion.

Moreover, the pro-tillage scenario brings into question whether in a country with diverse climatic regimes (and hence soil and water regimes) which vary considerably across geographical subregions of the country, a national approach to conservation is appropriate, particularly where there are both humid and semi-arid regions. The empirical results of this study point to the inappropriateness of applying relatively standardized policies related to the encouragement of conservation to subregions within the country. For example, in the case of the southern Texas High Plains, efforts by the USDA Natural Resources and Conservation Service [(NRCS), formerly the Soil Conservation Service] to promote minimum and no-tillage production systems employing so-called high-residue crops are not supported by the body of scientific evidence generated by the regional USDA Agricultural Research Service (ARS) staff on the profitability and conservation effectiveness of feasible cropping systems in the region. The existence of contrary views among government "experts" as to the most effective conservation practices for the region suggests the need for improved communication and cooperation between ARS and NRCS in the design and implementation of conservation policy.

After several years of going back and forth on the issue, the pro-tillage USDA/ARS point of view appears to have won out over the conservation rotation view in terms of conservation policy enforced on the ground. Scientific validity of the two scenarios aside, political forces have long favored the pro-tillage view; the practices implied by the pro-tillage school are less costly. Hence, as of the 1996 growing season, southern Texas High Plains farmers were once again allowed to use "roughening" of the soil to meet conservation compliance rather than adopt a conservation rotation or some other approach using a high-residue crop. This essentially meant an acceptance of pre-1985 wind erosion control practices for compliance. USDA/NRCS personnel, however, remain unconvinced. During the 1996 season, they rushed to stave off what they anticipated might be a major setback in their conservation progress in the region, both by encouraging farmers to retain their conservation rotations and by developing objective standards for what constitutes adequate roughening for conservation compliance. Some NRCS staff also have expressed the hope that blowing dust during the 1996 drought might have reminded area farmers of the need to retain the conservation practices they had adopted, even if no longer required for compliance.

The Economic Viability of Agricultural Production

With continuation of the agricultural entitlement, the results generally suggest that, under historical climatic conditions, the predictions about the transition in Texas agriculture due to water constraints (Lacewell and Lee), or discussions about needing to revert parts of the region to a Buffalo Commons (Popper and Popper), may be overly pessimistic about the long-run potential of dryland agricultural production. Under most assumptions examined here, dryland agricultural production in the southern Texas High Plains is economically viable for some time to come. The soil resource is not a serious constraint for a very long time (400 to 500 years). These results are similar to those of Burt and of Walker for the Palouse region of the Pacific Northwest, even though they conjectured that erosion might significantly lower yields and sharply reduce time horizons in regions like the southern Texas High Plains.

This is not to say, however, that farm incomes from agricultural production will remain constant. For the purposes of this discussion, farm income might be viewed as the sum of the per acre cost of own unpaid labor and the per acre net revenue multiplied by the number of farm acres that are operated. If the government wants to keep farm incomes supported at a particular level relative to the nonfarm population, support of such a policy in a semi-arid region experiencing an annual net loss in the soil stock will be increasingly costly, and runs counter to the general direction policy is taking with respect to farm subsidies.

As to the removal of subsidies, only under the high-cotton-cost assumption and 1991 prices do significant divergences from the baseline results occur. It appears that with the removal of subsidies, the issue of whether cotton production would be expected to continue on the southern Texas High Plains is quite sensitive to cost assumptions, and existing data fail to give us adequate precision in this area. If cotton costs are greater than $200 per acre, then the removal of subsidies brings regional agricultural production, other than reversion to grazing, to a halt. What this most likely means in the southern Texas High Plains is that cotton cropping on the least productive cropland will shift to grazing, and that some currently marginal grazing lands will convert to their natural state. This fairly optimistic outlook hinges, however, on the continuation of historical climatic patterns. Increases in temperature and storm intensities, and changes in mean precipitation, by both decreasing yields and increasing erosion, could significantly alter this outlook.

Wind Erosion Outlook

With respect to dryland agriculture production in the southern Texas High Plains, FAIR will not lead to a significant change in crop mix and will not put farmers out of production, while at the same time it will most likely lead to a reduction of CRP acreage and to a reduction of cost-share payments for conservation practices. This, combined with a slackening of area conservation compliance requirements even before FAIR was implemented, and predictions related to global climate change, bodes poorly for the wind erosion outlook on the southern Texas High Plains and across the nation.

Use of "Sticks" Rather than "Carrots"

The simulation results suggest that imposition of an erosion tax, even at a conservative level, under several reasonable price and cost assumptions, could shut down the agricultural economy of the southern Texas High Plains. The results also indicate that if cropping were to remain economically viable under an externality tax, annual erosion rates are not sufficiently different between the two primary feasible cropping systems in the region for a per acre tax reflecting off-site costs of erosion to significantly alter the cropping system choice relative to the base case effective price scenarios. A tax more likely to shift regional cropping patterns would be an externality tax associated with pesticide use and wildlife habitat destruction. Sorghum may have a significant advantage over cotton in these areas. With such a tax, we would eventually see a more mixed planting.

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