Impact of New Farm Bill Provisions on Optimal Resource Allocation on Highly Erodible Soils

John R. C. Robinson
Agricultural Economist, Texas Cooperative Extension Service, Weslaco TX
jrcr@tamu.edu

Glover B. Triplett
Agronomist, Plant and Soil Science Department, Mississippi State University
gtriplett@pss.msstate.edu

Seth M. Dabney
Agronomist, National Sedimentation Laboratory, Oxford, MS

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John R. C. Robinson, Glover B. Triplett, and Seth M. Dabney[1]

Abstract

The study focuses on incentives to produce crops under reduced tillage systems on highly erodible soils. A mixed integer, mathematical programming model was developed to identify optimal resource use under alternative farm program provisions. A positive counter cyclical payment only reinforces the incentive to comply with NRCS soil erosion constraints.

Introduction

The 1996 farm bill authorized payments to farmers that included, in the case of the marketing loan program, price subsidies on actual production of specified program crops. By supporting prices, such provision provide incentives to produce those crops when market prices are below loan rates. The 1996 farm program was innovative in providing decoupled payments which participating growers or landowners received on the basis of enrolled acreage (i.e., independent of crop production or market prices). In addition to these two forms of subsidy, the 2002 farm bill authorized a counter cyclical payment which is also calculated independently of crop production, but is an inverse function of season average cash price. For more explanation of farm program provisions see Outlaw (2003). The 2002 farm bill can be seen as an addition to the "safety net" for growers.

This paper examines the linkages between decoupled payments and on-farm resource allocation with a focus on incentives for conservation tillage. The majority of economic studies of alternative tillage systems have made partial budgeting or whole farm budgeting comparisons to show that conservation tillage systems sometimes are more profitable than conventional tillage systems (Crosson, Hanthorn and Duffy). Partial budgeting approaches

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[1] John Robinson is an Extension Economist and Associate Professor at the Texas A&M Research and Extension Center at Weslaco, TX. Glover B. Tripplet is a Professor of Plant and Soil Sciences, Mississippi State University, Starkville, MS. Seth M. Dabney is a Research Agronomist, USDA ARS National Sedimentation Laboratory, Oxford, MS.

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typically assume that hourly labor to perform field operations is neither limiting nor slack., which is often unrealistic since many farms hire full-time seasonal or annual labor. While differences in fixed equipment costs can be evaluated using partial budgeting, the comparisons are often not robust because they are made, often implicitly, on the basis of a single farm scale. Equipment is assumed to be used efficiently, regardless of farm size. Mixed integer programming models have also been used to solve for the optimal allocation of crops and tillage systems, plus related activities such as labor and equipment acquisition (Robinson and Falconer, Triplett et al.). The advantage of mathematical programming is that the economies of scale in resource allocation can be explicitly modeled.

On high erodible soils, the choice of crop/tillage system has implications for long-term productivity and short-run compliance with federal farm programs. The 2002 farm bill continued the conservation compliance provisions which link farm program eligibility to, among other things, maintenance of an soil erosion plan as approved by USDA Natural Resources Conservation Service (NRCS) technicians. For example, parameters reflecting soil loss under alternative crop/tillage combinations can be specified and used to constrain erosion below local limits ("T-values") specified by NRCS. Alternatively, the objective function could be modeled to only include farm program payments when the model solution contains crop/tillage systems that are withing NRCS compliance. In this way, "decoupled" farm program payments may be linked to crop selection choices.

This paper presents results from a mixed integer programming model of a representative row crop farm in Tate County, Mississippi. The study area was the site of a 10-year field trial examining the productivity and economics of alternative tillage systems (Triplett et al.). Soils on the site were dominantly Grenada silt loam but included small amounts of associated Memphis and Loring silt loams, all of which are both very fertile and very subject to erosion.

Data Development

Crop budget data from the 10-year field trials were collected and used to specify model parameters including typical yields, gross returns, field operations, machinery performance rates, variable costs and fixed cost. Crop yields and historic commodity prices were used to calculate gross returns for crop and tillage combinations. Crops included corn, cotton, grain sorghum, soybean, and wheat in a doublecrop system with soybeans. Tillage systems included conventional (chisel plow, disk 2x, smooth, plant, cultivate postemergence 2x), No-tillage (spray, plant, harvest) and a hybrid reduced tillage systems which involved minimal tillage. More background information on the field trials is provided by Dabney et al. (1993) and Triplett et al. (1996).

To specify labor and equipment usage, the calendar was divided into thirteen 4-week periods with assignment of typical field operations. Days suitable for field operations in each period (Spurlock et al. 1995) was coupled with equipment performance rates to calculate potential crop acreage per worker.

Soil erosion parameters were estimated using NRCS crop “t-factors” and “ T-values”. These were used to calculate the limit of soil erosion that will still be within NRCS compliance. Estimated soil loss for each crop/tillage system was estimated using the Revised Universal Soil Loss Equation.

Tate County average farm program yield and acreage information were obtained from the USDA Farm Services Agency (FSA) and used to model the farm program payments of a representative farm. Other farm program information collected were local crop loan rates, loan repayment rates, AMTA payment rates (for 1996 farm bill scenarios), and target prices (for 2002 farm bill scenarios). The online Base and Yield Analyzer software (Outlaw) was used to identify the likely base acreage revision for a representative farm under the 2002 farm program sign-up. The results of the Base and Yield analysis indicated that farm program payments under the 2002 farm program were highest by only adding oilseeds to reflect the 1998-2001 pattern of soybean plantings in Tate County. Thus for 2002 farm bill scenarios, the parameter for government payments was calculated based on a revised base acres estimate for the representative farm.

Model Development

A mathematical programming model was developed to reflect the general set of choices and tradeoffs faced by a farm manager in this study area. These include choices about tillage systems that potentially influence NRCS compliance and thus eligibility for farm program payments. Other more basic choices include how to allocate land and “lumpy” capital resources (e.g., equipment, full-time labor) to the most profitable activity. The objective function for this model is presented below in Equation (1) where:

- i= crops (cotton, sorghum, and conservation reserve program as a default option)
- j= previously discussed tillage systems
- p=previous crop, to specify rotation constraints within a tillage system
- k=tractors, tillage implements and other equipment
- t=time periods for labor constraints and Machine Trips parameter.

(1) $\text{Max Profits} = S_i\, S_j\, S_p\, ((\text{GrossReturns}_{ijp} - \text{NonMachineryVariableCosts}_{ijp}) * \mathbf{X_{ijp}})$

$+ \text{DecoupledPayment} * \mathbf{ComplianceIndicator_{ijp}}$

$- S_i\, S_j\, S_k\, S_p\, S_t$ (MachineryVariableCosts$_k$* MachineTrips$_{k,t,i,j}$*$\mathbf{X_{ijp}}$)

$- S_k$ (MachineryFixedCosts$_k$* MachineTrips$_{k,t,i,j}$*$\mathbf{Buy_k}$) - AnnualSalary* **Hire**.

The continuous variable $\mathbf{X_{ijp}}$ represents acres of cropping/tillage activities, while the integer variables $\mathbf{Buy_k}$ and **Hire** reflect purchases of lumpy resources. The binary variable $\mathbf{ComplianceIndicator_{ijp}}$ is zero when the model solution violates an NRCS constraint on soil erosion, thus removing decoupled payments from the objective function. (In reality, non-compliance would disqualify any loan deficiency payments as well, but these were not included for simplicity of calculation.) The parameter MachineTrips$_{k,t,i,j}$ is trips across one acre of a given crop/tillage combination with specified equipment. The AnnualSalary parameter is specified as $20,000 per year for a full-time equipment operator. The remaining parameters in the objective function specify typical crop budget cost or return values, in addition to the decoupled payment parameter which was discussed previously. In summary, the objective function maximizes profits by choosing crop/tillage combinations, where farm income (net of non-machinery variable costs) is further reduced by the costs associated with acquiring machines or full-time labor.

Equation (1) was specified in conjunction with the following land, labor, machinery capacity, rotation, and NRCS compliance constraints:

(2) $S_i\, S_j\, S_p\, \mathbf{X_{ijp}} \leq$ Land Scalar

(3) $S_i\, S_j\, S_k\, S_p$ (PerfRate$_k$*MachineTrips$_{k,t,i,j}$*$\mathbf{X_{ijp}}$) $\leq$ S_k (AvailableFieldHours$_k$*$\mathbf{HIRE}$)

(4) $S_i\, S_j\, S_k\, S_t$ (PerfRate$_k$*MachineTrips$_{k,t,i,j}$*$\mathbf{X_{ijp}}$) $\leq$ S_t (CapacityParameter$_{k,t}$*$\mathbf{BUY_k}$)

(5a) $S_i\, \mathbf{X_{ijp}} \leq \mathbf{PREP_{jp}}$

(5b) $\mathbf{PREP_{ip}} \leq S_i\, \mathbf{X_{ijp}}$

(6) $S_i\, S_j\, S_p\, \mathbf{X^*_{ijp}} \leq$ Land*$\mathbf{ComplianceIndicator_{ijp}}$ for all $\mathbf{X^*_{ijp}}$ such that SOILLOSS(i,j)>TFACTOR(i)*TVALUE is true.

Equation (2) is a straightforward constraint on land resources. Equation (3) constrains labor demand to be less than or equal to labor supply. This constraint is built around by two key parameters: equipment performance rates (hours per acre) and days available for fieldwork. Hiring one machine operator acquires a supply of driver hours to satisfy the labor demands of specific crops.

Equation (4) represents a set of *k* equations (i.e., one for each capital item) constraining machine hours demand to be less than or equal to supply of available capacity of that given machine. As in the labor constraint, the machinery capacity parameter was also a function of the machinery performance rate multiplied by available hours. Buying one machine gives the maximum potential machinery capacity in each time period.

Equations (5) are rotation sequencing constraints that require predecessor crops to likewise be in solution, thus generating an optimal rotation. A conservation compliance parameter was formulated using estimates of soil erosion under each crop/tillage combo. When any soil loss from a crop in solution exceeds the NRCS limit, a 0/1 indicator variable is generated by Equation (6) that eliminated government payments from the objective function.

The model was written and run in GAMS using the XA solver. Alternative runs were made to compare results under 1996 and 2002 farm program provisions at 1,500 acres using forecasted market prices for 2003. In addition, the objective function results under both farm program payment provisions were compared over a range of acreage sizes.

Results and Discussion

Table 1 presents market prices, calculated counter cyclical payment (CCP) rates, and the representive base crop shares for the representative farm. For this farm, cotton has the largest share of base acres with 40% of the total farm acreage. Furthermore, the CCP rate for cotton was at it's maximum of $0.134 per lb due to the low expected price for cotton. Thus the CCP under the 2002 program payment calculation was positive and represented an increase over what would have been paid under the 1996 program. In terms of the model, the DecoupledPayment parameter in Equation (1) was larger under the 2002 program payment scenario compared to the 1996 program payment scenario (Table 2).

In terms of resource allocation, Figure 1 shows the distribution of whole farm net returns under the two farm program payment regimes, for solutions for operations scales between 100 and 1,500 acres. The 2002 farm program payment distribution is obviously larger. Points **a** through **g** indicate changes in the slope of this curve, caused by either shifts in the optimal crop mix (from no-tillage soybean:corn rotation to additions of no-tillage soybean:wheat rotation), hirings of full-time labor, or purchases of equipment. The pattern of resource allocation was similar for the lower distribution of the 1996 program payment scenario. Points **h** and **i** specifically denote the acreage at which additional full-time labor was hired.

The addition of the CCP reinforces the incentive to comply with NRCS soil erosion constraints. This will be the case as long as the CCP is positive, which is a function of season average prices received and the official target price. Under the 1996 farm bill, the totally decoupled AMTA payment was the only incentive, and it was probably insignificant compared to other incentives for compliance such as eligibility for crop insurance. Yet this study and previous applications of this model (Triplett, Robinson and Dabney) demonstrated that the AMTA payment alone was enough incentive to choose soil conserving crop/tillage activities on highly erodible soils.

The influence of the CCP under the new farm program is similar in its effect to crop insurance. Access to both is contingent on compliance with NRCS erosion constraints. Both can provide an indemnity to growers when certain risky situations prevail (low yields for crop insurance, or low prices for the CCP). The question might be asked under what price conditions would this representative farm decision maker ever choose conventional tillage treatments. In several model runs (not shown) a 5X to 10X price increase (depending on the crop) resulted in a sufficient dwarfing of the government payments to bring a conventional tillage, non-compliance crop mix into solution. However, besides being an unrealistic price scenario, such high prices would likely increase growers' demand for crop insurance (also requiring NRCS compliance).

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Table 1. Farm Program Parameters for Representative Farm Model.

	Corn	Cotton	Soybeans	Wheat
Market Price	$2.25/bu	$0.404/lb	$5.03/bu	$3.67
CCP Rate	$0.07/bu	$0.137/lb	$0/bu	$0/bu
Share of Base	20%	40%	20%	20%

Table 2. Comparative Model Solutions at the 1,500 Acre Scale for Alternative Farm Program Payment Scenarios

	Solution w/ 1996 Payments	Solution w/ 2002 Payments
Whole Farm Profits (Obj. Function)	$117,709.20	$167,576.18
Crop/Tillage Mix	no-till corn:soybean rotation	no-till corn:soybean rotation
Equipment Complements	1	1
Full-time Labor Hires	1	1
NRCS Compliance?	YES	YES
Avg. Decoupled Payment/Acre	$28.82	$62.07

Figure 1. Net Returns for Operations of 100 to 2,500 acres, By Farm Program Payment.