MEASURING ECONOMIC AND ENVIRONMENTAL IMPACTS OF FEDERAL FARM POLICY SCENARIOS USING GEOGRAPHIC INFORMATION SYSTEMS: A WATERSHED CASE STUDY

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July 1994

Ag. Econ. Research Series 94-7, Dept. of Ag. Econ.
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ABSTRACT

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The conservation compliance provisions of the 1985 Farm Bill have decreased average erosion by more than 50% in the Tom Bealle watershed of Northern Idaho, as estimated from profit-maximizing mathematical programming models and erosion predictions using Geographic Information System (GIS) data. Requiring reduced tillage in order to participate in the farm program resulted in an average of 6.6 tons of erosion per acre for cultivated areas in the watershed, compared to 13.5 tons without conservation compliance provisions. Interestingly, using the original mandate of requiring that farmers not exceed "T" increased erosion to an average of 8.9 tons per acre for the watershed, as only 38% of profit-maximizing farmers would choose to participate in the farm program. Even if the maximum erosion level permitted were raised to 1.5 times "T," average erosion was predicted to be 8.6 tons per acre, as only 85% of farmers would participate. The use of alternative conservation systems reduced overall erosion more effectively than a strict erosion limit as farmers did not exit the farm program due to inability to reach erosion limits while maintaining profitability.

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Introduction

The conservation compliance provisions of the 1985 Farm Bill have had a dramatic impact in the dryland wheat region of the Palouse River Basin. This highly productive area suffers from severe soil erosion. Farmers receive relatively large incentives to participate in the farm program, as proven yields are high relative to national averages. The original legislation mandating that erosion not exceed the soil tolerance factor "T," approximately 5 tons per acre, met with great resistance here. Before enactment of the conservation compliance provisions of the 1985 Farm Bill, annual erosion was estimated to average 14 tons per acre for the entire Palouse River Basin (U.S. Dept. of Agr., 1978). The original requirement to meet "T" was later modifed, resulting in region-specific Alternative Conservation Systems (ACS) from which farmers can choose. While some have criticized this modification for allowing excessive erosion, this study shows that the original requirement would have been counterproductive in this region.

Soil erosion is generally recognized as an environmental problem associated with agricultural production which varies by topography, climate, soils, and cropping practices. Measuring economic damage attributable to soil erosion is a complex task because of site variability. Analytical software using Geographic Information Systems (GIS) data allows measurement of these landscape-specific characteristics. In this analysis, grid-based GIS data representing elevation, soil type and other erosion factors were overlaid with a vector-based GIS representing fields in a watershed. Erosion estimates were then extracted on a field-level basis for a number of rotation, tillage, and conservation practices.

A number of policy scenarios have been modeled using a mixed integer linear programming model which incorporates field level data for each farm unit in the study area. Actual proven yields and program crop bases were used in order to realistically portray profit-maximizing behavior for each farm operator. Market crop prices are based on previous Idaho state averages for the preceding five years. Deficiency payments are determined using national average market prices over the previous five years. 1990 Farm Bill provisions provide the baseline policy scenario. A number of variations are also modeled which are described in detail below.

Study Area

The Tom Bealle watershed in northern Idaho is located near Lewiston, within an area of severe soil erosion and water quality problems as identified by the Soil Conservation Service (USDA, 1981). Elevation in the 11,000-acre watershed ranges from about 900 feet to over 2300 feet, reflecting steeply sloped fields. Three-fourths of the 7,205 cropland acres are classified as highly erodible.

Rainfall in this semi-arid dryland farming region is approximately 12 inches per year. Approximately 60% of the land is planted in winter wheat every year. Other crops include dry peas and lentils, barley, and small amounts of canola, buckwheat, and bluegrass. Winter wheat is quite vulnerable to erosion, as most precipitation occurs in the winter months on the planted seedbed. Rain and snowmelt on frozen soil cause particularly severe erosion as the soil cannot absorb this moisture.

Methods

For this study, site-specific erosion estimates were determined under a variety of cropping, tillage, and conservation practices. Erosion was calculated at the cell level for each agricultural practice using the Universal Soil Loss Equation (USLE). The cell size for this study was 3.3 acres; each cell represents a data point. A digitized elevation map (DEM) was created and used to construct GIS maps with the slope gradient and length (L and S) components of the USLE. Soil types were also digitized for the watershed in order to estimate the soil erodibility factor by field (K factor). Maps were created for the remaining USLE components, some of which varied by field and crop choice such as the P (conservation practice) factor and some that were constant across the landscape and did not vary by farming practice such as the R (rainfall) factor. Erosion factor maps were multiplied using GIS software (IDRISI Project, Clark Labs, Clark University, Worcester, MA) in order to obtain a map with erosion value by cropping system for each cell.

Field-level erosion estimates were needed to model erosion impacts assuming profit-maximizing behavior for farmers in the watershed. A vector-based GIS map outlining each field was overlaid on the erosion maps in order to extract an average erosion value for the cells within each field. Field-level erosion estimates for each cropping system were used for policy analysis in a mixed integer linear programming model (MIP).

Erosion rates were calculated for five rotations, two tillage choices, and two conservation practices for a total of 20 options per field. Rotations consisted of winter wheat and dry peas (WP); winter wheat and spring barley (WB); winter wheat, spring barley, and dry peas (WBP); winter wheat, spring barley, and summer fallow (WBF), and winter wheat, dry peas, winter wheat, and summer fallow (WPWF). Tillage options included conventional and reduced tillage. For this study, the main difference between the two is that under reduced tillage the chisel replaces the moldboard plow. In order to meet conservation compliance provisions of the 1985 Farm Bill, farmers are required to meet certain residue levels on their fields, which is typically achieved through reduced tillage. Of the two conservation practices examined in this study, contour farming is widespread practice while use of divided slopes is less common. However, more farmers are using divided slopes as part of their conservation plans for meeting compliance.

Weighted average erosion rates for the watershed ranged from a high of 15.4 tons per acre per year for WPWF with conventional tillage and contour farming to a low of 4.33 tons per acre per year for WBP under reduced tillage and divided slopes. The average field-level erosion rate over 90 fields was 8.95 tons per acre per year with a standard deviation of 3.48 tons per acre per year. Field-level rates ranged from 0.49 tons per acre per year for WBP with reduced tillage and divided slopes to 37.85 tons per acre per year for WPWF with conventional tillage and contour farming. Obviously, targeted application of erosion control strategies is needed on a field-level basis.

Average per acre returns assuming profit maximization by farm unit for fields within the Tom Bealle watershed are presented in Table 1. Farm income for the baseline 1990 Farm Bill scenario, in which reduced tillage is required for participation, averages $3.45 per acre. This figure represent returns to management and land, using slightly modified budgets from the Whitman County, Washington, Palouse region to represent this lower rainfall region (Painter, Granatstein, and Miller). Policy scenarios included basic 1990 Farm Bill provisions with several interpretations of conservation compliance; 1990 Farm Bill without conservation compliance; a No Farm Programs scenario; a No Farm Programs scenario with universal mandatory conservation compliance; and the 1990 Farm Bill with various permanent grass programs.

For the baseline 1990 Farm Bill scenario, conservation compliance is interpreted as requiring reduced tillage. A more targeted approach is also modeled, in which farmers cannot exceed the soil tolerance factor "T" (or a multiple of "T") in order to receive deficiency payments. The original 1985 Farm Bill legislation restricted erosion to "T." As can be seen in Table 1, this goal was unrealistic for this highly erodible region. The participation rate is projected to fall from 100% in the baseline scenario to 38% under this scenario, and average erosion rises relative to the 1990 Farm Bill baseline value of 6.6 tons per acre.

Economic theory would predict that the use of erosion limits, such as "T" values, would target erosion constraints to the most highly erodible fields and thus promote efficiency in achieving erosion control. The realism of GIS data shows this premise to be false. In fact, overall erosion from the watershed is reduced most under the requirement of reduced tillage, as all fields are impacted, not just those exceeding the specific "T" value. Also, reduced tillage is achievable on all fields, while a targeted erosion limit may not be. Under the "T" target, profit-maximizing farmers choose to not participate in the farm program, which releases them from any erosion constraints and increases overall erosion. Average income falls to -$1.57 per acre and erosion rises to 8.9 tons per acre. A targeted erosion limit may be an efficient strategy for reducing erosion on the most erodible land. However, requiring reduced tillage on all land within a highly erodible region has a greater overall impact on erosion and significantly reduces offsite erosion damage. The current version of conservation compliance, interpreted as requiring reduced tillage for this study, outperforms any of the "T" level restrictions on erosion in this watershed in terms of erosion control. Farm income for 1.5 times "T" is slightly higher than the average reduced tillage baseline income, averaging $3.69 per acre across 14 farm units. For a 2 times "T" erosion limit, income rises to an average of $6.58 per acre, but erosion is 50% higher than the baseline at 9.7 tons per acre. Government cost in terms of deficiency payment outlays falls under the low participation rates, however (Table 1).

The results of the 1990 Farm Bill scenario without conservation compliance provisions illustrate the dramatic impacts of conservation compliance provisions in this region. Average farm income rises from $3.45 per acre to $8.10 per acre when conservation compliance provisions are removed. Erosion increases by over 200%, from an average of 6.6 tons per acre to 13.5 tons per acre. Government cost remains virtually unchanged. Thus, farmers are bearing the costs of conservation compliance, but gains in erosion control benefit both farmers, in terms of less topsoil depletion, and society, in terms of less off-site erosion damage.

Under a No Programs scenario, in which farmers have no planting conservation or restrictions and receive no government payments, average net returns were $9.75 per acre lower than under the 1990 Farm Bill at -$6.30 per acre. Erosion averaged nearly 5 tons more per acre, at 11.5 tons annually. This result demonstrates the dramatic impact of conservation compliance restrictions in this region of highly erodible land and high participation rates in the government farm program. Both farm income support and erosion control are greatly impacted by the federal program.

A No Programs scenario with mandatory conservation compliance, such as might be imposed by another government agency, results in the lowest farm income of all scenarios in this study at -$11.29 per acre (Table 1). Erosion is also quite low, at just 6.0 tons per acre. This scenario controls soil erosion without any government farm program outlays; however, farm operators would not be covering their costs of production, let alone earning returns to land and management.

The last set of policy scenarios shows great potential for controlling erosion and maintaining farm income without increasing government cost. In addition to the basic 1990 Farm Bill provisions, no erosion averaging over 15 tons per acre in any one field is allowed. A permanent grass program is encouraged in order for farmers to meet this restriction on their most fragile land. In the first scenario, no cost share or subsidy is available to cover the costs of establishing and maintaining the permanent grass cover. In the second scenario, a 50% cost-share for establishment and weed control costs is available. In the third scenario, all establishment and weed control costs are subsidized by the government. Without any government assistance, average farm income falls to -$4.97 per acre (Table 1). Only 41% of farmers choose to participate in the government farm program, so average erosion rises to 10.4 tons per acre. With a 50% cost-share, average income is -$2.76 per acre, erosion averages 3.4 tons per acre, and all profit-maximizing farmers choose to participate. Under a complete subsidy for the permanent grass cover, income rises to $3.59 per acre, slightly higher than the baseline 1990 Farm Bill with reduced tillage. Erosion is lowest for this scenario, averaging just 2.8 tons per acre. All farmers choose to participate, and government cost is just slightly lower than under the baseline 1990 Farm Bill scenario. This final policy scenario shows great promise for dramatically reducing erosion in this region without changing average farm income or government expenditures.

Conclusions

Results of profit-maximizing models show that government farm program payments are clearly an important component of farmers' profits in this region. Farmers are willing to comply with conservation compliance provisions in order to receive government payments. Although net returns to land and management are fairly low under the baseline policy scenario, averaging $3.45 per acre, average returns are negative at -$6.30 per acre without the farm program. In addition, erosion is predicted to increase an average of 74% over the watershed without the current farm program, assuming profit-maximizing behavior by farm managers.

Prior to the 1985 Farm Bill, federal farm policy was criticized for encouraging erosion through base-building incentives. To build base acreage that was eligible for deficiency payments, growers might plant marginal lands that were highly erodible and resist soil conserving rotations that included nonprogram crops. Revised base acreage provisions and conservation compliance in the 1985 and 1990 Farm Bills were designed to make farm policy more environmentally kind. Results of this study suggest that environmental gains are being realized by the current farm program. However, erosion could be reduced to well below the soil tolerance factor "T" under a policy scenario which limits erosion to no more that 15 tons per acre on any one field, in addition to the constraints to the 1990 Farm Bill. Government subsidization of permanent grass plantings for achieving this goal would maintain farm income and government cost outlays at current rates while decreasing average erosion in this watershed by 67%.

REFERENCES

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Table 1. Average Farm Income, Erosion, Program Participation Rate, and Government Cost by Farm Policy Scenario, Assuming Profit-Maximization.

Policy Scenario	Average Farm Income[1] ($/acre)	Average Erosion (t/acre)	Program Part. Rate (%)	Average Gov't Cost ($/acre)
1990 Farm Bill, reduced tillage required for participation	3.45	6.6	100	25.79
1990 Farm Bill, 1*T required for participation	-1.57	8.9	38	14.96
1990 Farm Bill, 1.5*T required for participation	3.69	8.6	85	21.69
1990 Farm Bill, 2*T required for participation	6.58	9.7	100	24.59
1990 Farm Bill, no conservation compliance	8.10	13.5	100	24.58
No farm programs	-6.30	11.4	N/A	N/A
Conservation compliance, no farm programs	-11.29	6.0	N/A	N/A
Policy scenarios with upper limit of 15 tons/acre erosion and a permanent grass cover option:				
1990 Farm Bill, no cost share for grass	-4.97	10.4	41	5.24
1990 Farm Bill, 50% cost share for grass	-2.76	3.4	100	19.18
1990 Farm Bill, gov.t subsidy for grass costs	3.59	2.8	100	25.21

[1] Returns to land and management assuming profit maximization.