Temporal and Spatial Evaluation of Soil Conservation Policies

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ABSTRACT

This paper presents estimates of the benefits and costs of alternative soil conservation policies in a spatially and temporally consistent framework. The policies considered are implementation of soil conservation practices with an objective of reducing erosion to a site's tolerance level and a policy with an objective of a voluntary 50% reduction in conventional tillage. Costs and erosion benefits of these two policies are compared with that obtained from CRP. The changes in erosion and cost are estimated relative to 1992 levels. The analysis is conducted on every NRI point in a 12-state region in the north central United States. Erosion metamodels estimated using site-specific resource, production, topography, and weather data make such an endeavor tractable. The results indicate that having farmers adopt conservation plans on highly erodible fields is a sensible, cost effective policy. The public benefits of controlling erosion more than offset the small increased cost from adoption of conservation practices and conservation tillage. A significant amount of current CRP land is not susceptible to high erosion rates, which drives down the average benefit to cost ratio across the study region. A more targeted CRP would increase this ratio to the point where it could approach unity.

Key words: conservation compliance, conservation tillage, CRP, metamodels, sediment damage, soil erosion, soil loss tolerance

TEMPORAL AND SPATIAL EVALUATION OF SOIL CONSERVATION POLICIES

Soil conservation policies have been an integral part of U.S. commodity programs since the 1930s when they were used to justify marketing allotments. Determining whether a given policy yields benefits that exceed its costs requires measuring the amount of soil saved. The Conservation Reserve Program (CRP) and conservation compliance are currently the major soil-conserving programs. Recent studies have used the 1992 National Resources Inventory (NRI) survey data to estimate soil savings from these two programs. Babcock, Lakshminarayan, and Wu estimate that the CRP saves about 700 million tons of soil per year. And Kellogg, TeSelle, and Goebel conclude that early adoption of conservation compliance plans is responsible for most of the 270 million tons of soil saved annually on highly erodible land that has remained in production since 1982. However, estimates of the amount of soil saved, and hence the aggregate benefits, of prospective soil conservation policies presents a great difficulty. Direct estimates are precluded unless similar policies have already been implemented. Simulations can be used to estimate soil savings, but soil erosion is highly dependent on management practices and natural factors that vary spatially and/or temporally such as crop rotation, tillage, soil type, slope, and weather. So long-term, detailed site-specific simulations that account for adopted management practices must be conducted before reliable estimates of soil erosion can be made for a given policy.

This paper presents a new method for estimating soil erosion rates under alternative soil conservation policies across a broad area of the north central United States and for using the method to estimate the soil saved from CRP and alternative policies. The method we develop is to estimate metamodels that have explanatory variables that change with alternative conservation policies and to use the metamodels to simulate soil erosion across a 12-state region under two alternative policies on non-CRP land. We estimate the metamodels using erosion estimates from EPIC (Erosion Productivity Impact Calculator [Williams, Jones and Dyke]), site-specific information on soils from the SOILS5 (Soil Interpretation Record System) database, and site-specific management information from the 1992 NRI (USDA). The first policy is a mandatory policy that has an objective of reducing erosion to a site's tolerance level holding crop rotation constant. The second policy is a voluntary policy that results in 50% of NRI points farmed with conventional tillage being switched to conservation tillage.

The Study Region and Use of NRI Data

Our study region includes the Lake States of Michigan, Wisconsin, and Minnesota, the Corn Belt, which includes Ohio, Indiana, Illinois, Iowa, and Missouri, and the Plains States of the Dakotas, Nebraska, and Kansas. This 12-state region accounts for 67% of the nation's cropland and large proportions of the nation's corn, soybeans, wheat, and sorghum acreage. These four crops plus alfalfa and summer fallow account for about 87.5% of the cropland in the study region. Corn and soybeans are the major crops in the Corn Belt and Lake States and account for 72% of cropland in these two regions. Corn and wheat are the major crops of the Plains and account for 51% of cropland. In 1992, cropland accounted for 53% of all land use in the Corn Belt, 32% in the Lake States, and 44% in Northern Plains.

The site-specific physical attributes and production practices in the study region were taken from the 1992 NRI database. The 1992 NRI is the third in a series of survey by the Natural Resource Conservation Service (NRCS) to determine status, condition, and trend of the nation's soil, water, and related resources. Data for the 1992 NRI were collected for more than 800,000 nonfederal locations. Sites for the NRI surveys were selected using the statistical techniques of stratification, area sampling, and clustering. Almost 200 attributes were collected at each NRI sample point. The 1992 NRI made a significant effort to gather detailed production and management information on those sampled points. The 1992 NRI reported the previous three-year cropping history, which we use to define crop rotation for each point. By linking the 1992 NRI to the SOILS5 database we can identify the combinations of production systems and site-specific resource settings that existed in 1992.

Fourteen major crop rotations were identified in the study region (Table 1). The most commonly used rotations in the Corn Belt and Lake States are corn-soybeans, continuous corn, and corn-soybeans-wheat. The wheat-fallow and wheat-sorghum-fallow rotations were the most popular crop rotation enterprises in the Plains. From the 1992 NRI we also identified fields where conservation practices such as contouring, terracing, and strip cropping were adopted. And, according to the NRI, the region had approximately 14.5 million acres (6.7% of total cropland) of irrigated cropland in 1992 (Table 1).

Sites using conservation tillage practices were also identified from the 1992 NRI, where conservation tillage is defined as one that maintains at least 30% residue cover. In 1992, about 37 million acres (17.5%) were planted with conservation tillage in this region (Table 1). A limitation of the 1992 NRI tillage data is that they do not disaggregate conservation tillage sites further into reduced and no-till categories. This breakdown is crucial for making accurate site-specific erosion assessments. The Conservation Technology Information Center (CTIC) publishes state- and crop-specific estimates of area under alternative tillage methods including reduced tillage and no-till. Tillage systems that maintains 30-70 percent residue cover on the field are considered reduced tillage and systems with residue cover exceeding

70 percent is considered no-till. With CTIC data for 1992 we computed normalized distributions of reduced and no-till acres by crop and state. Using these state- and crop-specific distributions we randomly classified all conservation tillage points as identified by the 1992 NRI as either reduced-till or no-till.

Research Method

The 2,141 general soils (each with a maximum of six soil profiles), 14 crop rotations, four tillage practices, four conservation practices, two irrigation systems (dryland and irrigated), numerous aquifers and drainage basins, and many weather conditions in the study region constitute millions of unique combinations of production systems and resource settings. Assessment of soil erosion from these unique environment, resource, and production settings is desirable. However, given the numerous combinations of site-specific attributes (such as slope and soil type) and cropping practices (crop rotation, tillage practices, and input use levels) it would be prohibitively expensive to simulate soil erosion at each site and for each policy. Furthermore, soil erosion can vary greatly from year to year at a particular site because of weather variations. Therefore, we should measure erosion rates over a fairly large number of years to make accurate assessments of the average annual erosion rate under a particular policy or production practice. The method used here—which combines spatial sampling, experimental design of biogeophysical model simulation runs on these sampled sites, and erosion metamodels—preserves both spatial and temporal heterogeneity.

Simulation models can be used to estimate the site-specific impacts of alternative policies or production practices on erosion rates (Wagenet and Hutson). This study uses EPIC to simulate site-specific soil erosion rates over a 30-year simulation period. EPIC is a physically based model with nine major components: hydrology, weather, erosion, nutrients, plant growth, soil temperature, tillage, economics, and plant environment. EPIC has been validated and calibrated on a wide variety of conditions, particularly for the conditions and practices prevalent in our study region (Williams, Jones, and Dyke). However, as with many other process models, EPIC is most useful for comparative assessments rather than point-specific absolute prediction.

As stated, it is not feasible to run EPIC at each NRI point under each alternative policy scenario. Instead, we use metamodels to estimate how soil erosion rates are affected by production practices and site-specific physical attributes. A metamodel is a reduced form regression equation that captures the complex relationships of the simulation model. This eliminates the need to run EPIC for every possible combination of production practices at every NRI point. We estimate metamodels from data obtained from a statistically designed set of EPIC simulation experiments that cover the range of relevant crop, soil, weather, and management characteristics (Bouzaher et al.).

A simulation experiment is a set of simulation runs intended to approximate the values of the response variable (y), in this case soil erosion, associated with a specified set of physical and management conditions (v). Let $y = g(v)$ be the true, unknown function describing the underlying erosion process. Given the simulation experiment data, we can specify an analytical metamodel $y = f(x, s, r; u)$ with relatively few management factors x, soil properties s, topography, climate, and hydrological conditions r, and an error term u. With these erosion metamodels, we are able to assess water and wind erosion for every site in the study region without conducting EPIC simulations for every site.

We conducted EPIC simulation experiments on a 10% sample of 1992 NRI points in the study region. Our sample design consisted of drawing a stratified single-stage sample (Carriquiry, Breidt, and Lakshminarayan). The two levels of stratification are given by MLRAs (Major Land Resource Areas) and by cropping system. In the second stratification stage, points within each MLRA are classified into strata according to cropping practices. The number of points selected within each cropping practices stratum is proportional to the relative size of the stratum in the MLRA. That is, the probability for selection is proportional to the area that each cropping practice covers in the MLRA. Individual points are selected at random within each cropping practice stratum, where the inclusion probability for each point in the stratum is equal to the overall sampling rate. A nice property of inclusion probability in a probability-based sampling is that it is unbiased (Cochran).

This procedure implicitly accounts for the area covered by each set of soil physical attributes because the sample selection for the 1992 NRI guarantees a representative spatial distribution of the points. Thus, a sample drawn at random from the strata, with constant inclusion probabilities for each point, should also be representative of soil physical attributes. In addition, because the 1992 NRI was drawn as an area sample, those soils that occupy a larger surface are more likely to be selected in the subsample. Estimates at the regional, state, and substate (MLRA) levels can be obtained in a statistically reliable manner by combining the 1992 NRI expansion factors with the sampling rates used to draw the subsample. Each NRI point is accompanied by an expansion factor that assigns the appropriate weight under the sampling design. For example, if the inclusion probability in the subsample is set at 0.1, and the expansion factor for the k^{th} point in the 1992 NRI is A_k, then the new expansion factor in the subsample is $[A_k / 0.1] = 10A_k$.

Soil Erosion Metamodels

For EPIC-generated wind and water erosion estimates, an ordinary least squares (OLS) regression model was fit initially. An examination of the residuals of the wind erosion model revealed severe heteroscedasticity and positive skewness. A test of the null hypothesis that the untransformed data are a random sample from a normal distribution was rejected. Better parameter estimates can be obtained by transforming the dependent variable to eliminate skewness and heteroscedasticity (Lin and Vonesh). It is common to take a contracting type of transformation, such as the square-root, cube-root, or fourth-root when untransformed data are positively skewed and have a wide range. A sixth-root transformation was performed on the wind erosion data.

The final estimated metamodels for water and wind erosion are

$$Water\_Eros = a_0 + a_1 \text{ slope} + a_2 \text{ latitude} + a_3 \text{ longitude} + a_4 \text{ clay} + a_5 \text{ pH} + a_6 \text{ permeability} + a_7 \text{ AWC} + a_8 \text{ (organic matter * bulk density)} + a_9 \text{ reduced tillage} + a_{10} \text{ no-till} + a_{11} \text{ contouring} + a_{12} \text{ strip cropping} + a_{13} \text{ terracing} + a_{14} \text{ irrigation type} + \sum_{h=15}^{17} a_h \text{ (hydrologic group)}_h + \sum_{c=18}^{30} a_c \text{ (crop rotation)}_c + u_1$$

and

$$(Wind\_Eros)^{1/6} = b_0 + b_1 \text{ slope} + b_2 \text{ latitude} + b_3 \text{ longitude} + b_4 \text{ clay} + b_5 \text{ pH} + b_6 \text{ AWC} + b_7 \text{ UAV} + b_8 \text{ (organic matter * bulk density)} + b_9 \text{ reduced tillage} + b_{10} \text{ no-till} + b_{11} \text{ contouring} + b_{12} \text{ strip cropping} + b_{13} \text{ terracing} + b_{14} \text{ irrigation type} + \sum_{h=15}^{17} b_h \text{ (hydrologic group)}_h + \sum_{c=18}^{30} b_c \text{ (crop rotation)}_c + u_2$$

where AWC is the available water capacity (field capacity), UAV is the average annual wind speed (m/s), slope is the average slope of land, and clay is percent clay content of the soil. Because of privacy concerns we do not know the longitude and latitude of the NRI points. However, we know the longitude and latitude of the nearby weather stations that were used to generate the daily weather data in the EPIC simulations. So we used these as proxy variables. The relevant management practices, tillage, conservation, irrigation, and crop rotation are represented by dummy variables. In general, n–1 categorical variables are needed to specify n categories. The reference variable for tillage, conservation, irrigation, and crop rotation are conventional tillage, straight-row conservation practice, nonirrigated system, and continuous alfalfa crop rotation. The hydrologic effects (i.e., partitioning of precipitation between runoff and infiltration) are represented by the hydrologic group dummy variables A through D, with A as the reference hydrologic group.

The soil erosion process is influenced by topography, weather (predominantly rainfall), and soil properties such as texture, structural stability, clay and organic matter content, soil moisture retention capacity, soil permeability, and soil pH (Lal and Elliot). These factors influence soil erosion both directly, in interaction with one another, and in interaction with management practices. The estimated water and wind regression metamodels shown in Table 2 summarize this complex physical process. Care was taken to avoid multicollinearity among the regressors. Nearly 70 percent of the variation in water erosion and 80 percent of the variation in wind erosion are explained by the regressors included in these regression metamodels.

Validating the metamodels is important because they are two steps removed from the underlying real processes. Validation tests were performed by comparing the metamodel predictions with the EPIC-simulated values and by using a random split-half validation (cross-validation) technique. In cross-validation the original data set is randomly split into two halves, a metamodel is fitted for each half separately, and the fitted metamodels are used to predict the other half of the data (Snee; Friedman and Friedman). According to Snee, cross-validation tests the in-use prediction accuracy of the model. Both these validations yielded good statistical results and confirmed the robustness of the estimated water and wind erosion metamodels. The sign and magnitude of the estimated coefficients from the two split-half models were also compared. The signs of the coefficients were the same in both samples, and the estimated coefficients were comparable in their magnitude.

The NRI reports average annual water and wind erosion rates calculated from the Universal Soil Loss Equation (Wischmeier and Smith) and Wind Erosion Equation (Skidmore and Woodruff). As an additional validation we compared our predicted values using 1992 site-specific information with the NRI estimates. Correlation of 80 to 90 percent between the point-level NRCS estimates and the metamodel predicted values for water and wind erosion were obtained.

Erosion predictions from the metamodels can be aggregated to any geographic region—a county, an MLRA, a state, or a USDA production region—using the weighted aggregation methods with point-specific expansion factors as weights. The weighted average erosion rate for the *i*th region is given by

$$EROS_i = \frac{\sum_{k=1}^{M_i} A_k EROS_k}{\sum_{k=1}^{M_i} A_k},$$

where $EROS_i$ is the average annual erosion rate (water or wind erosion) per acre for region i; A_k is the expansion factor for NRI point k in region i; M_i is the number of NRI points in the region; and $EROS_k$ is the average annual erosion rate at NRI point *k* that is estimated by substituting the production practices and physical attributes identified for the point into the metamodels. Figure 1 compares county-average annual water and wind erosion rates reported by the NRCS with the metamodel predicted rates.

Changes in Soil Erosion from 1982 to 1992

We used the estimated metamodels to compare soil erosion in 1982 with 1992 soil erosion. The unique combination of cropping practices and resource conditions at each NRI point in 1982 and 1992 were used as explanatory variables to predict soil erosion at each point. The results are reported in Table 3. The results in the top half of Table 3 take into account the reduction in erosion on CRP land. The bottom half shows the change in erosion rates only on non-CRP land. The average annual water erosion rate on all cropland in the study region declined 19% from 4.08 tons/acre in 1982 to 3.65 tons/acre in 1992. The average annual wind erosion declined 13% from 2.32 to 2.02 tons/acre. As shown by the bottom half of Table 3, most of this reduction can be attributed to CRP. When CRP land is excluded, water erosion averaged 3.89 tons/acre in both 1982 and 1992, while the wind erosion decreased slightly from 2.24 to 2.15 tons/acre. These results indicate that, as of 1992, there have been small, if any, reductions in erosion rates on cropped land in the study region. This result is somewhat surprising because of the presumed increases we have seen in adoption rates of soil-conserving practices, particularly no-till.

Table 4 provides some insight into the Table 3 results. First, note that although CRP took out 16.75 million acres of cropland in the region, farmers brought in an additional 11.5 million acres. If this new cropland is as erosive as CRP land, then we would expect little change in total erosion. Second, acreage in the highly-erosive corn-soybeans and wheat-soybeans rotations increased by 13.4 and 2.5 million acres, whereas acreage in the less-erosive continuous corn and wheat-sorghum-fallow rotations decreased substantially. Thus, total crop acreage did not decrease by the amount of CRP and the acreage that remained in production was planted to more erosive rotations. The negative effects of these changes in land use countered the positive effects of increased adoption of conservation tillage systems. Babcock, Chaherli,

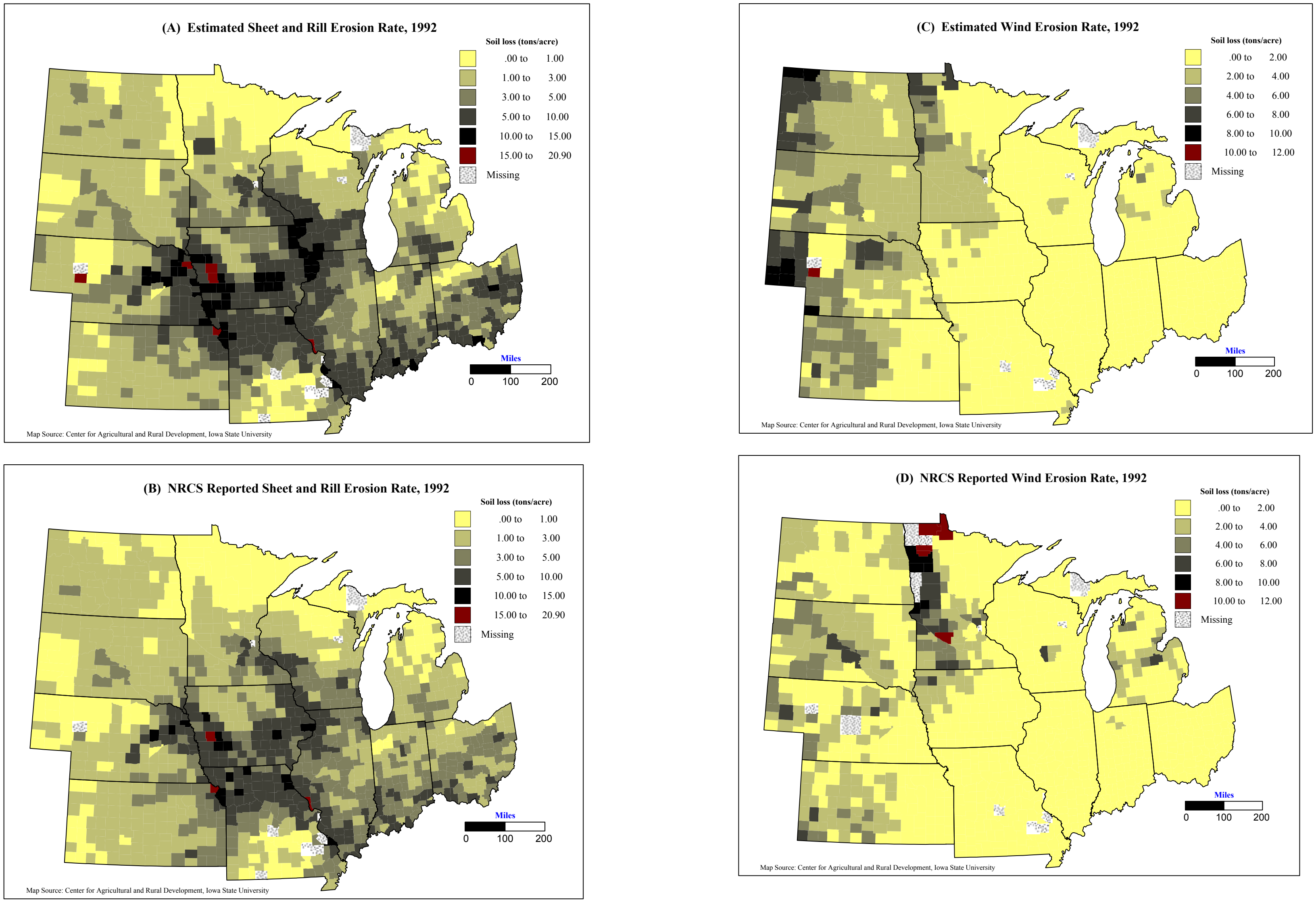

Figure 1. Comparison of metamodel estimated and NRCS reported county average annual water and wind erosion rates

and Lakshminarayan estimate that even though no-till acreage increased significantly from 1982 to 1992, much of this increase comes from switching reduced tillage land into no-till.

Conservation Policy Results

The two hypothetical policies we evaluate are (1) a mandatory T-based policy and (2) a voluntary 50% reduction in the use of conventional tillage. Neither of these policies approximates current conservation compliance policy. The T-based policy is stricter than current policy. And the tillage policy is not targeted at highly erodible land. However, the results of these two policies offer insight into the soil savings that are possible.

The objective of the first policy is to reduce soil erosion to soil loss tolerance levels for all cropped NRI points in the study region, whether the point is enrolled in commodity programs or not. If the estimated water erosion from current practices (1992 cropping practices) for a cropped NRI point exceeds the T-value for that point, then a conservation plan is implemented. Increasing levels of conservation practices and tillage operation are applied to each noncomplying point until the point comes into compliance or we exhaust possible remedies. The one remedy that we do not consider is crop choice. Wollenhaupt and Blase, who studied conservation compliance impacts on northern Missouri farms, observed that producers who learn how to produce crops under no-till will find that conservation compliance will not affect their crop rotation decisions.

We evaluate the voluntary tillage policy to determine soil erosion reduction that would occur if trends continue and 50% and NRI points that were cropped with conventional tillage in 1992 (45% of acres) were switched to conservation tillage. In essence, this could be viewed as a *laissez faire* policy whereby the government neither encourages nor discourages adoption of conservation tillage: farmers simply adopt it because it increases profits.

Table 5 shows the estimated changes in acreage under tillage and conservation practices for each of the two policies. The T-based policy was implemented only on violation acres. Under this policy approximately 38 million acres of cropland were switched from conventional tillage into reduced and no-till and approximately 35 million acres were moved from straight row cropping practices to contour crop, strip crop, and terraced cropping practices.

In Table 6 we provide a regional comparison of net soil savings on affected acres resulting from alternative policies including CRP. Soil saved estimates are relative to predicted levels using 1992 NRI data in the metamodels. For each policy we show total soil saved, the number of affected acres, and net soil saved per affected acre. In the study region 27% of cropped acreage (58.5 million acres) had erosion rates that exceeded T in 1992. The proportion of violation acreage to total cropped acreage ranged from 37% in the Corn Belt to 23% in the Lake States and 19% in the Plains.

The more targeted T-based policy results in a net soil savings of about 600 million tons, which represents a 46% reduction in total soil loss from 1992 levels. The average soil loss from both water and wind erosion across the study region would drop from 5.91 tons per acre to 3.17 tons per acre. The T-based policy achieves the greatest reduction in soil loss in the Plains states (59%) and the smallest reduction in the Corn Belt (36%). However, the poorly targeted conservation tillage policy would still save 277 million tons of soil, which represents a 22% reduction in total soil loss from 1992 levels. Across the study region, the conservation tillage policy would reduce average soil loss from both water and wind erosion from 5.91 tons per acre to 4.63 tons.

Not surprisingly, the more targeted T-based policy achieves much larger reductions in soil losses (total soil losses would be cut almost in half the 1992 levels; Table 6). CRP results in annual soil savings of 16 tons per acre. The T-based policy, which targets the remaining highly erodible cropland, would save 10 tons per acre. And the poorly targeted conservation tillage policy would result in annual savings of 3.7 tons per acre. It is interesting to note that the poorly targeted conservation tillage policy results in the same amount of total annual soil savings (270 million tons) as achieved by CRP, and about one-half the total soil savings of the T-based policy.

To determine the on-farm costs of these two policies we used FEDS (Federal Enterprise Data System) / RCA (Resource Conservation Act) budgets updated by the Center for Agricultural and Rural Development (CARD, Iowa State University) for the 1995 Farm Bill Analysis and the RAMS (Resource Adjustment Modeling System) linear programming modeling system to estimate changes in the gross returns of crop production under alternative policies relative to the baseline. RAMS models a risk neutral producer who is assumed to operate a competitive multiproduct farm and select input and output levels to maximize profits. RAMS is configured at the watershed level (Producing Area [PA]). PAs are hydrological unit areas defined by the Water Resources Council. Within a PA we adopt a unique land-group definition representing MLRAs. In addition, an MLRA is aggregated over major land groups defined from USDA land capability classes and subclasses. We maintain a distinction between highly erodible and nonhighly erodible land activities.

The crop production subsector of RAMS defines cropping practices as acres of crop rotations, either dry or irrigated, on highly or nonhighly erodible land, and under one of 16 combined tillage and conservation practices. We assume these activities represent current practices and are associated with base yields and production cost, derived from currently observed production data. Major resource and other restrictions define the constraint set of RAMS.

Conservation measures for erosion control involve both private and public expenditures. The costs of implementing soil conservation measures generally include costs of initial investment on conservation tillage equipment, annual installation, operation, maintenance, and costs of learning and technical assistance. In addition, there is the cost of production adjustments from implementing conservation tillage. There is a high degree of uncertainty about the costs of conservation practices and conservation tillage. The costs that we include in our analysis are those for which we have firm estimates. These are the annualized costs of installing and maintaining permanent soil conservation structures such as terraces and the reduction in gross returns under the given soil conservation policy. Costs for which we do not have firm estimates are not included because they would be incurred even in the baseline. These include initial outlays for conservation tillage equipment, and the costs of technical assistance and of learning to adopt soil conservation practices.

Farmers who successfully switch from conventional tillage to conservation tillage find that their variable expenses are often lower. Because we do not see 100% adoption of conservation tillage, it must be that these cost savings are less than perceived cost increases. We do not account for these cost savings. Thus, we implicitly assume that the costs we ignore are equal to the savings in variable expenses. This caveat should be kept in mind when judging the robustness of the cost estimates reported in Tables 7 and 8.

Table 7 presents the total cost of treatment and average cost of treatment per ton of soil saved. Table 8 presents the costs of treatment per targeted acre for the T-based policy, tillage policy, and CRP. In the study area, CRP that enrolled 270 million acres at a cost of $948 million translates into $3.51 per ton of soil saved compared with $0.56 per ton of soil saved (or $341 million) under the T-based policy and $0.48 per ton of soil saved (or $137 million) under conservation tillage policy.

CRP is seen as a high cost policy because (1) it must compensate farmers for a total loss in the net value of production on enrolled land, and (2) we attribute the entire cost of CRP to erosion reduction benefits. It is well documented that there are many other environmental benefits from CRP that we do not account for in this analysis including increased wildlife habitat and improved water quality (Heimlich and Osborn; Ribaudo 1989). If we have a goal of reducing soil erosion at minimum cost, then either of the other two policy options are superior to CRP in cost per ton of soil saved. Of course neither of the two alternative policy options reduces erosion rates to a T-value on all acreage, as CRP does. Under the T-based policy there are still approximately 25 million acres where erosion is above T even after switching to the most effective conservation treatment.

The average per acre costs of compliance is $5.83 for the T-based policy and $1.76 for the tillage policy (Table 8), which, not surprisingly, is much lower than the average per acre rental rate for CRP. The low cost of the conservation tillage option suggests that there would be significant gains to society by voluntary adoption of reduced and no-till practices. Even though there is significant difference in per acre costs between these two policies the cost per ton of soil saved is close because conservation tillage policy was implemented on all cropland regardless of current erosion levels. So, it is a poorly targeted policy. Therefore, the annual soil saved per acre is only 3.7 tons, compared with 10 tons under the T-based policy (Table 6).

Finally, in Table 9 we report total off-site sediment benefits from soil erosion reductions from these three alternative policies. The total off-site sediment benefits were calculated using Ribaudo's (1986) USDA region-specific low, medium, and high estimates of off-site sediment benefits from all sources for every ton of soil erosion reduced from cropland. Given the medium estimate, the T-based policy results in $606 million off-site sediment benefits compared with $285 million from tillage policy and $275 million from CRP. Besides off-site sediment benefit there are also on-site benefits from productivity increases, which are not estimated here. Comparing the benefit to cost ratio of the three policies, we conclude that CRP in our study region cannot be justified solely for of its erosion benefits because it has a benefit to cost ratio of less than one. It is likely, however, that the other policies have benefit to cost ratios that exceed one. A significant amount of current CRP land is not susceptible to high erosion rates, which drives down the average benefit to cost ratio across the study region. A more targeted CRP would increase this ratio to the point where it could approach unity.

Concluding Remarks

This study presents a method for predicting soil erosion reductions from prospective soil conservation policies across a broad landscape. Erosion metamodels estimated using site-specific resource, production, topography, and weather data make such an endeavor tractable. The results of our 12-state analysis indicate that alternative conservation policies differ widely in cost and benefits. However, even a poorly targeted *laissaz faire* policy, whereby farmers adopt conservation tillage techniques solely because of profitability, achieves significant reductions in soil erosion. Better targeting, such as with CRP and a policy that attempts to reduce erosion rates to tolerance levels, achieves greater reductions in soil erosion but at a higher cost. We estimate that the public benefits of controlling erosion more than offset the small increased cost from adopting conservation practices and conservation tillage.

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