THE CONSERVATION SECURITY PROGRAM: ECONOMIC AND ENVIRONMENTAL BENEFITS

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ABSTRACT: Farmers receive income from many things they produce in abundance -- food, feed, fiber and fuel. Farmers also may generate environmental benefits (improved water quality and fisheries and wildlife habitat) by managing their operations in certain ways. Unfortunately, farmers have limited ability to quantify the environmental benefits associated with land use practices. Furthermore, farmers may have to forego government commodity payments, thereby reducing their income from working lands, to produce positive externalities. Provisions under the Conservation Security Program (CSP), if fully implemented, may allow producers to receive some compensation for conservation practices that provide some positive environmental externalities to a watershed. This research used a computer simulation model to examine the relationship between government commodity and conservation programs, agricultural practices, water quality (nutrient and sediment loss), fish communities and net farm income within two small watersheds -- a coolwater stream and a warmwater stream. We used the Agricultural Drainage and Pesticide Transport (ADAPT) model in relation to land use to calculate in-stream suspended sediment concentrations using estimates of sediment delivery, runoff, baseflow and stream bank erosion, and quantified the effects of suspended sediment exposure on fish communities. When the agriculture practices that potentially qualify under the CSP were implemented watershed-wide, net farm income remained relatively unchanged in both study areas, relative to current conditions. We found a decrease in "lethal" concentrations of suspended sediment on fish in the coolwater watershed with an increase in conservation tillage and riparian buffers, and a decrease in nutrient application rates to recommended levels. However, land use change in the warmwater watershed did not significantly decrease the effects of suspended sediment on the fish community. This difference between watersheds is likely due to differential tolerance to suspended sediment between coolwater and warmwater fish communities and differences in topography, runoff and bank erosion between the two streams. Despite producers receiving compensation for changing their practices under a potential CSP, annual net farm income declined by 1-3% in either watershed.

KEY TERMS: BMPs; ADAPT; fisheries; economic; water quality.

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INTRODUCTION

Although it is widely accepted that suspended sediment has negative impacts on fish, and that the severity of the effects increase with increasing sediment concentrations and duration of exposure, few studies have attempted to make quantitative predictions of the effects of suspended sediment on fish assemblages (Newcombe and Jensen 1996). Expansion of field-scale agricultural models has allowed scientists to predict sediment and nutrient loadings to streams by incorporating within-field hydrological processes and watershed agricultural practices (Gowda et al. 1999a, Westra et al. 2002).

The first goal of this study was to combine estimates of sediment loads from a watershed-scale agricultural model, Agricultural Drainage and Pesticide Transport (ADAPT) (Chung et al. 1992, and modified by Gowda 1996) with information on the effects of sediment on fish assemblages (Newcombe and Jensen 1996) to examine the effects of land use on fish in agricultural landscapes. Secondly, we used the biophysical information from simulated production activities, combined with estimates of production costs and returns, to compare output between the baseline and a CSP scenario. Our objectives were to: 1) use ADAPT to estimate total sediment load in two watersheds in Minnesota (Wells Creek -- a coolwater stream, and a subwatershed of the Chippewa River -- a warmwater stream); 2) quantify the effects of suspended sediment concentrations and duration of exposure for fish assemblages for both watersheds; 3) compare the effects of suspended sediment on fish between current land use and the CSP scenario; 4) compare the effects on net farm income in both watersheds between current practices and the CSP scenario for each watershed. Our hypothesis was that net farm income and lethal and sublethal effects (as defined by Newcombe and Jensen 1996) of suspended sediment on fish would decrease as land use shifted from conventional row-crop agriculture to implementation of conservation practices under the CSP throughout either watershed.

Wells Creek, the first watershed studied, is located in the Driftless Area Ecoregion (Omernik and Gallant 1988) in Goodhue County of southeastern Minnesota. The stream historically supported a coolwater fish assemblage, with low species diversity and naturally reproducing trout populations. This watershed is dominated by agriculture with 61% of the total watershed area under cultivation, 10% was in grassland or managed pasture primarily for dairy cattle, and 26% of the watershed was forested, mainly on steep slopes and riparian areas. Data from the US Census of Agriculture (USDA 1999) for Goodhue

County indicated the majority of cultivated land is under a corn-soybean rotation, followed by small grain-hay rotations with some land in corn-small grain-hay rotation. Approximately 55% of cultivated land was under some type of conservation tillage in Goodhue County (CTIC 1999).

The other study area was a subwatershed of the Chippewa River drainage, located primarily in Chippewa County, with a small section in Swift County in western Minnesota. The Chippewa River is classified as a warmwater river, with a diverse fish assemblage (Anonymous 1998a). This watershed is within the Western Cornbelt Plains Ecoregion (Omernik and Gallant 1988) and primarily is in row-crop agriculture, with 81% of the land area in cultivation, 8% in grassland or pasture primarily for beef cattle, and 5% forested. Almost all of the cultivated land is under a corn-soybean rotation, with some land in sugarbeets, and approximately 1,300 acres in small grains with hay (USDA 1999). Data for Chippewa County indicated approximately 30% of cropland is under some form of residue management (conservation tillage) system (CTIC 1999).

METHODS

ADAPT is a field-scale water table management model that combines GLEAMS (Leonard et al. 1987) and DRAINMOD (Skaggs 1978). ADAPT can model fields with tile drainage, a dominant feature of fields in the Chippewa River subwatershed, and it has been calibrated to data collected in several watersheds in Minnesota (Davis et al. 2000).

Land cover, agricultural management practices (crops, rotation and tillage), slope and soil information were overlaid with Geographic Information System (GIS) to create data input files for the ADAPT model that reflected the spatial distribution of practices in the watershed. For this approach, each watershed was divided into subwatersheds (termed Transformed Hydrological Response Units or THRUs; Gowda et al. 1999b), an ADAPT simulation was performed for each THRU, a hydrograph was developed for each subwatershed, the hydrographs were combined, and then routed to the outlet of each watershed to derive an estimate of the sediment delivered to the mouth of both streams.

Estimates were developed for the baseline land use and the CSP scenario by simulating different proportions of each land use or farming practice in each watershed. Land use in the watershed was assumed to correspond to that of the county in which the watershed was located (i.e., Goodhue for Wells

Creek and Chippewa for Chippewa). Information on the crop acreage and livestock numbers from the latest Census of Agriculture (USDA 1999) was combined with the land use data to reflect the predominance and location of various production practices in the watershed. For each of the agricultural systems analyzed (cropping and livestock, traditional pastured and intensive grazing systems), specific hydrology and erosion files were created using information for the predominant STATSGO map units from the MUUF (Map Unit Use File) soils database for the corresponding soils in these watersheds in Minnesota.

We defined base flow for both streams as the flow that was exceeded 90% of the time from daily stream gauge data (Greg Payne, Minnesota Pollution Control Agency, personal communication). Base flow for the Chippewa River was 0.5 m^3/sec and 1.12 m^3/sec for Wells Creek. We assumed the proportion of in-stream sediment concentrations due to stream bank erosion as 20% in Wells Creek (based on estimates for the Whitewater River watershed, a similar watershed in southeast Minnesota, Anonymous 1998b) and 40% in the Chippewa (Joe Magner, Minnesota Pollution Control Agency, and Dave Mulla, Department of Water, Soil, and Climate, University of Minnesota, personal communication). Bank erosion estimates were constant for both scenarios to separate the effects of land use on in-stream sediment concentrations from those due to stream bank stabilization. However, stream bank erosion likely would decrease when agricultural practices changed to include increased riparian buffers with permanent cover along streams so the estimated benefits from the CSP scenario are conservative.

We calculated in-stream sediment concentrations (mg/L) based on estimates of daily sediment load, daily runoff, base flow for each stream and the proportion of in-stream sediment due to stream bank erosion. We used estimated daily suspended sediment concentrations to evaluate the effects of sediment on fish assemblages in each stream, by calculating the total number of days for each year that sediment concentrations would be lethal or sublethal to fish in that stream. For our calculations, we referenced a meta-analysis of fish responses to suspended sediment in streams that quantitatively related the biological response of fishes to suspended sediment concentrations and duration of exposure (Newcombe and Jensen 1996). Newcombe and Jensen (1996) characterize sublethal effects as reduction in feeding rates or feeding success, physiological stress such as coughing and increased respiration rate, moderate habitat degradation and impaired homing. Lethal effects are described as reduced growth rate, delayed hatching, reduced fish density, increased predation, severe habitat degradation and mortality. We used the thresholds of Newcombe and Jensen (1996) to calculate the total number of days that sediment concentrations and duration of exposure met or exceeded the sublethal or lethal levels for the fish assemblages. The fish assemblages in the analysis included juvenile and adult salmonids (representing Wells Creek), and adult freshwater non-salmonids, mainly composed of warmwater species (representing the Chippewa).

RESULTS

Of a total of 18,263 days over the modeling period, sediment loading occurring between 2024 and 2590 days in the Chippewa, compared to a range of 1614 to 1729 days in Wells Creek (CSP and baseline). The average duration of runoff events was longer in the Chippewa than Wells Creek, which resulted in longer average exposure times to suspended sediment for fish in the Chippewa watershed. Water runoff in both watersheds decreased slightly under the CSP scenario (3% reduction from baseline in Wells Creek and 1% reduction from baseline in the Chippewa). However, the mean in-stream sediment concentration was higher in Wells Creek (range 293 mg/L to 1476 mg/L). The Chippewa watershed had less variation in mean sediment concentration among scenarios, with values from 377 mg/L to 585 mg/L.

In Wells Creek watershed, annual sediment loading decreased by 31% with CSP agricultural practices from the estimated baseline load of 39,615 tons. Nitrogen loss decreased by 37% from baseline load of 3,001 tons annually and phosphorus loss declined by 52% from the estimated baseline load of 7,547 tons annually under the CSP scenario in Wells Creek. In the Chippewa River subwatershed, an estimated 2,000 tons of sediment reaches the main stem of the Chippewa River annually. This load decreased under the CSP scenario by 25%. Under the CSP scenario, nitrogen loss declined by 17% (from an estimated 13,966 tons annually) and phosphorus loss decreased by 40% (from an estimated 5,108 tons annually) in the Chippewa.

Mean sediment concentrations for both streams and both scenarios were above the threshold for sublethal effects to fish, but were not lethal for an exposure of one day or less. However, mean sediment concentrations could have been classified as lethal for greater than one day of exposure. The mean annual number of days with sublethal or lethal sediment concentrations to fish was slightly higher in the Chippewa than Wells Creek. The mean number of days per year with lethal sediment concentrations to fish ranged from 10.2 to 11.6 in the Chippewa, depending on the scenario, compared to 0.2 to 7.6 days in Wells Creek. Mean sublethal events in the Chippewa ranged from 31.1 to 40.8 days per year, compared to 25.8 to 32.4 in Wells Creek. Though not significantly different in the Chippewa ($p>0.99$ for mean annual days with lethal sediment concentrations, $p>0.060$ for sublethal), these values represented a slight decrease in lethal and sublethal events.

There were significant differences between mean values among scenarios for lethal events ($p<0.0001$) in Wells Creek. The baseline had significantly higher mean annual days with lethal sediment concentrations than the BMP scenario. Under the BMP scenario, lethal fish effects were estimated to decline by almost 60%. Counterintuitively, the number of sublethal events in Wells Creek increased with CSP practices (although not statistically significant).

Under the CSP scenario, we estimated annual total revenue decreased by $435,461 while annual total costs declined by $417,574 in Wells Creek. As a result, annual net farm income declined by less than $18,000 (1%) from the baseline with certain CSP agricultural practices implemented throughout the watershed. In the Chippewa River subwatershed, total revenue decreased by approximately $301,995, but estimated total costs declined by $274,405. As a result, annual net farm income declined by less than $28,000 (3%) when certain agricultural practices (that conform to the provisions of the CSP) were implemented throughout the Chippewa River subwatershed.

DISCUSSION

Effects of land use practices on fish assemblages, as well as on patterns of sediment and runoff, were dependent on physical attributes of each watershed. The mean number of days with lethal and sublethal sediment concentrations was higher in the Chippewa River than in Wells Creek, which is likely a function of the combined influences of differences among fish assemblages, land use practices, topography, and soils between the two watersheds. In general, the fish assemblage in the Chippewa watershed was more sensitive to sediment concentrations than the coolwater assemblage in Wells Creek for exposure longer than one day. Sediment concentrations were often lower in the Chippewa River watershed than those in Wells Creek, but were delivered for a longer duration.

The concentration of suspended sediment in a stream on any given day is a product of several factors, including land use practice, soil type, vegetative cover, topography, precipitation, and time of year (Wood and Armitage 1997). Whereas physical differences such as soil type, topography and precipitation amounts and timing likely contributed to differences in suspended sediment concentrations between watersheds, we varied land use in our analysis to examine how implementing certain CSP-compliant practices would affect suspended sediment concentrations and fish assemblages in watersheds with different physical attributes. We determined that although the implementation of conservation practices played an important role in controlling the amount of sediment that reaches a stream, interactions between land uses, biological attributes of the fish assemblage in a stream, and physical properties of a watershed ultimately determine the degree of change within a watershed needed to have a measurable effect. Thus, the environmental benefits society hopes will result from farmers using conservation practices may be mitigated by physical and physiological characteristics and processes of the watershed.

In Wells Creek watershed, the steeply sloped, well-drained soils allowed runoff to rapidly reach the stream, resulting in a pattern of peaks of high sediment concentrations that quickly subside. In contrast, the relatively flat, moderately to very poorly drained soils of the Chippewa watershed take more time to drain. Paradoxically, this leads to a greater number of days and more protracted periods with runoff, although sediment concentrations are generally lower. Thus, the relatively flat topography influences runoff patterns in the watershed, which may explain why the Chippewa River watershed with less annual rainfall than Wells Creek had more consecutive days with measured runoff.

The results indicated that beneficial effects on fish assemblage might be achieved with relatively minimal adverse effect on agricultural production and net farm income. In Wells Creek, slightly more than 5% of row-crop acreage was converted to grass riparian buffers under the CSP scenario. Changing land management practices reduced net farm income by less than 1% ($18,000) per year from baseline levels. Another way to look at this is that producers in Wells Creek would need to receive an additional $18,000 annual compensation (under CSP of some other conservation program) to be as well off as they are now. Under the CSP scenario, for retiring 1,366 acres of cropland to benefit fish assemblage (among others) in Wells Creek, additional conservation program payments amount to about $13 per acre annually.

In the Chippewa River subwatershed, the story is similar, though slightly more costly. When producers used conservation tillage and recommended nutrient rates, annual total costs decreased but total revenues decrease slightly as well. Furthermore, a little more than 2% of cultivated cropland (879 acres) in the baseline was removed from production and planted to grass buffer strips under CSP scenario. This reduced net farm income in this subwatershed by 3% ($27,590) annually from baseline levels. For producers to be as well of under this CSP scenario, they would need to receive $27,590 annually for lost income. Society would need to compensate farmers $31 for each acre of land retired from production. Relative to the current payments producers receive under the Conservation Reserve Program (CRP) in these two watersheds, compensation at this level would be a great bargain for society.

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