Economics of Riparian Buffers: a watershed perspective

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Economics of Riparian Buffers: a watershed perspective
by J. Colletti, R. Schultz, T. Isenhart, and S. Jungst
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Abstract
An economic analysis of a riparian management system (RiMS) applied to the 7,655 ha Bear Creek agricultural watershed in central Iowa was done. The present value (PV) cost (@ 5% real ARR) is $2.16 million to establish and maintain for 20 years riparian buffers, streambank stabilization, and constructed wetlands in the upper one-half of the Bear Creek watershed. The RiMS model assumed 20 m wide, multiple species tree/shrub/perennial grass buffers planted on 169 ha of land (only 90 ha in crops), 30% of 17.7 km of stream banks protected by bioengineering techniques, and two major wetlands totaling 8.9 ha constructed to intercept large tile lines. To justify the RiMS model in the watershed means that expected PV benefits must equal or exceed the PV cost. PV willingness to pay (benefits) for desired surface water quality improvements in Bear Creek total about $610,000. With the consideration of other nonmarket and market values associated with the RiMS, such as improved aesthetics and wildlife habitat and production of fiber, the efficiency of this specific RiMS model can be improved.

Introduction
Our society wants and needs various food and fiber products to sustain its economic activity. The United States relies on the highly efficient (read low-unit-cost) production agriculture of the Midwest to produce corn and soybean crops to be used directly and indirectly as food and industrial materials. Iowa produces great quantities of corn and soybeans from over 24 million acres. Whereas the success of modern production agriculture in Iowa in terms of yield is well known and accepted, the unintended environmental problem, nonpoint source (NPS) pollution (read sediment, nutrients, and pesticides) is hotly debated.

Nationwide, NPS pollution of our water resources is a serious problem. Soil sediment eroded from cropland contributes about 1.4 billion Mg (megagram or metric ton) annually to our waterways. In total, over 2.7 billion Mg of soil enters water as NPS pollution each year [Welsch, 1991]. In Iowa, it is estimated that 240 million tons of rich Iowa topsoil enters the Missouri River each year [Kelley, 1990]. In Iowa, scientists have estimated that two Army Corps of Engineers reservoirs receive thousands of metric tons of soil sediment daily. Saylorville Lake, located on the Des Moines River, receives an estimated 4,000 Mg of sediment per day. Whereas, Lake Red Rock, farther downstream from Saylorville and with three additional uncontrolled drainages entering its conservation pool receives about 15,000 Mg per day [Kelley, 1990].

Pesticides and fertilizers also contribute NPS pollution to our nation’s waters. Atrazine and alachlor, two pesticides used in row crop production, have been found in Midwestern surface waters for some time [Kelley, 1990]. Phosphorus (P) and nitrogen (nitrate-nitrogen) are major fertilizers that can enter the surface and groundwater resources in great quantities. It was estimated that in 1989, nearly 1 million Mg of P entered our Nation’s waterways. In 1980, an estimated 2.6 million Mg of nitrate-nitrogen became NPS pollution [Welsch, 1991]. Kelley [1990] reported that in 1991 many Iowa surface waters had nitrate-nitrogen levels exceeding 10 mg l⁻¹. Kelly also reported water flowing from tile lines entering various water-
ways having nitrate-nitrogen levels of 70 to 80 mg 1-

Removal of fertilizer/pesticide NPS pollutants is expensive and is borne by downstream users of surface and groundwater. For example, the city of Des Moines, IA has invested over $4 million in new equipment to filter nitrates from the drinking water extracted from the Des Moines and Raccoon rivers. And, it is considering another $13.5 million investment for an advanced filtration system to remove atrazine from the polluted river water [Hubert, 1992]. Welsch [1991] reported that it costs about $10 to $15 per month for a family of three for community water facility to remove excess nitrate from groundwater. It is an expensive bill to pay to clean-up the NPS pollution in Iowa attributed to production agriculture, and largely the costs are borne by downstream users.

Government agencies (e.g., US Department of Agriculture – Natural Resources Conservation Service, US Environmental Protection Agency, Iowa Department of Natural Resources – Environmental Protection Division), and the agricultural community (producers, service businesses and industry) have addressed NPS pollution by developing upland soil conservation (best management) practices (e.g., contour farming, minimum/reduced tillage) and better fertilizer/pesticide management (e.g., more accurate and better-timed applications).

To complement the in-field best management practices (BMPs), permanent vegetation placed in critical areas (e.g., in-field and near water bodies) have been evaluated and determined to be among the set of "most effective" BMPs (Prato and Shi, 1990). However, the permanent vegetation typically used in Iowa and throughout the Midwest has been mainly the grass-only filter strips.

Only recently has the role and importance of stream-side forest [tree and shrub] vegetation in reducing and transforming NPS pollution from agriculture been clearly documented and quantified [see Schultz et.al., 2000; Welsch, 1991; Lowrance, 1992, Lowrance, et.al., 1985]. Naturally occurring and human-created riparian ecosystems consisting of grass, tree, and shrub components can effectively remove sediment moving from croplands, and filter and transform nitrate nitrogen, phosphorus, and atrazine before these pollutants entering the surface or groundwater [Schultz et.al., 2000; Welsch, 1991; Lowrance, 1992; Lowrance, et.al., 1985]. Moreover, natural or constructed vegetative buffer strips provide terrestrial and aquatic habitat and enhanced aesthetics [Schultz et.al., 2000; Welsch, 1991].

Public Goods, Nonmarket Benefits, Improved Water Quality, and Contingent Valuation Method

NPS pollution poses a difficult resource allocation and valuation problem. It is unclear who should pay for the clean-up of polluted water resources because of the dispersed nature of NPS pollution. Farmers do not plan to cause NPS pollution and may not be able to determine that the NPS pollution entering a stream on their property actually came from their agricultural practices. In fact, farmers largely do not include on-site or off-site NPS pollution damage in their cost accounting. Yet NPS pollution does occur, and improvements in polluted water are highly valued and desired by society.

An improvement of NPS polluted water also represents a public good. The benefit from an improvement in water quality is the sum of the value associated with the improvement by all people effected directly or indirectly. This value is called willingness to pay (WTP). WTP measures people's stated value of a specific improvement in water quality [Freeman, 1979]. To make efficient resource allocation decisions, it is important to have an accurate accounting of private and public (social) benefits and costs. Thus,
decisions regarding amelioration of NPS pollution need to consider the effects and the values that individuals and society place on these impacts.

Economists have used the contingent valuation method (CVM) to elicit verbal responses to questions where people give their willingness to pay for a specific nonmarket good or service (e.g., improved surface water quality) rather than do without the good [Smith, 1996; Kealy et al., 1990; Mitchell and Carson, 1989; Cummings et al., 1986; Bishop et al., 1983]. The nature of the good, in this case improved surface or groundwater quality, can make it difficult for consumers to understand the good being valued. With care and focus on value-in-use (as opposed to nonuse values such as existence, bequest, and option values), CVM questions can generate reliable and valid estimates of WTP [Smith, 1996; Kealy, 1990; Mitchell and Carson, 1989].

Study Area

The Bear Creek watershed spans about 7,660 hectares in Story, Hamilton, and Hardin counties (Bercovici, 1994). Total stream length is 88 km (~54 miles) (Bercovici, 1994). Eighty-six percent of the watershed has a slope between 0 and 5 percent. The steepest slopes are usually associated with the stream channels (Jungst et al., 1993). An analysis of 1992 aerial photographs showed 33 percent of the watershed to be in corn production, about 22 percent in permanent grass waterways, over 15 percent in soybean production, 10 percent in annual set aside, and over 8 percent in pasture land. The remaining land area was a mixture of forests, farmsteads, la- goons, and roadways with the majority of it in forestland (~9 percent of the total land area).

Methods

A discounted cost analysis was done to determine the private and public costs including opportunity costs of installed multi-species riparian buffers, constructed wetlands (to intercept drain tiles) and streambank stabilization techniques (to reduce soil erosion) in the Bear Creek watershed. To this analysis is added the effect of the 1996 Conservation Reserve Program—with its continuous priority program for riparian buffers. Note that there is no federal governmental support for constructed wetlands or streambank stabilization. Thus the CRP impacts the cost of riparian buffers only. The continuous sign-up CRP provides a landowner with 50% cost share and a 20% rent premium (above the mean rental rate for the land, which for land in Bear Creek means annual rents of around $150 per acre). Finally, the estimated WTP values for improved surface water quality of Bear Creek are given providing a type of economic analysis that combines private and public costs and benefits from riparian BMPs.

The riparian area before repair.

The Bear Creek riparian buffer at work.
The working hypotheses are that 1) RiMS model is thought to be complementary to upland BMPs and 2) it provides effective reductions in NPS pollution in the Bear Creek watershed that are sustainable over the long-run.

**Non-dynamic Riparian Management System (RiMS) Assumed**

Based on numerous studies, it is assumed that the most effective use of riparian BMPs is in the upper one-half of the Bear Creek watershed. The economic analysis applied to the Bear Creek watershed level also assumed a non-dynamic (fixed) establishment pattern. This means that a fixed 20-m wide riparian forest buffer (consisting of trees, shrubs, and grasses) is assumed to be established along the upper 1/2 of Bear Creek. Further, based on research results by the Departments of Botany and Forestry at ISU concerning siting and efficacy of constructed wetlands, it is assumed that two wetlands are constructed on the West and East branch of Bear Creek near the headwaters. Finally, ISU research suggests that roughly 1/3 of the stream bank length of Bear Creek needs stabilization techniques to reduce soil erosion. The riparian buffer, constructed wetland, and streambank stabilization constitutes the non-dynamic RiMS applied to the Bear Creek watershed.

Because all costs and revenues occur over time, they must be discounted all to a common point in time via appropriate discounting formulae. Deciding on the appropriate discount rate is critical to proper time adjustment of future cash flows. This study uses constant costs and returns (WTP) and a real discount rate. This means that all cash flows are estimated without inflation and that the relevant nominal discount rate (i) is deflated to omit inflation. A 5% real alternative rate of return (discount rate) and 20-year analysis period are used in this study.

**Results**

**Land Effects**

Using Geographic Information System (GIS) analysis (Bercovici, 1994; Jungst et. al. 1993), a non-dynamic RiMS model applied to the entire Bear Creek watershed, will at most impact 338 ha (~860 ac) by establishment of a 20 m wide riparian buffer. And, out of the 338 ha only 180 ha is classified as agricultural land. Thus, the private and public loss in terms of annual crop land taken “out of production” (but placed into conservation/environmental benefit production) is only 53% of the apparent affected land. This study will assume that establishment of a 20-m wide riparian buffer ha affects 169 ha and only 90 ha are actually converted from row crop or pasture production to a riparian buffer.

**Riparian Buffer Cost**

Based on 1998 costs and multiple experiences by the authors since 1990 in establishing riparian buffers in the Bear Creek watershed on private farms, the mean cost for establishing a multi-species riparian buffer is estimated to be $1,300 per ha including the first year maintenance cost (see Table 1). Estimated annual maintenance cost for years 1 – 8 is $168 per ha. For comparison purposes, the cost of planting a buffer in a field that was in pasture is slightly less. Also, if a

<table>
<thead>
<tr>
<th>Previous Land Use</th>
<th>Multi-species RB ($/ha)</th>
<th>Grass only buffer ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual crop field</td>
<td>$1,300/ha</td>
<td>$370/ha</td>
</tr>
<tr>
<td>Pasture field</td>
<td>$1,200/ha</td>
<td>$440/ha</td>
</tr>
</tbody>
</table>

Stabilizing the streambank of Bear Creek.
perennial cool-season grass only filter strip is established, its cost is only 1/3 of the multi-species RB. Cool-season grasses are much less effective in reducing near-stream and stream channel nonpoint source pollution.

Table 2 presents the present value cost (@ 5% real ARR) of establishing and maintaining riparian buffers of a fixed 20-m wide size on all land in the upper one-half of the Bear Creek watershed. Table 2 also includes the opportunity cost of not producing a row or pasture crop from the agricultural acres converted to riparian buffer. Thus, the present value cost including rent foregone is about $819,000.

<table>
<thead>
<tr>
<th>Item</th>
<th>Time (Yr.)</th>
<th>Unit cost</th>
<th>Multiplier</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish 169 ha buffer</td>
<td>0</td>
<td>$1,300/ha</td>
<td>1.00</td>
<td>$219,700</td>
</tr>
<tr>
<td>Maintain 169 ha¹</td>
<td>1-8</td>
<td>$163/ha</td>
<td>6.46</td>
<td>$178,100</td>
</tr>
<tr>
<td>Rent lost 90 ha²</td>
<td>1-20</td>
<td>$375/ha</td>
<td>12.46221</td>
<td>$420,500</td>
</tr>
<tr>
<td>Total PV Cost @ 5%</td>
<td></td>
<td></td>
<td></td>
<td>$818,300</td>
</tr>
</tbody>
</table>

¹ - GIS analysis indicates that for the upper one-half of the Bear Creek watershed, a 20 m wide buffer will take 169 ha of land. Of this only 90 ha is actually in row or pasture production.

² - the opportunity cost (rent lost) is applied only to the 90 ha of agricultural land (row and pasture) taken out of production.

### Streambank Stabilization Cost

Streambank stabilization techniques are assumed to be needed on only 30% of the length of Bear Creek. The percent critical need value is based on initial estimates from an on-going research study of Bear Creek (personal communication G. Zaimes, ISU, Dept. of Forestry, 1999). With an estimated $21/ sq. m establishment cost and an annual maintenance cost of $2.60 / sq. m for years 1 – 20, the present value cost @ 5% real ARR totals $844,000.

### Constructed Wetland Cost

Research at Iowa State University by the Wetland Ecology group (Drs. B Crumpton and T Isenhart) suggests that effective processing of nitrate–nitrogen will occur if a shallow constructed wetland is sized at a ratio of 1 ha per 100 ha of tile drained agricultural land. This ratio is used in the study. Research also indicates that the two large tiles at the lower ends of the west and east branches of Bear Creek (near the headwaters of the watershed) contribute over 50% to the base flow in Bear Creek. It is assumed that two constructed wetlands totaling 8.9 ha in size will have a significant impact on reducing the amounts of nitrate-nitrogen that would otherwise directly enter Bear Creek and by-pass the bio-filtering capacity of the riparian buffer. The west Bear Creek sub-watershed drains about 730 ha, so the constructed wetland is 7.3 ha on this branch and the east Bear Creek wetland is 1.6 ha.

Cost estimates for constructed wetlands are highly variable because of limited application in this watershed and elsewhere. The current, best estimate to establish a one hectare wetland is about $25,000. Annual maintenance costs are estimated to be $2,500 per ha. Thus, the present value cost over a 20-year period @ 5% real ARR of these two constructed wetlands is about $494,000.

Table 3 indicated the total present value cost of a non-dynamic RiMS model applied to the upper one-half of Bear Creek. Without considering any cost share or rent assistance from the government, the RiMS price tag is $2.1 to $2.2 million.

<table>
<thead>
<tr>
<th>RiMS Component</th>
<th>Present Value Cost In $ 000s @ 5% real ARR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian buffer with opportunity cost 169 ha @ $1,300/ha</td>
<td>~$820</td>
</tr>
<tr>
<td>Streambank stabilization 30% of 17.7 km</td>
<td>~$844</td>
</tr>
<tr>
<td>Constructed wetlands 7.3 ha wetland on West Bear Creek 1.6 ha wetland on East Bear Creek</td>
<td>~$494</td>
</tr>
<tr>
<td>Total PV Cost of Riparian Management System</td>
<td>~$2,158</td>
</tr>
</tbody>
</table>
The Conservation Reserve Program (as amended in 1996 to focus on conservation buffers) is perhaps the most viable assistance program available to landowners. The landowner whose land qualifies for the CRP can receive 50% cost share of establishment (plus a small annual maintenance payment) and either rental payments with a 20% premium for a 10 or 15 year contract period. The impact on the total present value cost of a RiMS model in the upper one-half of Bear Creek is significant. As seen in Table 4, the total price tag drops to about $465,000.

Willingness to Pay for Bear Creek Surface Water Quality Improvements

Colletti et al. (1993) estimated using a contingent valuation method, that people in the Bear Creek watershed were willing to pay about $48 per person per year to improve the surface water quality of Bear Creek. In 1993, there were approximately 1,000 people living in the watershed. Thus, over a 20 year period the present value WTP totals about $610,000. Of course the critical assumption here is that the RiMS model causes the desired improvement in the surface water quality of Bear Creek.

Inclusion of Other Benefits

Schultz et al (2000) indicate that by valuing the production of hay from the perennial grasses and woody biomass at $15 and $25 per Mg, respectively, will further reduce the RiMS price tag (PV cost) in Table 4 by 17%. Current local market prices paid for switchgrass used as hog bedding and for woody biomass for energy are $60 and $35 per Mg, respectively. Other benefits that exist, but are not quantified (yet), include wildlife habitat, aesthetics, and carbon sequestration.

Conclusions

As Schultz et al, (2000) and Karr and Schlooser (1978) suggest, the best opportunity for society and farmers to obtain long-term net benefits associated with agriculture is by integrating upland (field) BMPs and BMPs associated with the near-stream and stream channel – the RiMS model. The RiMS model analyzed in this study impacts about 2% of the land in the Bear Creek watershed. The shift in land use is small relative to the potential incremental gain in nonpoint source pollution control.

A riparian management system properly sited, installed, and maintained can add significant capabilities to the terrestrial and aquatic ecosystems in terms of reducing the movement of nonpoint source pollutants into Bear Creek (Schultz et al., 2000). The cost to the private landowners and society for incremental protection of Bear Creek is substantial (between $0.5 million and $2.1 million). Accounting for benefits is more difficult. However, people in the Bear Creek watershed have indicated a desire to improve the surface water quality and a WTP for this improvement. With additional quantification of other market and non-market (value in use) benefits such as hay, biomass, wildlife and fisheries improvement, aesthetics, and carbon sequestration, there could be net benefits from a riparian management system integrated with agricultural production within a watershed.

Iowa State students are taught the processes of watersheds and the value of riparian buffers.
References


