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Long-term holistic study of two Iowa watersheds

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Long-term holistic study of two Iowa watersheds

Abstract
The Agroecology interdisciplinary research issue team assembled in March 1991 to address several goals: (1) To assess the impacts of agricultural practices on the structure and function of regional agroecosystems; (2) To design and test small-scale agricultural landscape management systems that can lessen negative environmental impacts of agriculture and enhance natural ecosystem functioning; and (3) To develop a holistic approach for reconstruction and/or restoration and management of regional agroecosystems that are environmentally sound, socially acceptable, and economically feasible.

Keywords
Water quality quantity and management, Watershed and ecoregion

Disciplines
Agriculture | Natural Resources Management and Policy | Water Resource Management

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Background

The Agroecology interdisciplinary research issue team assembled in March 1991 to address several goals:

1. To assess the impacts of agricultural practices on the structure and function of regional agroecosystems;
2. To design and test small-scale agricultural landscape management systems that can lessen negative environmental impacts of agriculture and enhance natural ecosystem functioning, and
3. To develop a holistic approach for reconstruction and/or restoration and management of regional agroecosystems that are environmentally sound, socially acceptable, and economically feasible.

The team approaches these challenges from a landscape perspective in which the watershed is viewed as the basic functional unit of an agroecosystem. Its current focus is a five-year project that focuses on riparian (streamside) management in agricultural lands, with emphasis on ameliorating nonpoint source (NPS) water pollution and generally enhancing the environment. As transitional zones between terrestrial and aquatic ecosystems, riparian areas play important roles in keeping ecosystems functioning naturally—on Iowa farmland and elsewhere.

The team has conducted work on two watersheds: (1) Storm Lake, in Buena Vista County, and (2) Bear Creek, in Story County (see Fig. 1). Objectives during the first three years of the team’s work involved assessing the environmental and socio-economic characteristics of both watersheds and identifying areas in their riparian zones that are vulnerable to agricultural NPS pollution and suitable for Best (riparian) Management Practices (BMPs). For comparative purposes, data are being collected and analyzed similarly in both watersheds. Vulnerability maps based on these data provide the basis for decisions about landscape
management options, including specific BMPs, for both riparian and upland areas.

The next step will involve cooperative efforts among local farmers and natural resource management agencies to employ management practices on an experimental basis. These will be evaluated for technical effectiveness, economic efficacy, and social acceptance.

**Approach and findings**

**Landscape assessment and modeling:** Geographical Information Systems (GIS) technology is being used to analyze both watersheds' landscape features and uses and develop models for land management approaches that will reduce NPS pollution. The original data base created in this effort has been refined to employ five-acre cells as opposed to 20-acre cells, which improves model precision. One model is currently assessing movement of sediment within the Storm Lake watershed; at Bear Creek, the primary data base was completed more recently, and some comparisons of landscape features—slope, percentage of erodible land, wetlands, and agricultural use—between the two watersheds are now possible.

**Geophysical surveys:** To monitor surface water quality, team members are continuing development of a data base in both watersheds, each involving about 16 sampling stations. Three years of data revealed consistent patterns: high levels of nitrate-nitrogen, the herbicide atrazine, and suspended sediments occur during spring and summer in both creeks, at levels frequently exceeding the U.S. EPA Maximum Contaminant Levels (MCL). Estimates of creek loading rates in 1993 suggest that heavy precipitation and high streamflows flush these materials from the ecosystem. As an example, atrazine concentrations during the summer of 1993 exceeded EPA MCLs, while they did not in the summer of 1992. Bear Creek suspended sediment loading rates, during four baseflow events in the spring of 1993, yielded estimated 24-hour sediment loads at the creek mouth of 1.8 to 8 tons. No samples were taken during flood events, when sediment loads are significantly higher. Loading estimates along the length of the stream can help to characterize subbasins by the NPS pollutant loadings and thus identify their need for pollution management practices.

Concentrations of nitrate and herbicides tend to be highest in the headwaters where more area is under cultivation and the land is cropped closer to the streams. Downstream concentrations are lower because of dilution from increased streamflow, denitrification, and metabolism of herbicides by microbial activity. Little Storm Lake marsh reduces nitrate concentrations because of the marsh's high biological activity, which also provides substantial organic matter to the lake, contributing to its chronic turbidity problem.

Effluents from tile drainage systems also revealed nitrate-nitrogen, atrazine, and dissolved solids at levels often exceeding the U.S. EPA MCL. Atrazine concentrations seldom exceeded EPA MCLs, but at least one of the two
metabolites of atrazine, which may be more problematic than atrazine itself, was present in the water. These elevated levels are also tied to precipitation events. While nitrate-nitrogen levels are reduced slightly during a soybean year, decomposing soybean residue may contribute to high concentrations the following spring. Elevated atrazine concentrations are also seen during a soybean year, suggesting continued leaching of that herbicide. If tile water chemical concentrations could be reduced, the cold and nearly sediment-free water would benefit the ecology of streams prone to excessive heating in summer and heavy sediment loads following storm events.

At Bear Creek, **groundwater quality** was estimated on the basis of several years' data from experimental wells of various depths. In the Storm Lake watershed, water quality information came from a 1993 survey of 55 farm wells located near the lake. At both sites, the presence of various chemicals in water in shallow aquifers shows a clear link to surface events. Water in the deeper bedrock aquifer shows none of the surface influences of the shallower groundwater.

Wells in the Storm Lake watershed were analyzed for nitrate-nitrogen and chloride twice in 1993. Total coliform bacteria (TCB) were counted once. Shallower wells (less than 50 feet deep) were highly vulnerable to contamination from agricultural land use; approximately 30% contained more than the safe MCL for nitrate-nitrogen. Even in half of the wells 50-100 feet deep, nitrate-nitrogen levels exceeded the MCL. High TCB counts were found in 72% of all wells and in 97% of wells less than 100 feet deep. These levels pose potential human health concerns. At Bear Creek, the highest nitrate-nitrogen concentrations were found in shallow gravel groundwater. None was detected in water samples from the deepest well (300 ft deep) in the limestone bedrock groundwater system.

Storm Lake wells were not tested for atrazine, but atrazine was found in Bear Creek wells at levels below the MCL, and occasionally in the deep bedrock well. Again, this is a concern because atrazine's two metabolites may be more problematic than the atrazine. These metabolites were exclusively the ones found in the aquifers.

**Biotic surveys:** Surveys of aquatic organisms in Bear Creek and in Powell Creek of the Storm Lake watershed have now been conducted for three years. They have focused on fishes and bottom-dwelling invertebrates, which serve as biotic indicators of stream ecosystem health. Results have been generally consistent from year to year.

The two streams have similar fish faunas, sharing at least 13 species in common. A total of 20 species have been counted in Bear Creek and 22 in Powell Creek. Bear Creek flows into the Skunk River, while Powell Creek empties into Storm Lake through Little Storm Lake marsh. Thus, some species found uncommonly in both streams are strays from the receiving water bodies. Because of high water and difficult collecting conditions, fewer species were collected in both streams in 1993 than in the previous two years.

Fish community composition was evaluated by applying the Index of Biotic Integrity (IBI), which involves scoring of 12 metric measures to produce index values describing various aspects of community structure and function. Scores are summed to produce values ranging from 12 (for a very poor community) to 60 (for an excellent community). In 10 collecting periods over three years, median IBI values for fish collections have ranged from 32 to 38 for Bear Creek and from 26 to 34 for Powell Creek. In all cases, Bear Creek IBI values were greater than or equal to those of Powell Creek for the same seasonal period. These results indicate that Bear Creek, a larger stream, supports a somewhat more balanced fish community than does Powell Creek. While both streams are dominated by fishes that tolerate agriculturally disturbed habitats, both also support some more environmentally sensitive species that serve as ecological indicators.

Benthic macroinvertebrates (consisting of insects and to a lesser extent snails, clams, leeches, crustaceans and other species) have been collected systematically from Powell Creek for
three years. Analysis of the first two years reveals that over 70% of these organisms are plant-eating; the remainder are predators. A herbivore to carnivore ratio of about 3:1 is typical of invertebrate communities of small Midwestern agricultural streams. Unlike the fish communities, which exhibit only minor seasonal changes in composition, the invertebrate taxa typically show dramatic seasonal changes, particularly among the insects. This is because the aquatic insect fauna consist chiefly of larval organisms that seasonally metamorphose into terrestrial adults. General abundance of invertebrates was also found to differ among five sites on Powell Creek. Greatest densities occurred at intermediate stream reaches characterized by permanence of flow and relatively sediment-free substrates.

Field surveys of terrestrial riparian vegetation in the Storm Lake watershed were conducted in summer and fall 1993. In most cases, stream border areas consisted of a few plant species, and large stretches were uniform in species composition. Six vegetation types were recognized along creek lengths: (1) Crops, mainly corn and soybeans—32%, (2) brome grass—33%, (3) reed canary grass—20%, (4) a mix of wetland species—1%, (5) weeds—10%, thought to result from plowing and planting from previous years, and (6) planted alfalfa cover, clover, and mixed grasses—4%.

Socioeconomic surveys: Farmers and other residents of the Bear Creek watershed were surveyed in 1991 and 1992 on their perceptions of local surface water quality and their willingness to contribute to environmental management programs for improving it. Surveys conducted in the Storm Lake watershed also included recreationists using the lake.

The Storm Lake survey of local residents asked 300 households to provide information on (1) their use of Storm Lake, (2) the value they would place in improving lake water quality, and (3) socio-demographic characteristics. Response rate was 75%. The farm survey targeted all farm owners and operators in the watershed. It also included questions on current farming practices, the individual’s knowledge about and attitudes toward water pollution sources in the watershed, and willingness to adopt riparian buffer strips to reduce NPS pollutants in the lake. Response rate was 70% of 74 operators and 60% of 74 owners.

In the Storm Lake area, boating and fishing are major recreational and economic activities. To determine social values associated with recreational activity, team members conducted 18 visits during summer 1993 to interview recreationists and request participation in the third survey, which was sent to a randomly selected group in November. Response rate was 84%.

Results indicate that the lake’s water quality is valued highly, but that this value depends on the extent of the improvements and the target group being surveyed. Local residents, for example, are willing to pay roughly $30 per year to maintain current water quality. Additional improvements do not appear to be highly valued, nor are residents interested in programs that will merely postpone the rate of water quality deterioration. Recreationists and farmers appear to place less value on maintaining the lake’s present condition; the former are willing to pay $9 per year, while the latter are willing to pay as much as $20 per year. Over 60% of farm respondents were willing to set aside acreage for riparian buffer strips with support of $120 per acre.

These surveys were augmented with a separate polling of about 60 farmers conducted in spring 1993 by the Buena Vista County office of the U.S. Soil Conservation Service. On the basis of the surveys, farming practices appear to be similar in the two watersheds—for example, the great majority of farms were described as corn-soybean operations, and the percentage of land planted in these crops is similar for the two watersheds. Very few farmers reported row-cropping on highly erodible land. Fewer than 10% of the farmers practice no-till, while row and field cultivating is used extensively (about 55% for Bear Creek and 70% for Storm Lake). Less than 30% of the Storm Lake farmers practice fall tillage on soybean stubble, but 85% do some fall tillage.
on corn residue. Chisel plowing is the preferred fall tillage technique there, but disking is commonly used in corn stalks. About 5% of the farmers did not plan to do spring tillage in 1993. Field cultivation is the primary spring tillage technique in soybean stubble; that and disking are used about equally in old corn. Very little moldboard plow use was reported.

Over 90% of the Storm Lake farmers reported applying dry fertilizer to their fields, primarily in spring. Liquid nitrogen is applied by over half of the farmers, again, chiefly in spring. Only one farmer reported using organic fertilizer (manure) alone. About two-thirds planned to apply herbicides during preplanting operations through incorporation; the remainder planned to post-apply the herbicides, or, to a lesser extent, make pre-emergent surface application.

Farmers of both watersheds generally believe that riparian buffer strips can be an effective means of protecting local water resources. About 90% of the Storm Lake farmers felt that buffer strips could be effective in reducing inputs of eroded soil and pesticides to waterways. Nearly that proportion also believed that vegetative buffer strips can be a cost-effective tool in reducing NPS pollution.

**Experimental buffer strip technology:** Toward meeting the team’s second objective—to design and test small-scale agricultural landscape management systems that can lessen negative environmental impacts by agriculture and enhance natural ecosystem functioning—researchers installed a multi-species riparian buffer strip (MRBS) system in 1990 on the Ron Risdal farm 1.5 miles north of Roland (see Fig. 2 and photos). The MRBS was established with the help of a grant from the Leopold Center and Iowa Department of Natural Resources 319 funds.

The Bear Creek site constitutes one of the few existing models of such restoration in the United States. A combination of fast-growing trees, shrubs, and switchgrass are arranged to take advantage of the strengths of each plant species. This buffer strip functions as a perennial ecosystem that can improve soil quality, buffer the creek from agricultural chemicals, protect the riparian zone from erosion and develop its ability as a nutrient and sediment sink, increase the diversity of the agricultural land-

![PERMANENTLY VEGETATED (TREE SHRUB GRASS) RIPARIAN BUFFER STRIP](image)

**PERMANENTLY VEGETATED (TREE SHRUB GRASS) RIPARIAN BUFFER STRIP**

HERBICIDE AND FERTILIZER ADDITION  
EROSION PRODUCED SEDIMENT

FERTILIZER AND HERBICIDE ADSORBED TO SOIL ORGANIC MATTER AND/OR TAKEN UP BY PLANTS  
SEDIMENT AND ASSOCIATED CHEMICALS TRAPPED BY BUFFER STRIP

Fig. 2. Permanently vegetated riparian buffer strips improve water quality by filtering sediments, herbicides, and fertilizers moving through them.
The photo above shows a segment of Bear Creek in 1990, prior to buffer strip installation.

This photo shows the same segment of Bear Creek in 1994.

scape, and provide the landowner with an alternative crop.

The buffer strip consists of five rows of trees, two rows of shrubs, and a 24-foot width of switchgrass. The system is testing fast-growing tree species for their potential in a short-rotation (8-10 year) woody culture that would provide biomass for a number of non-timber products. These species, which resprout from the stump after they have been cut, can tolerate a minimum of 3-4 harvests before productivity decreases. Such a system is well suited to a riparian zone because these species are native and the harvesting methods are minimally disruptive. The two rows of shrubs can be planted to a wide range of species depending on landowner objectives—for example, wildlife habitat or food, or the production of crops such as hazelnuts. The switchgrass strip interfacing with the crop field is a native prairie grass with strong stems that resist bending by surface runoff waters.

Trees in the buffer strip have grown 18, 15, 10, and 6 feet in height for willow, poplar hybrids, silver maple, and green ash, respectively, over four growing seasons. The infiltration capacity of the soil in the buffer strip is three times better than that of the adjacent crop field because the large amount of plant root biomass in the buffer strip reduces soil density and increases porosity. Not only is surface runoff from the adjacent crop field slowed when it enters the buffer strip; it also infiltrates into the soil, where chemicals in solution are exposed to the "cleansing" capabilities of the "living filter" of the plant-soil system. As a result, nitrate-nitrogen and atrazine concentrations in the soil under the buffer strip remain much lower than those in the adjacent upslope field.

The buffer strip system also includes willow posts installed in the creek bottom and in the backslope of the creek channel to help stabilize the streambank. Sections of streambank are planted to willow posts anchored with bundles of silver maple tops; these bundles deflect water and trap sediment while the willows become established. Because as much as 50% of the sediment in a stream may come from streambank erosion, this technique should be an integral part of a riparian zone management system along severely eroding banks.

The buffer strip system also includes a small constructed wetland that interrupts and filters the NPS pollutants from tile water before it enters the stream. Small wetlands with a 1:100 size ratio (1 acre: 100 acres of drained crop field) can reduce incoming nitrate-nitrogen by 80-90%, to levels well below EPA MCLs. These wetlands are important because tile drainage system water, which carries some of the highest concentrations of agricultural chemicals, bypasses the terrestrial plant community of the buffer strip.

In summary, MRBS can be established along any stream and around lakes and ponds. Although numerous design variations can be made to accommodate landowner objectives, present land use, and topography, the basic model has trees planted next to the channel, then shrubs, and then grass, using several species of each plant type. While riparian trees
are best, upland hardwoods can be used. A minimum width of 66 feet is recommended. In addition to the terrestrial MRBS, the system should include streambank stabilization with willow posts and small constructed tile wetlands where applicable.

**Future directions**

To encourage adoption of these systems, demonstration projects are planned in both watersheds with support from IDNR 319 funds. The streambank bioengineering and constructed tile wetlands work is being continued with support from a USDA/EPA Agriculture in Concert with the Environment grant.

*Technology transfer:* To develop sustainable ecosystem management approaches for the riparian zones of these two watersheds, the team is educating watershed residents about the ecosystem's condition and providing them with acceptable management approaches that will mesh with their long-term goals for the areas. Bulletins that summarize both the environmental and socio-economic assessments are also planned, and a self-guided tour of the Bear Creek site is under development. In addition, a minimum of 500 landowners, professionals, and researchers per year have toured the MRBS in each of the past two years.

*Vulnerability maps:* Vulnerability maps developed in this work show topography, soil parameters, and land use as well as sediment, nitrate, and atrazine contributions of currently monitored areas. While such information is invaluable in identifying which upland portions of a watershed contribute "excessive" NPS pollutants to the riparian area, these maps must be used with sensitivity to the landowners whose property they depict. Sociologists will assist the team in identifying the best approaches for presenting such information to landowners and the public.

*Watershed water quality monitoring:* Two more years of monitoring will be conducted to capture the cyclical variations in surface runoff from fields in which crops are rotated each year, and to allow adjustment for the first three very wet years (1993 in particular).

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