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RIPARIAN MANAGEMENT FOR WATER QUALITY, THE BEAR CREEK EXAMPLE: GETTING THE MESSAGE OUT

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While a considerable body of evidence confirms that exiting vegetated streamside zones can be effective sinks for nonpoint source pollution (Castelle et al. 1994, Osborne and Kovacic 1993, Lowrance 1992, Cooper et al. 1987, Jacobs and Gilliam 1985, Lowrance et al. 1985, 1984, Peterjohn and Correll 1984), little information is available for restored or constructed streamside buffer systems. To demonstrate the benefits of properly functioning riparian zones in the heavily row-cropped midwestern U.S., the Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State Agroforestry Research Team (IStART) are conducting research on the design and establishment of integrated riparian management systems. The purpose of these systems is to restore the essential ecological functions that these riparian areas once provided. Specific objectives of such buffers are to intercept eroding soil and agricultural chemicals from adjacent crop fields, slow flood waters, stabilize streambanks, provide wildlife habitat, and improve the biological integrity of aquatic ecosystems.

The system consists of three components: 1) a constructed, multi-species riparian buffer strip, 2) soil bioengineering technologies for streambank stabilization, and 3) constructed wetlands to intercept and process nonpoint source pollutants in agricultural drainage tile water (Figure 1). The research was initiated in 1990 along a 1 km length of Bear Creek in a highly developed agricultural region of central Iowa. The buffer strip system has subsequently been planted along an additional 2.4 km of Bear Creek upstream from this original site.

Multi-Species Riparian Buffer Strip

The general multi-species riparian buffer strip layout consists of three zones (Figure 2). Starting at the creek or stream bank edge, the first zone includes a 10 m wide strip of 4-5 rows of trees, the second zone is a 4 m wide strip of 1-2 rows of shrubs, and the third zone is a 7 m wide strip of native warm-season grass. This design is important because the trees and shrubs provide perennial root systems and long-term nutrient storage close to the stream while the grass provides the high density of stems needed to dissipate the energy of surface runoff from the adjacent cropland.

Fast growing trees are recommended to provide a functioning multi-species riparian buffer strip in the shortest possible time. It is especially important that rows 1-3 (row 1 is closest to the streambank edge) in the tree zone include fast-growing, riparian species such as willow *(Salix sp.)*, cottonwood *(Populus deltoides),* silver maple *(Acer sacharinum)*, hybrid poplars *(Populus sp.*), green ash *(Fraxinus pennsylvanica)*, and box elder *(Acer negundo).* Appropriate moderate-growth species include black ash *(Fraxinus nigra)*, river birch *(Betula nigra)*, hackberry *(Celtis occidentalis)*, shellbark hickory *(Carya laciniosa)*, swamp white oak *(Quercus bicolor)*, Ohio buckeye *(Aesculus glabra)*, and sycamore *(Platanus occidentalis).* The key to tree species selection is to observe native species growing along existing natural riparian zones and select the faster growing species. If height from the top of the streambank to the water level at normal flow (summer non-flood stage) is more than 1 m and soils are well drained, species such as black walnut *(Juglans nigra)*, red oak *(Quercus rubra)*, white oak *(Quercus alba)*, white ash *(Fraxinus americana)* or even selected conifers can be planted in rows 4 and 5. The slower growing species will not begin to function as significant nutrient sinks as quickly as faster growing species. Other selections could be made based on species growing in neighboring uplands.

Shrubs are included in the design because of their permanent roots and because they add biodiversity and wildlife habitat. Their multiple stems also function to slow flood flows. The mixture of species that have been used by IStART include ninebark *(Physocarpus opulifolius)*, red-osier *(Cornus stonifera)* and gray dogwood *(Cornus racemosa)*, chokecherry *(Prunus virginiana)*, Nanking cherry *(Prunus tomentosa)*, hazel *(Corylus americana)*, and nannyberry *(Viburnm lentago)*. Other shrubs can be used, especially if they are native species and provide the desired wildlife/aesthetic objectives. These other species could include speckled alder *(Alnus rugosa)*, serviceberry *(Amelanchier arborea)*, silky dogwood *(Cornus obliqua)*, hawthorns *(Crataegus sp.)*, wild plum *(Prunus americana)*, pin cherry *(Prunus pennsylvanica)*, peachleaf willow *(Salix amygladoides)*, and sandbar willow *(Salix interior)*.

The grass zone functions to intercept and dissipate the energy of surface runoff, trap sediment and agricultural chemicals in the surface runoff, and provide a source of soil organic matter for microbes which can metabolize the nonpoint source pollutants. A minimum width of 7 m of switchgrass *(Panicum virgatum)* is recommended because it produces a uniform cover and has dense, stiff stems which provide a highly frictional surface to intercept surface runoff and facilitate infiltration. Other warm season grasses, such as Indian grass *(Sorghastrum nutans)* and big bluestem *(Andropogon gerardii)* and native perennial forbs also may be part of the mix. Because of its structure, switchgrass should be used where surface runoff is most severe.

Weed control is of paramount importance during the first 2-3 years of establishment. The planting should be inspected frequently and appropriate herbicides or mowing used if needed. The tree and shrub rows should be mowed once or twice during the season to help identify the planting rows and to discourage rodent problems. The plantings should be inspected after every major storm event and areas repaired where surface runoff or flood flows have washed out plant material.

It costs about $350-$400 per acre to install the three zone multi-species buffer strip. This includes plant purchases, site preparation, planting, and maintenance costs in the first year. About $20 per acre should be figured for annual maintenance for the first 3-4 years.

The multi-species riparian buffer strip model presented here prescribes a zone of trees, a zone of shrubs, and a zone of prairie grass. Although these species combinations provide a very effective plant community, they are not the only combinations that can be effective. Site conditions (e.g. soils, slope), major buffer strip biological and physical function(s), owner objectives, and cost-share program requirements should be considered in specifying species combinations and placement.

Although the model that IStART has developed is 20 m wide on each side of the creek, stream, or river, a multi-species riparian buffer strip may have different widths that can be adapted to fit each site and land ownership. The total width of the buffer strip depends in large part on the major functions of the buffer strip and the slope and use of the adjacent land. If the major purpose of the buffer strip is sediment removal from surface runoff, a width of 15 m may be sufficient on slopes of 0-5%. If excess nutrient removal from the soil solution also is an important function, a width of 20 - 30 m would be necessary depending on the kind and quantity of agricultural chemicals applied and the soil and cultivation system used. If row-crops are found adjacent to the buffer strip, both the sediment and chemical removal functions would be important. If increased wildlife habitat is an objective of the buffer strip, widths of 30 - 100 m would provide a more suitable wildlife corridor or transition zone between the upland agricultural land and the aquatic ecosystem (Castelle et al. 1994).

Streambank Bioengineering

Several authors have estimated that greater that 50% of the stream sediment load in small watersheds in the Midwest is the result of channel erosion (Roseboom and White 1990). This soil usually consists of small silt and clay particles which are ultimately deposited in rivers, lakes or backwater areas, choking these areas with sediment and diminishing their value as habitat for fish and aquatic macroinvertebrates (Frazee and Roseboom 1993). This problem has been exacerbated by the increased erosive power of streams as result of stream channelization and loss of riparian vegetation. The typical solution is to buttress blocks of concrete, wood or steel along the stretch of the bank which is eroding (Frazee and Roseboom 1993). Such solutions are costly to build and maintain and provide little aquatic habitat. An alternative streambank stabilization technique is the use of locally available natural materials such as willow posts or other live plant material, often in combination with revetments of rock, cut cedar, or other woody material. These techniques are often referred to as soft engineering or soil bioengineering.

Several different soil bioengineering techniques have been employed by IStART. On vertical or actively cutting streambanks, combinations of willow 'posts' and/or anchored dead tree revetments are used to slow bank collapse. These plant materials provide a frictional surface for absorbing stream energy and trapping sediment. The goal of these plantings is to change the streambank angle from vertical to about 50° to allow other vegetation to become established. Willow *(Salix sp.)* cuttings are collected during the dormant season, cut into 0.3 - 2 m sections,

and stored in a cool place until planting. Small cuttings with diameters between 0.6 cm - 5 cm can be manually installed. Large diameter cuttings should be hydraulically installed using an auger mounted on a backhoe.
One or two rows of the largest cuttings are placed into the stream bed at the base of the streambank at a spacing of 0.6 x 0.6 m between posts. An additional 2 - 4 rows of small diameter cuttings should be planted into the bank above the low water line. Small wing dams of willow posts can be extended into the stream by placing double rows of 3 - 4 posts at right angles or pointed slightly downstream.

Where there is a concern for active undercutting of the bank, the toe of the bank can be stabilized using bundles of Eastern red cedar *(Juniperus virginiana)* or small hardwoods (5-6 year old) silver maples, willows, etc. can be tied together into 2 - 4 tree bundles. A row of these bundles is laid horizontally along the bottom most row of willow posts with the bottoms pointed upstream and the bundles anchored into the bank. Where potential undercutting may be severe, rock can be used along the toe. Where high, flashy flood flows are expected, grass can be seeded and natural fiber mats can be stapled to the banks with willow cuttings planted through them. These bioengineering solutions are very effective and less expensive than traditional streambank stabilization techniques.

Constructed Wetlands

A characteristic of many parts of the upper midwest is the presence of an extensive network of subsurface tile drainage. Such tile drains provide a direct path to surface water for nitrate or other agricultural chemicals which move with the shallow groundwater. In such instances, constructed wetlands which are integrated into new or existing drainage systems may have considerable potential to remove nitrate from shallow subsurface drainage (Crumpton and Baker 1993, Crumpton et al. 1993).

To demonstrate this technology, a small (500 m^2) wetland was constructed to process field drainage tile water from a 4.9 ha cropped field. The wetland was constructed by excavating a depressional area near the creek and constructing a low berm. The subsurface drainage tile was rerouted to enter the wetland at a point furthest from the stream, maximizing residence time of drainage tile water within the wetland. A simple gated water level control structure at the wetland outlet provides control of the water level maintained within the wetland. Cattail rhizomes *(Typha glauca)* collected from a local marsh or road ditch were planted within the wetland and native grasses and forbs planted on the constructed berm. Initial water quality results are very encouraging. In the case of nitrate-nitrogen, inflow concentrations have generally ranged between 8 and 15 mg L^{-1}. In contrast, outflow concentrations were substantially lower during most times. In general, the nitrate removal efficiency of freshwater wetlands can be maximized by providing ample residence time for contaminant laden water to come into contact with microbially active surfaces. In addition, as vegetation and litter accumulate over time, nitrate removal efficiencies can be expected to increase.

System Effectiveness

The above recommendations will provide a integrated riparian management system that effectively intercepts and treats nonpoint source pollution from the uplands. However, it should be stressed that a riparian management system cannot replace upland conservation practices. In a properly functioning agricultural landscape, both upland conservation practices and an integrated riparian system contribute to achieving environmental goals and improved ecosystem functioning.

Long-term monitoring has demonstrated the significant capability of these systems to intercept eroding soil from adjacent crop land, intercept and process agricultural chemicals moving in shallow subsurface water, stabilize stream channel movement, and improve instream environments, while also providing wildlife habitat, biomass for energy, and high quality timber (Schultz et al. 1995). The buffer strip traps much the sediment carried in surface runoff and has reduced nitrate and atrazine concentrations moving through the soil solution by over 90 percent, with resulting concentrations well below the maximum contaminant levels specified by the U.S. EPA. The constructed wetland has also proven to be very effective in processing nitrate and other nonpoint source pollutants moving in the agricultural tile drainage water. Wildlife benefits have also appeared in a very short time with a nearly five fold increase in bird species diversity observed within the buffer strip versus an adjacent, unprotected stream reach.

Literature Cited

Castelle, A.J., A.W. Johnson, and C. Conolly. 1994. Wetland and stream buffer size requirements - a review. J. Environ. Qual. 23:878-882.

Cooper, J.R., J. W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian areas as filters for agricultural sediment. Soil Sci. Soc. Am. J. 51:416-420.

Crumpton, W.G. and J.L. Baker. 1993. Integrating wetlands into agricultural drainage systems: predictions of nitrate loading and loss in wetlands receiving agricultural subsurface drainage. Pages 118-126 in J.K. Mitchell, editor. *Integrated Resource Management and Landscape Modification for Environmental Protection.* American Society of Agricultural Engineers. St. Joseph, MI.

Crumpton, W.G., T.M. Isenhart, and S.W. Fisher. 1993. Transformation and fate of nitrate in wetlands receiving nonpoint source agricultural inputs. In G.A. Moshiri, editor. Constructed Wetlands for Water Quality Improvement. Lewis Publishers. Chelsea, MI.

Frazee, R.W. and D.P. Roseboom. 1993. Pages 208-213 in J.K. Mitchell, editor. *Integrated Resource Management and Landscape Modification for Environmental Protection.* American Society of Agricultural Engineers. St. Joseph, MI.

Jacobs, T.C. and J.W. Gilliam. 1985. Riparian losses of nitrate from agricultural drainage waters. J. Environ. Qual. 22:467-473.

Lowrance, R.R. 1992. Groundwater nitrate and denitrification in a coastal plain riparian forest. J. Environ. Qual. 21:401-405.

Lowrance, R.R., R. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint source pollution. J. Soil Water Conserv. 40:87-91.

Lowrance, R.R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. BioSci. 34:374-377.

Osborne, L.L. and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biol. 29:243-258.

Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65:1466-1475.

Roseboom, D.P. and W. White. 1990. The Court Creek Restoration Project: erosion control technology in transition. Pages 25-40 in *Proceedings of XXI Conference of the International Erosion Control Association*. Washington, DC.

Schultz, R.C., J.P. Colletti, T.M. Isenhart, W.W. Simpkins, C.W. Mize, and M.L. Thompson. 1995. Design and Placement of a multi-species riparian buffer strip system. Agroforestry Systems 29:201-226.