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Riparian Forest Revegetation For Water Quality Improvement

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Riparian forest ecosystems are most often recognized as ribbons of green vegetation following a stream as it flows through agricultural fields and down through ravines and valleys to eventually join a major river system. Riparian forest ecosystems occupy a transition zone which is distinguished from the upland areas by a difference in topography, soils and hydrologic regime. This zone stretches from the waters' edge up through the adjoining floodplain (Smith, 1995).

The hydrologic regime of riparian ecosystems contain readily available water supporting high rates of production for plants, insects, animals and microbes (Hawkins 1991). The plant community exhibits structural and taxonomic diversity which provides protection for the water quality and structural integrity of the stream by moderating seasonal and storm flooding intensities, providing water storage with delayed release, ameliorating stream temperature fluctuations, providing a source of organic matter and serving as a sink for sediments and nutrients moving off of the upland environment (Stuart et al. 1993). The structural complexity of the vegetation provides wildlife with a migration corridor and a variety of habitats and food sources (Hawkins 1991).

The lush growth and low lying, level landscape found within riparian forest ecosystems make them an attractive resource for human uses such as timber and agricultural production, and residential settlement (Hawkins 1991). The impacts of human landuses have caused degradation and elimination of up to ninety-nine percent of riparian forest ecosystems which in turn has caused unintended and undesirable consequences for water quality such as nonpoint source pollution, alterations of hydrologic regimes, and destruction of wildlife habitats and populations. (Schultz et al. 1993).

Recognition of the important role that riparian forests perform in the protection of water quality has created a continually increasing interest in the development of strategies for the protection and restoration of riparian forest ecosystems. Research about the forms and functions of the riparian forest are continuing to be conducted. Strategies for water quality improvement have been developed by all levels of agencies ranging from local municipalities to state and federal environmental services. Three human uses of this landscape, agricultural production, timber harvesting and urban development, have had significant impacts on water quality. The following is a discussion of designs and management strategies being investigated for the restoration of riparian ecosystems being degraded or destroyed by each of these landuses. Strategies that are created may be used to protect and preserve remaining riparian forest landscapes in the future as they eventually receive pressures for human use.

Buffers Systems in Agricultural Landscapes

Agricultural practices have replaced a majority of natural riparian landscapes and in so doing have produced the degradation of the aquatic ecosystems that serve to drain the surrounding land. The consequences of efficient, high production agriculture, include non-point source (NPS) pollution, hydraulic alteration of waterways with altered flow rates, and disruption of wildlife habitats through changes in chemical concentrations and increased sedimentation (Schultz et al. 1995).

Non point source, NPS, pollution contributes to 2.7 Mg of soil entering the countries waterways each year (Schultz et al., 1995). In 1993, the U S Department of Agriculture, National Resource Conservation Service (NRCS), developed riparian forest buffer guidelines for the control of NPS pollutants from agricultural lands. The guidelines consist of three zones of management. Zone 1 is a tree and shrub layer adjacent to the stream and has a minimal width of 4.5 m. Vegetation management practices are not prescribed within Zone 1. Zone 2 extends 18.3 m from the first and is a continuation of trees and shrubs which are managed to stimulate maximum nutrient uptake. Finally, Zone 3 is a strip of grasses and forbes. This zone has a minimum depth of 6.1 m and may be grazed or harvested to maintain its intended function of slowing surface runoff and converting it to sheet flow.

A study conducted by Osborne and Kovacic (1993) compared the filtering abilities of the two types of vegetation recommended in the NRCS guidelines. The simple comparison was intended to quantify the individual effectiveness of grass and forested buffers in intercepting the nutrients and sediments specifically moving off agricultural land. The study took place in a landscape dominated by row-crop agriculture, along the East Branch of the Embarrass River in Champaign County, Illinois. A stream reach of one kilometer in length was selected for the study and divided into three equal treatment plots. The first vegetated buffer strip (VBS) treatment was a cover of reed canary grass (Phalaris arundinacea) 39 meters deep. The second VBS was an existing, mature riparian forest, dominated by cottonwood (Populus deltoides) and silver maple (Acer saccharunum) 16 meters deep. (This riparian forest was 6.8 meters shorter than the depth recommended by the NRCS buffer strip guidelines.) The final plot acted as a control treatment for the study and was planted as a row-crop that extended from the adjacent upland field down to the stream bank.

Measurements were taken for concentrations of nitrate-N, and dissolved and total phosphorus. Samples were collected for both surface runoff and groundwater concentrations at a depths of 60 cm and 120 cm because earlier studies had reported that up to 29% of total nitrate-N and 38% of total phosphorus moved in groundwater. Sampling results showed that both the forest and grass buffer strips were effective in significantly reducing the concentrations of nutrients in both shallow water movement and in groundwater when compared with the control strip's sampling results. It was also noted that the forest buffer strip was more efficient in overall removal of nitrate-N and the grass buffer strip removed more phosphorus. Samples taken during the winter and early spring revealed that increased concentrations of both N and P were moving out both the forest and grass VBS.

Osborne and Kovacic 1993) concluded that each type of vegetation was effective in intercepting nutrients and sediments moving off of agricultural fields. They hypothesized that the removal of nitrate-N was higher in the forest buffer strip because there was more carbon available in the organic litter layer for denitrification. The grass buffer strip may have been more effective in removal of phosphorus due to its ability to slow water movement and trap sediments. The increased concentrations of nutrients entering the stream during cold weather suggested that the vegetated buffer strips were effective only during the active growing season.

The results from this investigation provided directions for additional research. A team of researchers from Iowa State University designed a study to investigate the effects that multiple species and alternative configurations of riparian vegetated buffer strips would have in improving water quality. The study included sampling that would span the life cycle of the vegetation in each buffer strip in an effort to reveal seasonal and long term effectiveness of each design combination. The study is located in the Bear Creek Watershed in north central Iowa in an area where agricultural practices have generally eliminated all riparian ecosystems.

The goal of the project was to attempt to design riparian buffer strips that had the ability to function similarly or possibly more efficiently than natural riparian communities. The designs used a combination of trees, shrubs and prairie grasses selected to perform effectively as nutrient, pesticide and sediment sinks for NPS pollutants. Multiple plant species were selected with regard to disease survivorship, appropriateness for the ecosystem and maximum above-and below ground structure to provide maximum year-round interception of surface and vadose zone soil solutions (Schultz et al. 1995). The designs also incorporated the use of specially selected fast-growing tree species grown as short-rotation woody crops systems (SRWC). SWRC systems produce biomass for energy use in 5-8 years and timber for harvest in 15-20 years. The short-rotations intervals were intended to help maintain active nutrient and pesticide sequestering by the woody community. The frequent harvests within the buffer strips provided potential economic returns to defray management costs for the landowner. SWRC systems do not have to be replanted for three to four harvests because the tree species are selected to reproduce vegetatively from stumps or root sprouts. The rapid regrowth ensures continuity in water and nutrient uptake and physical stability of the soil through out the life of the riparian buffer strip (Schultz et al. 1993). Cottonwoods hybrids (*Populus spp.,* e.g., *Populus* clone NC-5326), silver maple *(Acer saccharinum* L.), willow (*Salix spp*.) and green *ash (Fraxinus pennsylvanica* Marsh.) are tree species that exhibit the desired traits of rapid growth and coppice regeneration.

Shrubs were intended to add an additional rooting pattern which holds soil, intercepts nutrients and provides organic matter for soil microbes (Schultz et al., 1995). Shrub species selected were also selected for the ability to regenerate vegetatively. Shrubs selected were red-osier dogwoods (*Cornus stolonifera*), ninebark (*Physocarpus opulifolius* L.), common chokecherry (*Prunus virginiana*), Nanny viburnum (*Viburnum lentago*) and Nanking cherry (*Prunus tomentosa*).

Prairie grass provides a contact with a high frictional surface which slows runoff and spreads it into a uniform sheet flow essential for sediment removal. Native prairie grass was chosen for the project because it has a larger root biomass than cool season grasses previously used in riparian buffer strips studies. Switchgrass (*Panicum virgatum*) was selected for its ability to withstand the forces of flowing water (Schultz et al., 1993).

Five 20 meter wide and 90 meter deep buffer strips were designed. Two control treatments were designated with row-crops planted up to the stream bank. Three buffer strip treatments were designed with a combination of five rows of trees, two rows of shrubs and a strip of grass. The trees were planted with the first row at or near the stream bank (1.2m between trees and 1.8m between rows). The five rows were planted with a variety of species combinations to ensure diversity and to reduce the risk of loosing the entire stand to pests, disease or drought. Two rows of shrubs were planted upslope of the trees (0.9m between plants and 1.8m between rows) and finally, upslope from the shrubs a 7.3 m strip of prairie grass was planted.

Measurements were taken for concentrations of nitrate, ammonia, chloride and atrazine. Samples were taken within the stream, the vadose zone, groundwater, and deep groundwater to reveal the possible pathways of flow and chemical transport to the stream. Initial measurements taken within the first growing season, suggested that the plant materials chosen for each plot were not yet effective in nutrient removal. The early sampling differences between the amounts of nutrients and chemicals being transported was instead related to the substrate material in which the sample was being taken. Samples taken in alluvial gravels exceeded EPA limits during the flush of the first early spring melt and following summer storm events. The samples taken in shallow soils exceeded EPA limits briefly during the first spring fertilizer application. No measurable amounts of nutrients or chemicals were ever detected in the limestone bedrock. Once established, all of the plots planted with the combination of trees, shrubs and grass, had nutrient concentrations that stayed below 2 mg/l while the control treatments of row-crops reached peak readings which exceeded 12 mg/l (EPA Maximum Contaminant Level for nitrates is 3 mg/l).

The tree species with the most above ground biomass two years after planting were the cottonwood hybrid, followed by the silver maple and then the ash. All shrub species did well except for red-osier dogwood which had experienced varied die out possibly indicating a susceptibility to herbicides moving through the treatment buffer strips. Below ground biomass was also measured and the combination of the percentage of above and below ground biomass was found to be largest in the switchgrass, then willow, and finally silver maple.

The designed buffers proved to be effective structures in protecting riparian systems from extreme water, sediment and debris inundations due to flooding. The study was within the area of Iowa that experienced the devastating floods during the summer of 1993.

The duration of monitoring in this study makes it possible to determine the long term effects of specific species and planting designs in providing better results in riparian forest re-vegetation for water quality improvements. This study also provides insight into the results of using management strategies that incorporate multi-species plantings and harvesting rotations to prevent possible nutrient and chemical saturation’s and provide some economic benefits for the landowner.

Buffer Systems in Forested Landscapes

Forestry operations have left forests denuded and scared with road networks which contribute excess runoff and sedimentation to local aquatic ecosystems. Harvesting practices that remove timber from stream edges have caused streambank collapse, increased water temperatures and contributed excessive amounts of slash and fine organic debris to the watercourse. With the inclusion of regulating nonpoint source pollution in the Clean Waters Act, the forest industry was forced to create harvesting practices that prevented their contributions to water quality degradation. Riparian forest strips became one of their focuses for management practices because the strips had the ability to function as filters and barriers to degradation caused by the surface movements of sediments (Daugharty and Douglas, 1994). Methods for restoring or protecting riparian forest ecosystems are continuing to be developed by the industry and their regulating agencies.

Four approaches to riparian forest buffer strip design are described by O'Laughlin and Belt, 1995. FEMAT and PACFISH are two federally regulated design approaches. They both consist of two-step approaches to designating widths of buffer strips. Water quality is initially controlled with the simple one-size-fits-all width prescriptions which are intended to ensure that damages are not incurred within that zone before a true picture of the watershed is available. The second step sets new site-specific buffer widths and creates management practices that respond to information provided in environmental impact statements(EIS) prepared for each individual watershed. FEMAT and PACFISH are both designed to protect andromodous fish in the Pacific Northwest. PACFISH (1991) prescribes a simple 300 foot buffer strip for an eighteen month period while an EIS is completed. FEMAT (1993) suggests a width one and one half times the potential height of a site tree, the minimum width being 300 feet. FEMAT considers that width to be able to provide 100% of the shade needed to moderate water temperature, provide litterfall as a food source and large woody debris (LWD) to maintain optimal stream channel features and fish habitat.

The FPA, state Forest Practices Act, is also designed to implement the Clean Water Act regulations for controlling nonpoint source pollution. Individual states determine buffer widths by a prescribing a percentage of trees and shade required to remain after harvest. The FPA buffer widths can range from 50 to 200 feet. Future forestry practices are allowed within the riparian buffer as long as the tree density is maintained.

The "bankfull channel width" buffer option was developed by the Center for the Study of the Environment to protect salmon spawning and rearing habitat in the Pacific Northwest. Buffer widths are based on stream channel characteristics and stream order. The lower the stream order the wider the buffer strip must be, up to a maximum of six bankfull channel widths. A density of large woody debris (LWD) of approximately 10 trees over 100 meters of stream bank must be maintained to ensure stream channel complexity. An additional buffer zone may be added outside the initial width if that density is not present. Forestry practices are allowed within an FPA buffer.

The forestry industries current riparian buffer strips designs which prescribe one-size-fits-all or simple variable widths are cumbersome and difficult to manage. Those prescribed widths require substantial areas of land and as the widths increase the buffers may grow together and create islands of land that are inaccessible to harvest without crossing through another buffer (Bren, 1995). The industry is continuing to research the functions and management of riparian systems and designs that use multiple criteria such as stream width and length, riparian zone slope and existing shade cover may be more practical in determining effective buffer designs (Barton, 1985).

Development of Buffer Systems for Urban Landscapes

As urban areas begin to expand, regions previously unaffected by development are now in need of strategies for protection and restoration of existing riparian forest ecosystems to maintain or improve water quality. Urban planning should consider riparian forests ecosystems with management strategies developed as an integral part of the community plan.

There is little room for experimentation within the remaining watersheds that are ecologically viable or depended upon for domestic water supplies. A design method for calculating effective riparian buffers that uses geographic information system's (GIS) technology may provide an alternative to finding experimental watersheds. GIS models can be developed to combine soil information, hydrologic features, slope, current landuse and landcover data with local land regulations and tax parcel information to produce maps that portray areas that will maintain maximum benefits within functioning riparian forests or restore the highest levels of function within degraded riparian zones (Xiang, 1995).

To create effective riparian buffers strips in developing urban areas, landuse planners and design professionals must understand the functions of riparian ecosystems within their watersheds. Planning must begin with knowledge of the factors that control nutrient and sediment flows and the hydrologic regime of the aquatic system. It must also be recognized that riparian strips can not be relied upon as complete buffers for the detrimental effects that can be caused by upland development. Limitations must be offset by designing and managing upland activities and development so that it will not overburden the moderating effects in maintaining water quality of buffer strips (Smith, 1993). Urban water quality can be protected if landuse planning begins with the designation of riparian forest ecosystems as public infrastructures and community amenities.

Literature Cited

Barton, David R., William D. Taylor and R. M. Biette. 1985. Dimensions of Riparian Buffer Strips Required to Maintain Trout Habitat in Southern Ontario. North American Journal of Fisheries Management **5**: 364-378.

Bilby, Robert E. 1988. Interactions between Aquatic and Terrestrial Systems. Streamside Management: Riparian Wildlife and Forestry Interactions edited by Kenneth J. Raedeke. College of Forest Resources, University of Washington, Seattle, Washington.

Bren L. J. 1995. Aspects of the geometry of riparian buffer strips and its significance to forestry operations. Forest Ecology and Management **75**:1-10.

Corbett, Edward S and James A. Lynch. 1985. Management of Streamside Riparian Zones on Municipal Watersheds. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses, First American Riparian Conference, Tucson Arizona. USDA Forest Technical Service General Technical Report RM-120.

Daugharty, David A. and Robert A. Douglas. 1994. The "Puddle Jumping" Model of Sediment Movement through Riparian Strips. Proceedings on the Symposium on Riparian Zone Management. R & D Report #9, Fredericton, N. B. Canada.

Green, Douglas M. and J. Boone Kauffman. 1989. Nutrient Cycling at the Land-Water Interface: the Importance of the Riparian Zone. Practical Approaches to Riparian Resource Management an Educational Workshop, Billings, Montana.

Hawkins, Charles P. 1991. What are Riparian Ecosystems and Why are We Worried About Them? Proceedings of the Symposium Riparian Resources, Logan Utah.

Hubbard, R. K. and R. R. Lowrance. 1993. Spatial and Temporal Patterns of Solute Transportation through a Riparian Forest. Riparian Ecosystems in the Humid U. S.; Functions, Values and Management Conference, Atlanta Georgia.

Knight, Allen W. and Richard L. Bottorff. 1984. The Importance of Riparian Vegetation to Stream Ecosystems. California Riparian Systems: Ecology, Conservation and Productive Management / edited by Richard E Warner and Kathleen M. Hendrix. University of California Press. Berkeley. 160 pp.

Lowrance, Richard, Robert Todd, Joseph Fail, Jr., Ole Hendrickson, Jr., Raplph Leonard, and Loris Asmussen. 1984. Riparian Forests as Nutrient Filters in Agricultural Watersheds. BioScience **34**: 374-377.

Lalanson, George P. 1993. Riparian Landscapes. Cambridge University Press, Cambridge.

Mahoney, Don L. and Don C. Erman. 1984. The Role of Streamside Buffer Strips in the Ecology of Aquatic Biota. California Riparian Systems: Ecology, Conservation and Productive Management / edited by Richard E Warner and Kathleen M. Hendrix. University of California Press. Berkeley. 168 pp.

McKee, Art. 1991. Forestry Effects on Riparian Areas. Proceedings of the Symposium Riparian Resources, Logan Utah.

O'Laughlin, Jay and George H. Belt. 1995. Functional Approaches to Riparian Buffer Strip Design. Journal of Forestry, February: 29-32.

Osborne, Lewis L. and David A. Kovacic. 1993. Riparian Vegetated Buffer Strips in Water-quality Restoration and Stream Management. Freshwater Biology **29**: 243-257.

Peterjohn, William T. and David L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology **65** (5): 1466-1475.

Rhodes, Johnathon, C. M. Skau, Daniel Greenlee and David L. Brown. 1985. Quantification's of nitrate uptake by riparian forests and wetlands in an undisturbed headwaters watershed. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses, First North American Riparian Conference, Tucson, Arizona.

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.

Schultz, R. C. , J. P. Colletti, W. W. Simpkins, C. W. Mize and M. L. Thompson. 1993. Developing a multi-species riparian buffer strip agroforestry system. Riparian Ecosystems in the Humid U. S.; Functions, Values and Management Conference, Atlanta Georgia. p203.

Smith, Daniel S. and Paul Cawood Hellmund, editors. 1993. Ecology of Greenways. University of Minnesota Press, Minneapolis, Minnesota.

Stuart, Gordon W., C. Andrew Dolloff and Edward S. Corbett 1993. Riparian area functions and values - A forest perspective. Riparian Ecosystems in the Humid U. S.; Functions, Values and Management Conference, Atlanta Georgia. 81 p.

Swanson, Fred. 1991. Natural Disturbance Effects on Riparian Areas. Proceedings of the Symposium Riparian Resources, Logan Utah.

Tims, Jane. 1994. The Roles of the Riparian Zone as it Affects Water Quality. Proceedings on the Symposium on Riparian Zone Management. R & D Report #9, Fredericton, N. B. Canada.

US Department of the Interior, Bureau of Land Management. 1993. Riparian Area Management; Process for Assessing Proper Functioning Condition. TR 1737-9 1993.

Xiang, Wei-Ning. 1995. GIS-based land acquisition analysis for establishing water quality protection buffers. Proceedings on the Symposium on Riparian Zone Management. R & D Report #9, Fredericton, N. B. Canada.