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Riparian Refugia in Agroforestry Systems

By Mary Ellen Dix, Erol Akkuzu, Ned B. Klopfenstein, Jianwei Zhang, Mee-Sook Kim, and John E. Foster

In the last 200 years, cultivation, grazing, and other activities initiated by humans have destroyed more than 80 percent of the strips of vegetation along North American and European streams and other bodies of water (Décamps and Naiman 1989; Petts et al. 1989). This disappearance of the riparian zones is continuing with little concern for ecological consequences. At the same time, riparian buffer strips are being promoted as a preferred management practice in the United States, especially in the Great Plains, to protect water resources from soil and chemical pollution (Schoeneberger 1994; Schoeneberger et al. 1995; Schultz et al. 1995a; Wight et al. 1995; Rietveld 1996). Few natural riparian zones remain, however, to serve as models (Naiman et al. 1993). New riparian systems, designed and implemented to provide ecosystem stability despite limited biodiversity, offer food and habitat for both beneficial and pest organisms.

The riparian zone is defined as a three-dimensional area adjacent to water that interacts with both aquatic and terrestrial systems. Such zones absorb contaminated runoff before it joins the surface water or delay its flow (Gregory et al. 1991; Xiang 1996). In an agroforestry ecosystem, along with neighboring hedgerows and other woody plantings, they help control soil erosion and floods, protect livestock, produce biomass, and increase economic yields. These benefits are the primary reason that riparian zones are included in agroforestry system management and aquatic system restoration (Naiman et al. 1993), but riparian zones also increase ecosystem diversity by providing refuge (habitat, food, and protection) for plants, invertebrates, and vertebrates in an otherwise adverse environment.

Trees at Work

Plants, especially trees, are crucial in the effective functioning of a riparian zone (Blankenship 1996): 80 to 90 percent of the nitrogen, 85 to 95 percent of the sediment, and more than 90 percent of the herbicides running off crop fields can be trapped by a 66-foot-wide zone of vegetation that includes trees, shrubs, herbs, and grasses (Schultz et al. 1995b; Schultz 1996). After passing through this buffer, water that enters the streams is cleaner, and adjacent streambanks are more stable than areas where buffer zones do not exist (Schoeneberger 1994; Schoeneberger et al. 1995; Wight et al. 1995; Rietveld 1996).

The rhizosphere of trees usually supports an abundance of microorganisms, including some that can degrade herbicides, insecticides, and other toxic compounds (Haselwandter and Bowen 1996). Many ectomycorrhizal fungi in forests can metabolize organic forms of nitrogen (Read et al. 1989). Mycorrhizae can help increase the uptake of nutrients—phosphate and iron in particular (Cromack et al. 1979). Mycorrhizal hyphae can also increase accumulation of heavy metals into plant tissue. These functions are important in riparian zones because they help mitigate the impact of toxic wastes and other nonpoint sources of agricultural pollution.

Mycorrhizal associations frequently ameliorate environmental stress by improving uptake of vital nutrients and water by the host plants. By increasing nutrient uptake from soil, mycorrhizal stimulation of trees may compensate for poor soil. The extent of benefits depends on the abundance and diversity of mycorrhizal associates, production of roots and root hairs, soils, and tree genotypes (Haselwandter and Bowen 1996).

Unfortunately, the abundance of mycorrhizae in some agricultural ecosystems is typically low because row crops have limited root systems and rhizosphere microorganisms. Thus, tree seedlings planted in riparian zones may benefit from inoculation with mycorrhizal fungi before planting. Such inoculations are especially effective when soils are nutritionally poor or have few or maladapted mycorrhizal fungi.

Riparian zones with high vegetative diversity are preferred because these communities can adapt to environmental extremes and compensate for...
adversely affected species (Moffat 1996). A grassland with high species diversity, for example, is more productive, recovers more quickly from drought, and uses more available soil nutrients than a grassland community with low biodiversity (Tilman 1996). If diversity of plant species in riparian zones performs a role similar to that in grasslands, highly diversified edges should increase the stability of the riparian ecosystem. Moreover, neighboring matrices of agricultural, aquatic, and forest ecosystems will also benefit.

**Beneficial Residents**

Trees in riparian refugia provide refuge for vertebrates and invertebrates—both crop pests and their natural enemies (Dix et al. 1995). Spiders, an important predator of insects, are more abundant in turf and crop fields that have woody edges because trees increase their available habitat (M.E. Dix, unpubl. data).

In predominately agricultural watersheds, the riparian corridor is crucial to the survival of turtles, amphibians, snakes, small mammals, and birds:

- Decline of amphibian populations is attributed to diminished riparian habitat (Szaro 1991; Blankenship 1996).
- Reptiles, amphibians, and small mammals do not venture far from riparian areas (Szaro 1991; Blankenship 1996).
- Migratory birds seek food and protection in riparian zones during migration (Blankenship 1996).
- Breeding songbirds and cavity-nesting birds prefer wooded floodplains to upland woodlands or herbaceous habitats (Stauffer and Best 1980).
- In Arizona more than 85 percent of wildlife species are attracted to and require the riparian zone for survival, and most bird species visit riparian areas daily (Blankenship 1996).
- In Iowa bird abundance and diversity are more than three times greater in grassy waterways than in adjacent row-cropped fields (Bryan and Best 1991).
- In Nebraska bird abundance and species richness are significantly higher in wooded riparian zones than in herbaceous riparian zones (Fitzmaurice 1995).

Because the rich soil of riparian zones is desirable for crops, land managers often remove the woody vegetation and replace it with crops and a narrow zone of herbaceous vegetation. When all woody vegetation is removed, 32 of 37 bird species will abandon riparian zones. Increasing structural and vegetative diversity, however, by including areas of woody and herbaceous vegetation in the riparian zone benefits 22 of 30 species (Stauffer and Best 1980). Thus, managing large areas of the riparian zone to increase vegetative diversity, snag size, vertical stratification of the vegetation, sapling and tree size, and other critical survival factors would benefit most bird species (Balda 1975; Stauffer and Best 1980; Best et al. 1990). Nevertheless, certain portions of the riparian zone should be managed to benefit a few rare species, such as sandhill and whooping cranes. These birds protect themselves from predators during the day by feeding in wetland meadows and at night by standing in shallow running water on sandbars away from wooded riparian zones (Balda 1975; Stauffer and Best 1980; Krapu 1981).

Bees, bumblebees, butterflies, and parasitic hymenoptera use flowering trees, grasses, herbs, legumes, and other flowering vegetation in the riparian zone as pollen sources. Ash (Fraxinus sp.), oak (Quercus sp.), willow (Salix sp.), maple (Acer sp.), poplar (Populus sp.), and other wind-pollinated trees provide pollen for honeybees before crops and other pollen sources bloom; willows also serve as a source of nectar (Ayers and Harman 1992; Shuel 1992). Syrphids and other dipterous pollinators visit such flowering plants as vetch (Coronilla sp., Fabaceae), sweet clover (Melilotus sp., Fabaceae), milkweed (Asclepius sp., Asclepiadaceae), and various members of family Asteraceae—goldenrod (Solidago sp.), ragweed (Ambrosia sp.), coneflower (Rudbeckia sp.), and thistle (Cirsium sp.)—for both pollen and nectar (Ayers and Harman 1992; Lagerlöf et al. 1992).

Pollinators thrive if a number of small riparian areas are designated for flowering species and the natural generation of successive vegetation. This veget-

tation serves as an alternative pollen source when crop pollen is unavailable. An herbicide-free zone at least two meters wide must be maintained around these areas, however, or only a few herbicide-resistant grasses and herbs, such as Elymus repens (Gramineae), will survive. Such limitations on plant diversity may lead to low numbers of pollinating insects (Lagerlöf et al. 1992).

Recent research in Michigan demonstrated that some parasitic wasps seek woodlands, including wooded riparian zones, for food and shelter. Adult Erirborus trebri (Hymenoptera: Ichneumonidae), a parasite of the European corn borer (Os- trinia nubilalis), feed on pollen and nectar in field edges and woodlands. Parasitism of corn borer larvae was significantly higher near wooded edges (Landis and Haas 1992). In the Great Plains the riparian zone harbors a few vestiges of forests and consequently may play an important role in the survival of many important natural enemies.

**Harboring Pests, Too**

Riparian zones also serve as refugia for important forest and crop pests, such as bark beetles (Scolytidae), southern corn rootworm (Diabrotica undecimpunctata, Coleoptera: Chrysomelidae), boll weevil (Anthonomus grandis grandis, Coleoptera: Curculionidae), and European corn borer (Dix et al. 1995). In the northern Great Plains, endemic populations of elm and ash bark beetles are common in riparian areas. Outbreaks move from these riparian sites into planted urban and rural trees (Dix, pers. observ.). In the central and southern Great Plains...
The Stability of Continual Change

Plains, southern corn rootworms and boll weevils, respectively, overwinter in debris beneath trees. Native hosts of the European corn borer are common in wooded riparian zones (Dix et al. 1995). Riparian zones, unlike monocultures of trees and crops, cannot be rotated to eliminate insects, diseased plants, or other pests and thus also must be included in guidelines for managing pest organisms.

Genetically engineered poplar, corn, and other crops are a promising option for reducing pesticide use in agriculture and improving water quality (Raffa et al. 1993; Dix et al. 1997; Klopfenstein and Hart 1997), but a problem arises: how to prevent resistant insects from developing. Refugia are part of the answer, and in fact, lease agreements for the use of genetically engineered vegetation compel the establishment of refugia. For example, the use of Naturegard, an insect-resistant, genetically engineered corn of Mycogen Plant Science, requires the establishment of refugia as part of a resistance-management plan for hybrid select corn that is naturally resistant to corn borers or genetically engineered for resistance. Because herbaceous and woody vegetation in riparian zones also serves as alternative hosts for corn borers and poplar pests, respectively, these zones likely can also serve as refugia for pests of genetically engineered plants (Anon. 1995; Dyer 1995).

Balancing Act

Long-term sustainability requires adaptability, and thus riparian ecosystems must be managed to promote adaptability. Riparian ecosystem management maintains a balance among core reserves, buffers, and the matrix of land used more intensively by humans. Successful management must achieve required refuge biodiversity in core and buffer areas while allowing humans to meet their resource goals (Grumbine 1994). A final design must reflect needs of high-input agriculture, multiple landowners, minimal implementation costs, and maximal economic returns. Goals for riparian systems must therefore represent a consensus of scientists, economists, farmers, outreach experts, and administrators.

Restoring riparian zones is a long-term process that must balance short-term human needs with long-term environmental requirements for refugia. Large-scale restoration of riparian zones may mitigate some adverse effects of forest removal—whether in the Great Plains or North America or the world. Because riparian zones affect water, edge, and agroforestry systems, partnerships among foresters, agronomists, hydrologists, and farmers are essential to balance current knowledge of ecological relationships with complex sociopolitical and ethical values (Gregory et al. 1991; Bartuska 1994).

Literature Cited


