Woody Plant Selection for Riparian Agroforestry Projects[1]

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Abstract—Riparian buffer strips primarily function to protect and enhance water resources while maintaining a reservoir of plant and animal diversity. In agroforestry practices, riparian buffer strip establishment entails the deliberate planting or management of existing plant species to enhance those qualities important in mitigating nonpoint-source pollution. These systems can provide numerous other benefits; such as enhanced wildlife, wood and other specialty products, and landscape beautification, depending on the diversity and arrangement of the plant materials. Riparian buffer management strategies will necessarily have to take into account plant attributes and interactions that enable these multiple benefits to be reaped. The need to maintain and establish riparian systems is projected to escalate as their ecological and economic roles in the landscape are better documented. This demand will necessitate a supply of diverse, native or locally-adapted shrubs and trees suitable for riparian buffer systems; thus representing a potential new market for nursery producers of conservation planting materials.

AGROFORESTRY: A BEST MANAGEMENT PRACTICE FOR AGRICULTURE

"The American agricultural system is unparalled in its ability to produce food and fiber, providing quality products for both domestic consumption export. Total agricultural production today is over 2 times the level of 1930. Much of this productivity gain has been made possible by improvements in fertilizers and pesticides for crop protection, as well as crop varieties and cropping technologies" (Carey 1991). Unfortunately, we are now having to come to grips with the side effects of these practices. One of the more serious side effects is the "bio-simplification" of the agricultural landscape. With a concomitant loss of ecological integrity and thus sustainability within the agroecosystem, continued and intensified inputs (e.g. fertilizers, pesticides, cultivation) are necessary to maintain production; further exacerbating the deleterious impacts on the system (see discussion in Schoeneberger 1993).

Because of the serious environmental problems associated with intensive agriculture, a movement towards more sustainable agricultural systems is essential and inevitable. AGROFORESTRY is being promoted as means, in concert with other Best Management Practices (BMPs), to couple ecological sustainability with economic stability.

The International Center for Research in Agroforestry (ICRAF) defines agroforestry as "a collective name for land use systems and technologies where woody perennials are deliberately used on the same management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence". The Center for Semiarid Agroforestry (CSA), established by the USDA-Forest Ser vice with a focus on temperate, semiarid regions, has expanded this definition to the use of WORKING TREES (planting the right tree in the right place for a specific purpose) in agricultural and community ecosystems to protect, conserve, diversify, and sustain vital economic, environmental, human, and natural resources.

Agroforestry includes both **production agroforestry** (growing a tree crop in combination with an agricultural crop to increase the overall productive capacity of the land), and **conservation agroforestry** (working trees in agroecosystems to provide environmental services and multiple benefits; tree products being secondary). Specific agroforestry practices in temperate regions include windbreaks for field, livestock, and farmstead protection; riparian buffer strips; living snowfences; wildlife habitat; fuelwood and fine hardwood plantations; alley cropping; as well as specialty plantings for honey production or aquaculture. Additional community-oriented practices include municipal watershed stabilization, sludge/ wastewater disposal, noise abatement, and screening and dust control.

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Benefits derived from these plantings include water and air quality, soil conservation, wood products, improved wildlife habitat and additional amenities such as aesthetics and recreation. Tree windbreaks, riparian buffer strips, tree plantations, and other agroforestry practices can play a prominent role in sustainable agricultural systems because they provide year-round and long-term multiple benefitg ranging from wood products to environmental services, such as erosion and water quality control.

Successful agroforestry is dependent on having adapted plant material that will flourish in the stressful environments in which they are to be planted. Tree improvement efforts, utilizing a multidisciplinary approach that combines classical tree improvement with ecophysiology, entomology, forest pathology, soil science, and biotechnology, is underway at CSA in cooperation with the University of Nebraska, as well as several other institutions in the Great Plains.

By using a number of different approaches (i.e. molecular genetics of innate and engineered systems), the process of screening and producing stress and pest resistant conservation trees for the Great Plains can potentially be accelerated. Used in conjunction with materials that can be selected from the now mature provenance plantings established throughout the Great Plains in the 1960's and new findings from the USDA Soil Conservation Service's Plant Material Labs, suitable "agroforestry" planting materials should be readily available for propagation and distribution purposes.

NON-POINT SOURCE POLLUTION

Nonpoint source pollution, versus point source pollution, develops over large areas, making identification and mitigation a difficult task. It includes inputs of sediment, nutrients from fertilizers, animal wastes, pesticides, as well as other substances, via runoff and subsurface flow. Nutrients (e.g. nitrate and phosphorus) and sediment are the leading nonpoint source pollutants of concern. However, the current and more sensitive monitoring efforts have identified pesticides (e.g., atrazine) as a growing problem, especially in the Midwest.

The original Clean Water Act of 1972 was amended in 1987 to include programs to specifically regulate nonpoint source pollution from farms, forests, streets, and construction sites. Despite this effort, nonpoint pollution is now thought to account for about 75% of the pollution in our waterways (Benjamin 1993). The massive agricultural conversion of the Great Plains is a prime example of an intensive economic, social and political enterprise that has produced significant nonpoint source pollution from excessive and/or improper grazing, cultivation, and agrichemical usage.

On easily permeable soils where groundwater percolation is the main pathway of pollutant movement, BMPs are necessarily focused on strategic in-field practices that limit input into the groundwater (e.g., better prescribed fertilizer application). In less permeable soils, where lateral flow is the predominant path and/or where storm runoff accounts for the major flush of pollutants from the land to the waterways, **riparian buffer systems,** acting as biological filters between the field and aquatic ecosystems, can be used to mitigate NPS pollution of waterways. Used in concert with in-field BMPs, riparian buffer systems represent a very versatile and effective tool so that **both** economically-reasonable and ecologically-sound agricultural production can be achieved.

Figure 1 – Forested riparian buffer system in the agricultural landscape. Note the linear and fragmented nature of this landscape feature.

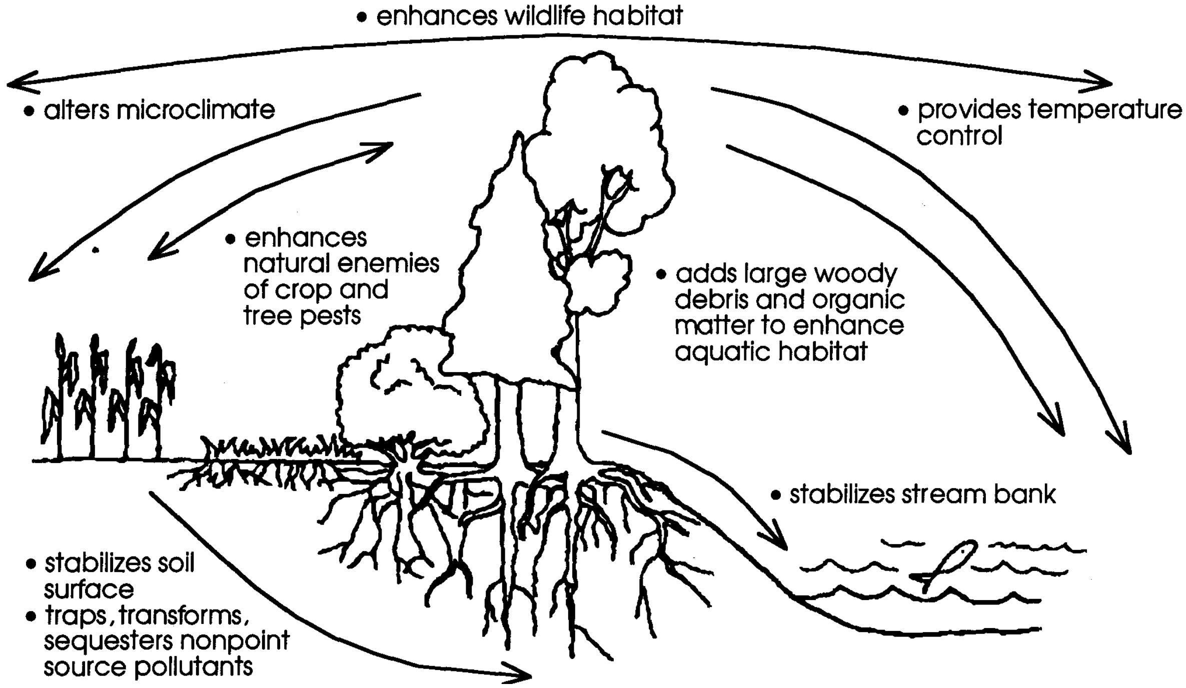

Figure 2 – Multistrata riparian buffer systems benefit the agroecosystem through numerous interactions between the terrestrial and aquatic ecosystems it interfaces with.

RIPARIAN BUFFER SYSTEMS

Riparian systems consist of a narrow band of vegetation immediately adjacent to waterways. The waterway can be a stream, lake, river or other body of water, and can be of a perennial or intermittent nature. The characteristics of the riparian system makes it a distinctive landscape feature due to its fragmented, linear structure (Figure 1).

Riparian forests are considered extremely important because of their role in maintaining water quality. Physically, chemically, and biologically, they function as a "buffer" between adjacent upland terrestrial inputs to adjacent aquatic ecosystem. The trees and associated vegetation trap and filter out the nutrients, pesticides and other nonpoint source pollutants, and create a belowground environment where further sequestration and breakdown of these pollutants can take place via microbial processes. The root systems further serve in the physical stabilization of the stream bank. Smith (1976) reorted that bank sediment in vegetated areas (16-18 percent volume of roots) had over 20,000 times more resistance to erosion than comparable bank sediment without vegetation!

Numerous and continuous interactions occur between this fragmented woody system and the adjacent terrestrial and aquatic systems (Figure 2), that can be readily manipulated and capitalized on. In addition to enhanced water quality, properly managed forested riparian buffer systems enhance food and shelter for both terrestrial and aquatic wildlife, increase carbon sequesration, enhance biological control agents (i.e. arthropods) of tree and crop pests, promote stream bank stabilization, and may provide wood products ranging from fuelwood to lumber.

As they become established over time, forested riparian systems are generally characterized by high plant and animal species diversity; making them one of the more dynamic and productive ecosystems. Although these systems comprise only a small percentage of landcover, particularly from the Great Plains westward, their biological and hydrological importance far exceeds the proportion of land cover they comprise. Unfortunately this critical habitat is disappearing at an alarming rate. The tendency in modern agricultural systems is to farm or graze up to the water's edge. Lack of proper management and urban encroachment have further resulted in loss of riparian systems. These practices have generally resulted in accelerated vegetation, soil and water degradation.

DESIGNING AND MANAGING RIPARIAN BUFFER SYSTEMS FOR MULTIPLE BENEFITS

The establishment of multistrata riparian buffer systems, that consist of a border of forage, shrubs and trees adjacent to a perennial or ephemeral stream, is being examined by a number of federal and state agencies as a BMP to alleviate NPS pollution of our surface and groundwaters (Figure 3). The advantage of the multistrata system is that the grass and shrub components are fast to become established and provide buffering capacity early on; while the trees, which have a much larger capacity to fix nutrients and carbon, become established and effective. The use of multiple strata, also translates into greater flexibility and potential for capitalizing on the many benefits afforded by these systems.

Specifications for generic forested riparian systems are available (Welsch 1991, see Figure 3), but are based predominantly on the research and, thus, conditions existing in the eastern United States (Lowrance et al. 1985). Utilization of this tool in the West and Midwest must be based on a better understanding of the biological, economic, and social constraints of these regions if these systems are to meet the needs of the individual and the watershed.

Several research efforts are underway to develop optimal forested riparian buffer system designs for the Midwest; the three most three most notable efforts being at Iowa State University, University of Iowa, and that recently initiated at CSA in cooperation with the University of Nebraska-Lincoln. The CSA's program encompasses research to optimize the capacity and efficacy of riparian designs, development of BMP guidelines (i.e. species selection and arrangement), demonstrations in rural and community situations, and technology transfer to natural resource professionals.

Specific areas of design and management of riparian buffer systems in the Great Plains that need to be addressed include: 1) guidelines for riparian buffer strip dimensions, especially width,

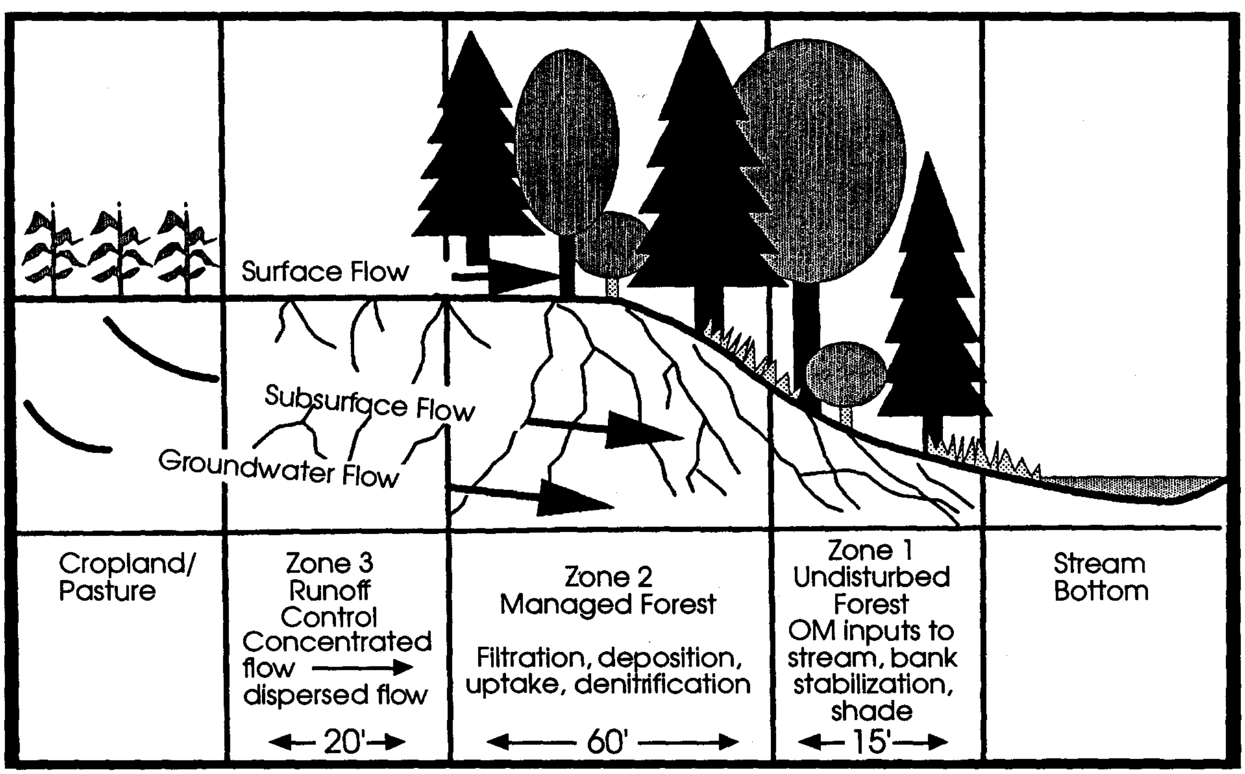

Figure 3 - Generalized multistrata riparian buffer specifications and functions for NPS pollution mitigation in agricultural systems (modified from Welsch, 1991).

2) placement within the watershed with regards to adjacent land-use, other BMP options, and desired environmental end-points, 3) valuation of amenities derived from these systems by the landowner and by the public, 4) subsequent management of riparian buffer strip to maintain NPS and other functions (i.e. periodic harvesting of plant materials, maintenance of diffuse flow into riparian buffer strip), and 5) the selection and arrangement of plant materials to attain multiple benefits.

SELECTION OF MULTIPURPOSE WOODY PLANTS FOR FORESTED RIPARIAN SYSTEMS

The very nature of riparian systems lends itself well for multipurpose management. As Short (1985) points out though, numerous management goals can be developed for riparian systems but each goal may dictate management policies, strategies, and tactics; and will interact to produce different final products. Multiple use/multiple species management is "doable" today in the sense computers can be used to provide the decision-making framework.

The Soil Conservation Service is in the process of developing their national plant species database - "PLANTS": Plant List of Attributes, Nomenclature, and Taxonomy. PLANTS will provide a standardized botanical data set for use by other software applications (i.e. windbreak design) so that appropriate multispecies / multipurpose plantings can be designed. Unfortunately, the attributes section is still far from being completed. This is particularly true with regards to plant selection for riparian plantings where we are just now defining the criteria we should be looking for in the plant materials. Perkey et al. (1993), provided a listing of tree species and their ability to produce timber, wildlife, aesthetic, and water quality benefits, as well as their relative flood tolerance, but readily admit the categories are subjective and may change as more information becomes available. This document was also developed for the Northern, Central, and Eastern Deciduous Forest Regions, and thus has limited value from the Great Plains westward.

Bottomline, vegetation for riparian forest systems should be native or locally-adapted material, show rapid initial growth, can be economically propagated, and be relatively stress and pest tolerant. However, to optimize the water quality benefits afforded by riparian systems, along with the many other amenities these systems can provide, additional criteria must also be met.

Rooting characteristics may be one of the key selection criteria for riparian buffer strip vegetation. The density and depth of rooting play a big role in the ability of the plant species to intercept NPS subsurface flow, as well as in determining the strength of the stream bank to resist erosion. Fine root turnover provides the majority of carbon input into the belowground system (up to 4 to 5 times as much carbon as contributed by aboveground litter), thus influencing the capacity of the system to microbially process the NPS pollutants. Denitrification, a microbial process whereby excess nitrate is transformed to gaseous nitrogen and thereby released to the atmosphere before it can enter the waterway, is dependent on this C input.

Several of the other belowground plant considerations are not that easily discerned but do play a major role in how a riparian system operates. For instance, we know different species of plants influence the quality and quantity of microbial activity, much of which may play a role in filtering NPS pollutants. More importantly, we know by selecting and interplanting a mixture of species, the diversity and quantity of these microbial functions may be further enhanced (Bopaiah and Shetty 1991).

Because trees and other woody perennials are effective nutrient traps, they provide a longer-termed sequestration of nutrients and other chemicals. In selecting plants materials for riparian buffer strips, specifically for this capability to trap NPS pollutants, consideration must be with regards to the specific nutrient uptake by each plant species through time. The capacity to sequester nutrients and chemicals varies with species (i.e., oak requires more nitrogen than spruce or pine) and age (i.e., nutrient uptake being most rapid in young trees). Thus the selection criteria will need to include the inherent capability of the plant to take up nutrients, as well as what management of that species will need to take place to maintain a useful level of uptake.

Selection of plant species for purposes of enhancing wildlife habitat, along with the water quality aspects, will be dependent on the specific group being targeted. While proper placement of riparian vegetation to control streamwater temperature for fish habitat is well understood, selection of the specific plant species for enhancement of fisheries is not as well known. A recent article by Sweeney (1993) points out that the selection of plant species in the riparian area can dramatically influence the fisheries habitat by altering the quality of food available to the macroinvertebrate populations that the fish depend on for food. His studies indicate a **mixed, native** species composition in streamside areas will support a wider variety of macroinvertebrates than a monoculture or non-native woody perennial composition is capable of supporting.

Other considerations that will need to be taken into account when selecting species for forested riparian systems include structural, disease, and allelopathic limitations. Depending on the specific placement of a riparian system within the agroecosystem and the nature of the waterway, selection of short-statured woody plants may be necessary to avoid unwanted microchmate shifts via the shelterbelt effect of the planting on adjacent crops and/or to avoid streambank "de"stabilization. Disease considerations that go beyond the use of stress and pest resistant genotypes must also include avoidance of species that serve as alternate hosts for disease organisms. For example, you would want to avoid planting juniper species near apples orchards as they serve as the alternate host for cedar-apple rust.

In considering allelopathic interactions in woody plant mixtures, both advantageous to disadvantagous interactions are possible. By proper selection of plant materials, undesirable weeds may be controlled through allelopathy, such as that encountered with the use of *Leucena leucocephala* and *Abies balsamea.* Unfortunately, the allelopathic inhibition of plant establishment may suppress establishment of desirable plants, such as that observed with black walnut.

Bottomline, selection of woody plant vegetation for riparian buffer strips in the Great Plains will need to take into account the following criteria: soil/site limitations; rooting depth; nutrient uptake and cycling; pesticide, pest, and abiotic stress tolerances; terrestrial and aquatic wildlife values, as well as value for aesthetics, recreation, and wood products; and those other considerations that determine the species ability to mitigate NPS pollution and provide other amenities.

The impetus for "WORKING" forested riparian buffer systems will only continue to escalate as the NPS pollution of our waterways becomes elucidated. The impetus for having these systems was perhaps no more poignantly illustrated than by the impacts of the 1993 floods that rampaged the midwest. More information will be needed to develop the necessary guidelines required for forested riparian establishment and management. But more importantly, a diversity of suitable plant material will need to be readily available to capture this window of opportunity to implement a "WORKING TREE" strategy.

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