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RIPARIAN FOREST BUFFERS: BUILDING A SUSTAINABLE BIOENERGY FUTURE

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Abstract: As society transitions to bioenergy production on agricultural lands, this future must be formulated in a way that the other services from agricultural lands are not compromised. Agroforestry, and in particular riparian forest buffers (RFBs), can contribute to a sustainable, multi-functional bioenergy future. RFBs can mitigate adverse impacts from bioenergy production systems such as polluted runoff from grain-based ethanol operations as well as potentially augment feedstocks for bioenergy production. Properly designed, located and managed, RFBs can do this while providing other services the landowner and society demand from these lands, including air and water quality, wildlife habitat, carbon sequestration and alternative income opportunities.

Current research is contributing to our technological understanding of whether and how bioenergy objectives can be met within RFB practice design and management. Our greatest challenge, however, is building the socio-economic and political frameworks that will ultimately determine its acceptance and adoption by landowners and resource professionals. Education will be imperative, not only of potential landowners but also those involved in policy and program formulation and delivery, to develop mutually beneficial connections between bioenergy production and other ecosystem services. Shifts in farm policy, programs and markets will be necessary to make adoption of RFBs more attractive to landowners. Programs like the newly created Biomass Crop Assistance Program (BCAP) will be invaluable to help landowners transition to a diversified bioenergy system.

Tools for designing and locating RFBs to optimize multiple services, including bioenergy, are needed to facilitate discussion and formulation of shared agendas among landowners, resource professionals and the energy industry. Strategies for current and future use of RFBs within bioenergy production systems requires going beyond our current business-as-usual approach. We must shift from a single issue focus to creating RFB designs, programs, and policies that satisfy multiple objectives.

Keywords: riparian forest buffers, bioenergy, biofuels, ecosystem services, planning

INTRODUCTION

In an effort to reduce America's dependence on foreign oil, combat volatile petroleum markets and provide cleaner and more climate change-friendly energy sources, the U.S. has mandated that 36 billion gallons per year (GPY) of ethanol be blended into conventional petroleum-based gasoline in America by 2022. Current production of biofuels, primarily corn-based ethanol, has grown to more than 9 GPY during 2008. While this rapid increase in biofuel production has had some economic benefits, new information is suggesting that the impacts on soil, water and wildlife resources will exceed any short-term benefits (Marshall 2007, NRC 2007). One study suggests that the increase in corn cultivation required to meet the goal of 15-36 GPYof renewable fuels by the year 2022 would increase the annual average flux of dissolved inorganic nitrogen (DIN) export in to the Gulf of Mexico by 10–34% (Donner and Kucharik 2008). Generating just 15 GPYof corn-based ethanol by the year 2022 will increase the odds that annual DIN export exceeds the target set for reducing hypoxia in the Gulf of Mexico to >95% (Donner and Kucharik 2008). Clearly, we have policies in direct conflict with each other.

Economic fallout of biofuel production on food, feed and fuel markets, as well as determining the real environmental footprint of its production cycle, are also areas of much concern and discussion. Doornbosch and Steenblik (2007) have concluded that the "potential of the current technology of choice – ethanol and biodiesel – to deliver a major contribution to the energy demands of the transport sector without compromising food prices and the environment is very limited." Even cellulosic-based bioenergy systems, while possibly more sustainable, have related concerns and are now being scrutinized in terms of environmental greenness and broader issues of sustainability.

To compound these problems, ecosystem services provided by lands enrolled in conservation programs, such as Conservation Reserve Program (CRP), will be greatly minimized or lost as lands are pulled out of enrollment and converted back into crop production – either for biofuel crops or as a replacement for displaced food crop production. In Nebraska, there is currently 1.12 million acres enrolled in CRP but there is an expected reduction in acres by 84% in the next five years (Pheasants Forever 2009).

Despite these substantial problems, agriculture will still need to be a part of the energy solution. It is clear that bioenergy production from agricultural lands can not be implemented as a 1-dimensional program without having serious repercussions on other ecosystem services, these programs must be formulated in a way that these other services from agricultural lands are not compromised. Through innovation, we can proactively create management practices and systems that connect energy, food production and ecosystem services on agricultural lands. Riparian forest buffers (RFBs) by their very location, composition and impacts on the landscape provide a beginning step in this direction – an opportunity to augment services on agricultural lands that will be required for sustainable bioenergy production (Schoeneberger et al. 2008).

Riparian Buffers – Connecting Energy/Food Production/Ecosystem Services Objectives

Riparian forest buffers (RFBs) can provide numerous services, including water quality protection, wildlife habitat, carbon sequestration and recreational and income-generating opportunities (Fig. 1).

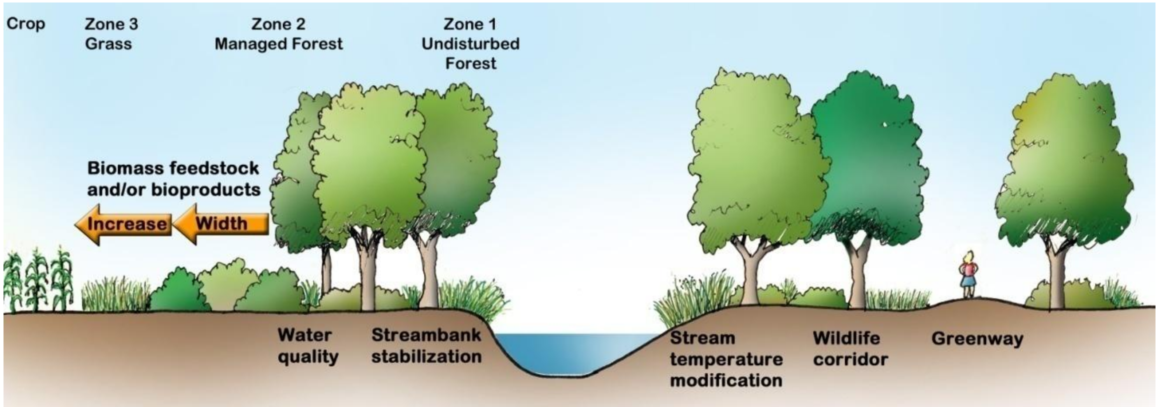

Fig. 1. Riparian forest buffers can be managed for multiple purposes, including those in support of energy objectives. More innovative designs, species selection, and management guidelines will be needed for these energy objectives to be met, along with others landowners and society already demand from them. (Source: Schoeneberger et al. 2008)

With proper design, placement and management, they may provide many of these services *while* also contributing to energy objectives in a number of important ways (see Box 1).

Box 1. Roles Riparian Forest Buffers Can Play in Support of Energy Objectives.

- CONSERVATION SERVICES: RFBs may mitigate adverse ecological impacts created by bioenergy production, especially in regards to water quality.
- COMBINED HEAT & POWER (CHP) for ETHANOL PLANTS: Plant materials in RFBs may be a source of feedstock to generate electricity and steam reliably on-site; reducing GHG emissions and operating costs.
- BIOENERGY PRODUCTS: Many plants suitable for use in RFBs, especially in Zone 2, produce fruits and nuts that have high yields and bio-oil properties (e.g., hazelnut, Osage orange, Chinese tallow, Jatropa)
- BIOMASS FEEDSTOCK: The biomass components of RFBs may serve as sources of feedstock to augment commercial ethanol production.
- ON-SITE/LOCAL HEATING POWER PRODUCTION: As the technology for small (5-50kW) generators that can utilize a variety of forest & agricultural residues becomes more available, RFBs can provide sources of residue for meeting on-site heating and power needs.

RFBs need to be an integral component of any bioenergy crop production strategy in order to provide critical water, soil and wildlife conservation services, especially in systems involving monocultures and/or annual crops. Advantages of using RFBs in bioenergy production are listed in Box 2. By modifying RFB design (while not compromising its primary purposes for water quality, streambank stabilization, or wildlife habitat); these buffers can ‘assume additional duties’ in support of energy objectives. These RFBs can be part of a “combined food and energy” (CFE) system on the farm (Kuemmel et al. 1997). This more multipurpose approach is gaining interest and support, especially in Europe where they are dealing not only with bioenergy, greenhouse gases and sustainable agricultural issues, but also the significant reduction in European Union (EU) crop subsidies to the agricultural sector.

Potential management options being examined include integrating annual crops with mixed perennial plantings, such as willow and Miscanthus, as a means to generate biofuel materials, ecosystem services, and a livable income for the farmers. The riparian environment is ideal for realizing the good growth of short rotation woody crop species (SRWC) and is also an area where we are trying to maximize the phytoremediation potential with these fast growing trees. By providing these multiple services, which include those that support energy - *while* leaving the bulk of the land still open for agricultural production, RFBs could be both a viable and an appealing piece to begin linking the energy, food production and ecosystem services on these lands.

Box 2. Advantages of Using Riparian Forest Buffers in Support of Energy Objectives

- RFBs are located on lands that are marginal/sensitive to most agricultural operations but which are suitable for many perennial herbaceous and woody crops.
- The use of perennial herbaceous and woody plants in multi-species RFBs does not require the high level of inputs of annual crops and can harvest the excess nutrients; resulting in water protection and production of biomass.
- Reduction in annual soil disturbance, along with year-around plant cover provides greater soil and water quality protection and wildlife habitat.
- Herbaceous and woody species that can and have been utilized in Zones 2 & 3 have more favorable net energy conversion ratios than corn, with many of the woodies (e.g. willow, hybrid poplar and cottonwood) having ratios of ~1:11, co-firing with coal, and ~1:16 through gasification.
- The woody component in a bioenergy-modified RFB offers greater flexibility in harvest times, easier storage (e.g. ‘on-the-stump') and greater flexibility in end-use, all which contribute to reducing farmer risk.
- The multipurpose, diversified nature of a bioenergy-RFB provides added resilience against climate change variability and extremes.

Riparian Buffer Planning and Design for Bioenergy

Incorporating energy objectives into RFB designs will require new RFB guidelines, standards, and designs. Establishment, management and harvesting protocols that include a bioenergy component will be of the utmost importance so that production and harvesting do not compromise RFB functions for other services. Further, the RFB must be integrated into a whole-farm management plan as well as the larger landscape context. As with all RFB planning and design efforts, including that for bioenergy, the main questions that need to be addressed are:

1. *What do we want the RFB to accomplish?*
2. *Are the location and/or conditions appropriate for these purposes?*
3. *What plant species and combination of species should be used in the RFB?*
4. *What management will be required to attain these objectives from the RFB?*

To effectively answer these questions, a multi-scale planning and design process should be used (Ndubisi 2002, Bentrup et al. 2003). Multi-scale planning is necessary because riparian functions vary at regional, landscape, and site scales and not all objectives can or should be achieved with riparian buffers at every location (NRC 2002). Landscape and individual site constraints and opportunities will dictate what goals are feasible, which in turn will be modified by community and landowner desires and needs. Landowner goals, like minimizing soil erosion and producing feedstock for bioenergy production, can often be accomplished by just focusing on the site conditions while a larger scale perspective is often required for community-driven goals, like water quality and wildlife habitat.

A key element in the planning process is the use of GIS-based spatial assessments to determine where objectives can be realistically accomplished. Several assessments already exist that can identify locations to grow agroforestry specialty products, improve riparian connectivity for wildlife, and enhance water quality (e.g., Bentrup and Leininger 2002, Bentrup and Kellerman 2004, Dosskey et al. 2006). Other types of assessments that could be conducted for bioenergy buffers include proximity to a biofuel refinery and flood-prone lands suitable for SRWC. By combining these types of assessments, locations can be identified where multiple objectives can be simultaneously achieved.

In regards to plant selection, current species combinations/systems have been designed primarily for the purposes of improving water quality and enhancing wildlife values. New planting designs will need to be created to take advantage of emerging carbon markets and other ecosystem service markets. Other considerations include stress and pest resilience by the RFB plants themselves and may also include species/combination selections that can provide pollinator habitat and biocontrol of pests in adjacent crops.

While there is significant information on the bioenergy properties of many herbaceous species, more work needs to be conducted on the yield and sustainability of short rotation woody species production under different site conditions and management practices. Performance of SRWCs (e.g., poplar, willow and black locust) will need to be evaluated not only in regards to growth on marginal lands and in creating positive interactions with nearby crops, but also in terms of cellulosic qualities for biofuel use. We already have a pretty solid foundation for using willows for applications ranging from bioenergy, living snowfences, phytoremediation, and riparian buffers, while others are adding to our understanding on the potential of poplars to harvest nutrients from runoff, providing both phytoremediation and biomass.

Many of these woody species may have the potential to produce high value bio-oil and other bioproducts. Hazelnut, a shrub-like tree already used in many conservation practices, has been found to have higher yields of bio-oils and with better thermal qualities than soybean (Xu et al. 2007)). Studies with Osage orange, a species once extensively planted in hedgerows are revealing that this plant can yield significantly large amounts of latex and other potentially high value compounds important for energy, chemotherapy, insecticidal and other uses (Alan Gravett, personal communication).

Using new species and species combinations, however, brings another whole set of potential problems. A big consideration will be the potential for 'weediness' or invasiveness. In RFB plantings, the emphasis has been to use native plant materials where at all possible, recognizing that ecosystems can generally keep native plants in check. Unfortunately, many of the high value bioenergy species have the potential to become invasive, especially some of the nonnative grasses, such as Miscanthus, and species being genetically bred for attributes such as greater water use efficiency, like switchgrass). Similarly, these plantings could also then harbor and promote populations of pests. Through planning and careful assessment, we need to consider all potential impacts to better design for multiple functions and to prevent creating new, unforeseen problems.

Getting Them into the Ground

While we are developing the technological basis of how bioenergy objectives can be achieved within RFBs we need a similar investment to build our understanding of the socio-economic and political factors that will determine getting bioenergy buffers in the ground. Some of the questions that need to be answered include:

1. *How do we build the infrastructure needed to transition to a cellulosic-based biofuel future?*
2. *Can multipurpose RFBs serve as a transitioning tool towards a mixed, diversified biofuel production landscape?*
3. *What incentives are needed to get RFBs in place?*
4. *What tools are needed to promote acceptance and adoption of the practice?*

Market uncertainty for cellulosic feedstocks is a big barrier right now. Investments for commercial production using cellulosics are based on having a secured base of feedstock availability. With corn-based ethanol production, this was simply a matter of switching end-use of a crop already in place. With cellulosic feedstock crops, we are faced with the challenge of getting feedstock in the ground years before a refinery plant is feasible. Farmers are reluctant to lose control of their land by putting it under perennial operations, especially as it requires a longer-term investment before they would realize a return.

Shifts in farm policy, programs and markets will be necessary to make adoption of RFBs more attractive to landowners. First, conservation programs in the Farm Bill need to have incentives and flexibility to promote CFE-like operations and not just piece-meal actions. Incentives should provide farmers with a reasonable level of support for offsetting upfront establishment costs and reducing their investment risks. The newly created Biomass Crop Assistance Program (BCAP) moves in that direction by providing payments to farmers while they establish and grow biomass crops in areas around biomass facilities. Switching crop subsidies to conservation payments for more carbon-neutral biofuels may be another alternative; one already occurring in the EU. Another way may be to develop ecosystem service markets which pay farmers for services provided from conservation practices. Unfortunately, ecological benefits of perennial crops, especially derived from diversified plantings, are hard to quantify, and, even then, may be less real to the farmer than the price per bushel of biofuel crop.

Education will also be imperative, not only to landowners but also those people involved in policy and programs formulation and delivery. A survey of farmers in Tennessee showed that few were aware of the potential of growing switchgrass for bioenergy, and an even smaller proportion of that group was willing to consider it (Jensen et al. 2007). What reaction should we expect if we try to promote more innovative, diversified systems for the farms? Growing biofuel crops, beyond that of corn, will require a major paradigm shift for farmers. Developing and managing combined food and energy farms will be an even bigger step. Again, RFBs that address landowner objectives in addition to societal objectives may be a way to ease into this transition.

To facilitate this transition, we will need tools to foster the discussion and formulation of shared agendas among landowners, resource professionals and the energy industry. The recently published *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways* provides science-based rules-of-thumb for designing multifunctional buffers, giving resource professionals the information they need to communicate complex concepts to landowners http://www.bufferguidelines.net (Fig. 2).

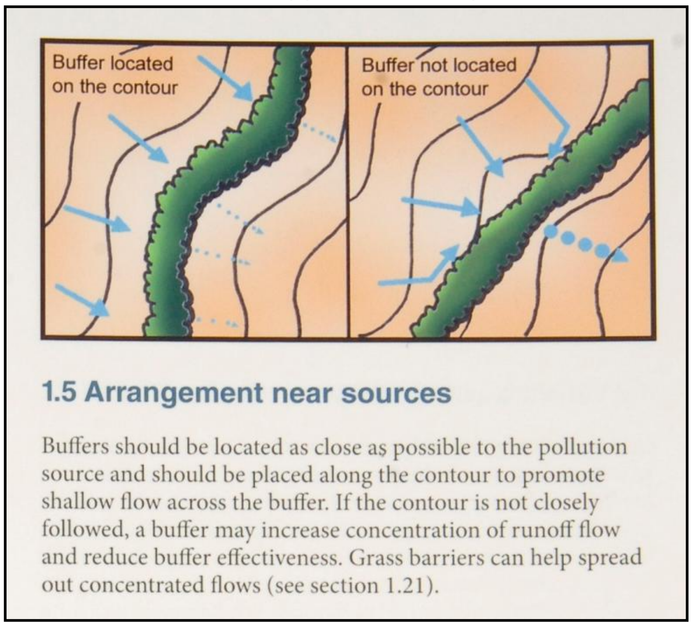

Fig. 2. An illustrated, easy-to-understand guideline from the publication *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways*

One survey has shown that landowners are often less inclined to adopt wide riparian buffers and yet buffers for bioenergy will probably need to be wide to accommodate all of the necessary objectives (Sullivan et al. 2004). In many cases, this barrier can be overcome when landowners see an image of what is being proposed. Visualization software, such as *CanVis* developed by the National Agroforestry Center, can help the landowners see these perennial systems as they would appear in different arrangements and over time on their lands. Visual simulations promote acceptance and adoption by communicating ideas clearly, by inviting feedback on the alternatives, and by instilling a sense of shared ownership in the practice so that it is supported and maintained for long run http://www.unl.edu/nac/simulation/products.htm (Fig. 3).

Fig. 3. Visual simulations depicting two different riparian buffer alternatives.

Riparian buffers can play an important role in the transition to a sustainable bioenergy future. The key will be to link it to the many other issues surrounding our agricultural lands. The potential for designing "bigger, better *and* bioenergy riparian buffers" is there but this potential will need to be better conceptualized and developed, better communicated to those responsible for developing program and policies, and better communicated to landowners, and most importantly, to the resource professionals that will be delivering this technology.

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