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Chapter 5: Connecting Landscape Fragments Through Riparian Zones

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5.1 Forest Loss and Ecosystem Services

Many formerly forested regions have been largely cleared and are now important crop and livestock producing lands (Fig. 5.1). This is true of many parts of the world including United States' southeastern coastal plain, Brazil's rainforests, Northern Europe's lowlands, China's northeastern plains, Indonesia's lowlands, and floodplains of most of the world's large rivers. Through widespread conversion of forests to intensively-managed agricultural uses, these countries have created highly productive agricultural economies.

Environmental issues have arisen as consequences of the loss and fragmentation of forests, including soil erosion, water pollution, and fish and wildlife population declines (Green et al. 2005; Schröter et al. 2005; Matson and Vitousek 2006). The pre-existing forests provided the public with high levels of desired ecosystem services, including clean water, healthy fish and wildlife, biodiversity, climate moderation, wood and food products, and aesthetic qualities (Fig. 5.2). Subsequent decline of these services has resulted in lower levels of social well-being, causing public concern (MEA 2005). To regenerate them, restoration of large tracts of land back to forest may be a logical goal, but it may not be feasible. Doing so may put the supply of plentiful and affordable food at risk, and, convincing numerous farm workers, landholders, communities, and industries to change their social fabric woven around agriculture to one centered on forestry may pose a daunting social challenge. A more acceptable alternative might be to restore forest in only the most critical portions of

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Fig. 5.1 Forest clearing has produced highly-productive agricultural landscapes. However, ecosystem services provided by those former forest lands, such as clean water and forest wildlife have diminished. Restoration of forest ecosystem services to agricultural landscapes requires landscape planning that integrates knowledge of natural science and social science principles (Photo credit: NRCS)

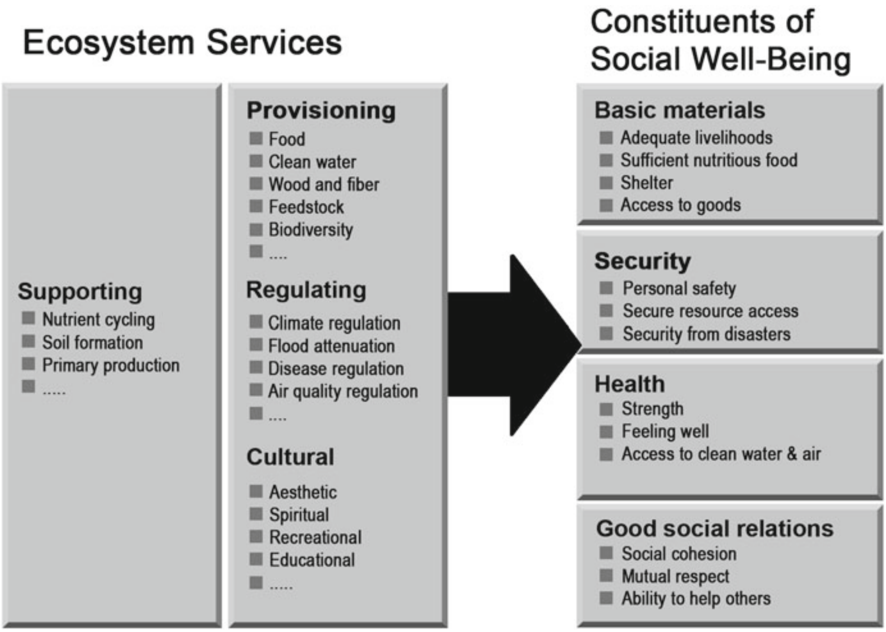

Fig. 5.2 Ecosystem services are benefits people obtain from ecosystems which in turn support components of human social well-being. Other human factors (e.g., economic, social, technological, cultural) also influence social well-being and feedback to affect ecosystems and ecosystem services (feedback not shown) (Adapted from Millennium Ecosystem Assessment 2005)

these landscapes, while maintaining most of the existing agricultural socio-ecological system. In this way, forest restoration can provide a balance between social acceptance and alleviation of environmental issues.

In this chapter, we describe how natural science and social science principles can be integrated to help resolve the trade-offs and challenges of restoring forest ecosystem services to agricultural landscapes.

5.2 Integrating Natural and Social Sciences

Restoration of forest ecosystem services in agricultural landscapes may not require restoration of large forest tracts. Small forest patches and strips, and even individual trees, restored in the right places and configurations can restore significant levels of forest functions that are associated with larger forest tracts (Garrett et al. 2000; Green et al. 2005; Nair et al. 2005; Breshears 2006; Manning et al. 2006; Benayas et al. 2008). Consequently, restoration of forest in relatively small, strategic locations may enable finding an acceptable balance among the many demands placed on agricultural landscapes.

Finding that acceptable balance, however, requires integrating natural and social science principles with a planning process whereby people set goals and make decisions that most, if not all, can agree on. Decisions must be made about where restoration should take place in the landscape, the size of the restoration zone, and specifics of vegetation design and management of these forest areas. Since successful restoration will require local landholders to be motivated to implement restoration plans, public goals for the provision of forest ecosystem services must be considered along with personal objectives of each individual landholder. Goal-setting, design development, and decision-making is facilitated by a participatory planning process involving local and public stakeholders that are informed with natural resource principles. Achieving restoration success, then, requires integrating natural and social sciences in a way that produces efficient and effective landscape management plans and encourages their implementation.

5.2.1 Natural Sciences – Riparian Zones and Continuity

Riparian areas are portions of landscapes where forest restoration can be especially effective for enhancing important ecosystem services, including cleaner water, and more fish and wildlife, among others (NRC 2002; Naiman et al. 2005). Riparian areas are lands adjacent to streams and lakes. In riparian areas, there is a high degree of interaction with the adjacent waterways. Riparian areas are flow-through zones for runoff from uplands, for channel-hyporheic interchange, and for overland flow by floodwaters that affect both water supply and water quality in adjacent waterways. Riparian vegetation contributes detritus to streams that creates structural habitat and fuels the aquatic food chain. Riparian areas have particularly high-value as habitat for terrestrial wildlife because of the close availability of water and the network pattern through landscapes that promote migration of wildlife between seasonal habitats and dispersal from population centers. For example, riparian areas constitute probably less than 5% of the total land area in the U.S., but are disproportionally effective lands for providing forest ecosystem services (NRC 2002; Naiman et al. 2005). Because of these special qualities, riparian zones are uniquely capable of producing high levels of multiple ecosystem services in otherwise nonforested landscapes.

A riparian forest buffer is a strip of forested area that separates and helps protect streams and other water bodies from negative impacts of adjacent land uses and for the provision of non-agricultural ecosystem services in agricultural landscapes (Welsch 1991). It is a restoration practice commonly designed for and managed to enhance water quality, aquatic habitat, and to increase wildlife populations (NRC 2002). Riparian forest buffers can also help to create visually pleasing landscapes and to provide erosion control among other benefits (Ryan 1998; Naiman et al. 2005). Even narrow buffers can have a large impact on water quality and wildlife in agriculture-dominated landscapes. For example, water quality and wildlife habitat can be substantially improved by forested buffers as narrow as 30 m (Welsch 1991; Sweeney 1993; Lowrance et al. 1995; Wenger 1999; Dosskey 2001; Kennedy et al. 2003). Since riparian areas occupy only a small fraction of the total landscape, forest restoration through the establishment of forested riparian buffers represents an area-efficient strategy for restoring forest ecosystem services to agricultural landscapes (NRC 1993).

5.2.2 Connecting Fragments Using Riparian Buffers

A key principle of enhancing ecosystem benefits using riparian buffers is the restoration of their continuity through the landscape. Continuity is critical for intercepting and filtering polluted runoff water and for providing corridors for the movement of wildlife (Welsch 1991; Crooks and Sanjayan 2006). In most agriculture-dominated landscapes, fragments of original or degraded forest remain; some in riparian areas and some in uplands. While these remnant forest patches may provide a modicum of ecosystem services, the gaps between them prevent them from achieving their full potential. By reconnecting existing forest fragments with a focus on restoring continuity through riparian zones, water-filtering and habitat-producing ecosystem services, as well as others, can be efficiently restored in a developed landscape.

A few additional ecological principles can help to identify locations for and designs of riparian buffers that will restore specific ecosystem services with even greater efficiency (Boxes 5.1 and 5.2). Individual locations vary in their capability of restoring certain ecosystem services because of topography, hydrology, or other site factors so the design of a riparian buffer can also vary from one location to another. For example, a habitat gap may represent a particularly efficient location for enhancing wildlife production (Box 5.2). However, a different location may intercept greater pollutant load and a widening of an existing buffer may be required for adequate water quality control (Box 5.1). Ecological principles for addressing other natural resource issues and ecosystem services can be added to these, if desired; the descriptions of which can be found in Dramstad et al. (1996) and Bentrup (2008). While the ecological principles outlined here indicate ***what*** can be done to efficiently restore important forest ecosystem services in developed landscapes, social science principles are necessary to determine ***how*** to encourage landholder acceptance and adoption in order to achieve implementation and sustainable results.

Box 5.1 Principles for Guiding Riparian Forest Restoration for Water Pollution Reduction

- Locate restoration areas where they will connect existing riparian forest fragments and extend the length of continuous forest along waterways and shores.
- Size restoration areas to be larger/wider at locations that intercept greater runoff load (Fig. 5.3).
- Size restoration areas to be larger/wider at locations that have steeper slopes or that have soils with lower infiltration capacity.
- Design forest plantings to promote denser herbaceous cover at locations that intercept greater overland flow.
- Select tree species that tolerate flooding for use on low floodplains and to stabilize eroding stream banks.

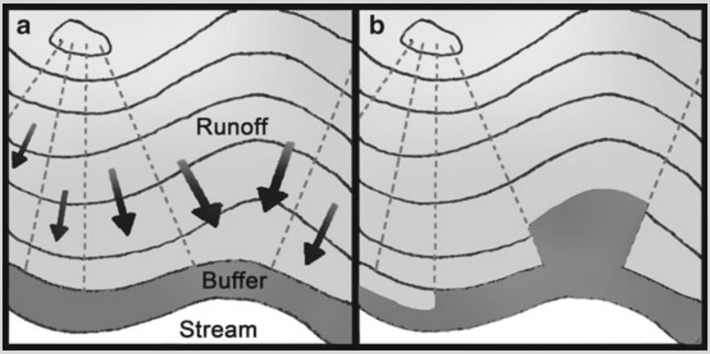

Fig. 5.3 Runoff is often non-uniform and flow is either diverging or converging due to topography, tillage practices and other factors. A fixed-width buffer will be less effective in these situations (**a**). Riparian buffer areas receiving greater runoff loads should be enlarged to intercept these greater loads (**b**)

Box 5.2 Principles for Guiding Riparian Forest Restoration for Terrestrial Wildlife Habitat Enhancement

- Locate restoration areas next to existing forest fragments to enlarge existing habitat areas and to connect fragments.
- Locate and shape restoration areas so that, when combined with existing fragments, they create block-shaped patches for promoting interior forest species, elongated patches for promoting edge species, or corridors for connecting habitat patches across the landscape.
- Select tree species, spacing, and management that create appropriate forest structure for enhancing desired species of wildlife.
- Locate forest restoration areas away from important grassland habitat areas.
- Restore gaps along larger streams first to provide the greatest overall benefit for wildlife (Fig. 5.4).

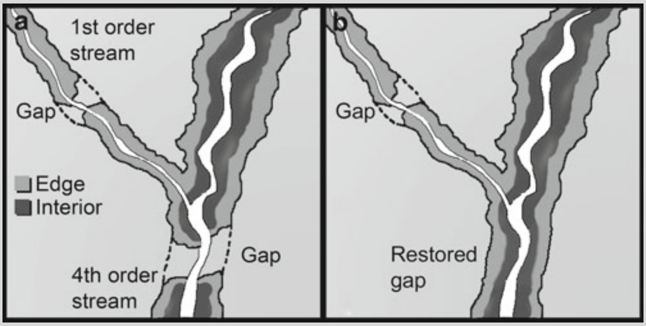

Fig. 5.4 Gaps in riparian vegetation along streams of all sizes are common in agricultural landscapes (**a**). Gaps along larger or higher-order streams should often be restored first to provide the greatest overall benefit for wildlife. These riparian zones have less negative edge effects and are more important regional corridors for wildlife movement (**b**)

5.2.3 Social Sciences – Encouraging Acceptance and Adoption of Riparian Buffers

Human values, attitudes, and perceptions play a critical role in how people create and maintain the landscapes in which they live and work. Any effort to create and maintain riparian forests on agricultural lands must appeal to this local social dimension in order to be successful (Parren and Sam 2003; Dutcher et al. 2004; Blay et al. 2008; Rosenberg and Margerum 2008; Schaich 2009). For example, one commonly held value among farmers in the United States is that good land stewardship is demonstrated by maintaining one's property in a clean and manicured manner (Nassauer 1988). Care for agricultural land is represented by visual cues such as straight crop rows, lack of weeds, mowed areas, and general landscape uniformity. Natural riparian forests with their meandering curves, downed woody debris and general lack of uniformity are often perceived by U.S. farmers as unmanaged and messy and hence do not represent the farmers' concept of good land stewardship (Ryan 1998; Ryan et al. 2003). Consequently, there is resistance from farmers to implement and maintain natural looking riparian forest buffers. To overcome this barrier, visual cues of care need to be incorporated into the design and management of a riparian forest buffer (Nassauer 1995).

Different values and concerns may exist in local agricultural communities that can lead to opposing views of forest restoration efforts (Parren and Sam 2003; Sullivan et al. 2004; Schaich 2009). For instance, riparian restoration is being used to create a network of forest corridors in West Africa to sustain isolated populations of forest elephants (*Loxodonta africana*). Some streamside villages showed strong interest in restoring riparian forest which they believe would resolve some of their water and fishing problems during the dry season while other villages in the area were opposed to any reforestation options as it means losing agricultural land (Parren and Sam 2003). In addition, some villagers have negative attitudes towards creating elephant habitat because elephants raid crop fields and can kill people (Gadd 2005). Restoration planners need to be cognizant of the full range of values, attitudes, and perceptions that stakeholders can hold towards forests and forest restoration and avoid oversimplifying their social concerns if they have hopes of creating locally supported restoration plans.

Additional social considerations may also need to be addressed in order to facilitate acceptance and adoption of riparian forest buffers (Schrader 1995; Rhodes et al. 2002; Ryan et al. 2003; Sullivan et al. 2004). Some countries have government agencies or non-profit organizations who offer financial incentives to landholders to encourage adoption. However, many landholders have concerns that riparian forest buffers will not provide any productive value after the incentives are gone and that these landscape elements will hinder farming operations. A few common social science principles related to location and design of buffers that may overcome such resistances to acceptance and adoption are listed in Box 5.3. A more exhaustive list can be found in Kaplan et al. (1998) and Bentrup (2008). By understanding these social dimensions, plans for riparian forest buffers can be modified to alleviate local social concerns while still creating a riparian forest design that is capable of providing the desired ecosystem services.

5.3 Landscape Planning to Achieve Forest Restoration Goals

Enhancing ecosystem services by restoring forest on agricultural lands often requires a larger planning area than individual farms and other agricultural landholdings. Coordinated and cumulative action on several farms is often necessary to achieve desired levels of ecosystem services. To accomplish this task, a multi-scale planning process is needed to pull together concerns and goals of individual landholders and the general public while accounting for opportunities and constraints dictated by the existing landscape. A planning process facilitates setting goals and making decisions about actions that will achieve those goals. A planning process also helps identify specific areas in the landscape to target riparian forest buffers where they will generate relatively greater ecological benefit at lower economic costs (Walter et al. 2007).

There are many ways to go about planning. In agricultural landscapes, the decision about whether to implement and maintain any restoration action often rests with many independent farmers and landholders. Even if there are public regulations concerning the placement and design of riparian buffers, an effective planning process is still necessary to reconcile and balance public goals embodied in the regulations with different goals of landholders. Some characteristics of a planning process that will do this include comprehensiveness, flexibility, scalability, and stakeholder involvement. A planning process needs to be comprehensive to address a wide range of issues and landscape conditions while being flexible enough to accommodate each decision-maker's (i.e., landholder) unique set of circumstances. For example, landholders are more willing to accept and implement a riparian restoration plan that is tailored to their needs rather than to an arbitrary and rigid set of buffer width standards (Dutcher et al. 2004). A multi-scale approach is required because each objective (e.g., farm economy, watershed water quality, landscape wildlife populations) is addressed at its own scale and each riparian buffer function operates at its own scale.

Box 5.3 Principles for Guiding Riparian Forest Restoration to Encourage Landowner Acceptance and Adoption

- Design the part of the restoration area viewable by public to be visually pleasing while the interior can be designed to achieve the desired ecological functions.
- Use selective mowing to indicate stewardship without greatly reducing the ecological functions.
- Provide visual frames to contain and provide order around the restoration area (e.g., wooden fence).
- Use interpretative signage and education programs to increase awareness and preference.
- Enhance visual interest and diversity by increasing seasonal color and by varying plant heights, textures, and forms while maintaining an overall sense of order.

(continued)

Box 5.3 (continued)

- Provide options for landowners to derive economic or personal products from the restoration area (i.e., fruit or nut products, hunting leases, decorative woody stems for floral industry).
- Allow the riparian zone to be "squared off" to facilitate farming operations (Fig. 5.5).

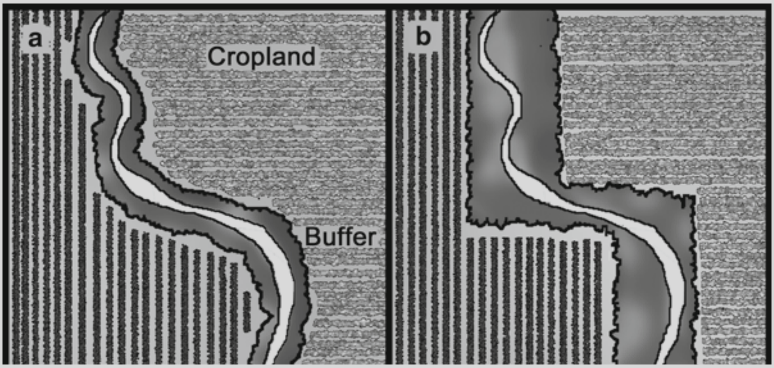

Fig. 5.5 A curving riparian buffer can hinder mechanical farming operations (**a**). The riparian buffer zone can be "squared off" to facilitate farming operations without significantly reducing ecological functions (**b**)

A key component of a planning process for forest restoration is local and public stakeholder participation throughout the planning, design, implementation, and management stages (Selin and Chavez 1995; Bentrup 2001; Blay et al. 2008). Because riparian areas by their nature cross many landholdings and influence factors well beyond their vegetative boundaries, stakeholders throughout the watershed or wildlife area need to be involved. One of the valuable aspects of a participatory-type planning process is to have face-to-face dialogue between stakeholders to learn about the commonalities and differences in their goals, expectations, and tolerances for riparian buffers (Gray 1989). This dialogue is essential because of the inherent differences between stakeholders. For example, the general public often desires wider riparian buffers while farmers desire narrower buffers (Sullivan et al. 2004). These types of differences can often be resolved through collaborative interaction and an acceptable and shared vision can be established for a sustainable network of riparian buffers (Averitt et al. 1994).

A multi-scale planning process that exhibits these characteristics has been suggested specifically for riparian buffer planning (Bentrup et al. 2003). It involves three basic components: regional reconnaissance, landscape-scale assessments, and site-scale buffer plans. A series of questions assists stakeholders through the process and provides specific but flexible guidance for analyzing resources and developing plans (Steinitz 1990; Smith and Hellmund 1993).

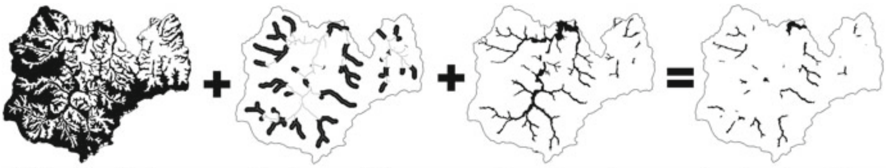

Fig. 5.6 Landscape assessments for sediment trapping, riparian connectivity, and woody florals are combined to determine where all three objectives can be achieved with a riparian forest buffer (Source: Bentrup et al. 2008)

5.3.1 Reconnaissance and Landscape Assessments

The regional-scale reconnaissance provides a quick overview of environmental conditions and resource issues. Often, riparian buffer planning efforts are focused on a single problem. However, by looking at the regional context, stakeholders are encouraged to consider multiple resource issues and to capitalize on capabilities of buffers to address several issues simultaneously. Some questions to answer with the reconnaissance include: What are the main resource issues in this region? What ecological and social processes are influencing these issues? What forest ecosystem services need to be restored to address these issues?

Based on the reconnaissance, more detailed landscape-scale assessments are conducted to describe existing resource conditions and trends of interest and to identify opportunities to enhance ecosystem services with strategically-placed riparian buffers. Questions that need to be answered at this stage include: Is the riparian landscape functioning well? How might the riparian and upland landscape be altered to improve functions? The natural science principles described earlier can be used during the landscape assessment process to help identify locations to target riparian buffers to achieve effectiveness and economic efficiencies. Geographic information systems (GIS) are useful for managing, processing, and analyzing spatial information in a visual manner that facilitates communication between stakeholders. With GIS, landscape assessments can be combined to identify locations where multiple objectives can be achieved with riparian buffers, allowing stakeholders to focus on potential opportunities rather than just resource problems (Fig. 5.6).

Armed with information produced through regional reconnaissance and landscape assessments, stakeholders can develop a shared vision for what they want to achieve and general options for how and where to attain their goals. These assessments provide the landscape-scale context for developing site-scale riparian buffer plans.

Fig. 5.7 Existing agricultural stream lacking a riparian forest buffer (**a**). A visual simulation of a proposed riparian forest buffer (**b**) (Photo credit: NRCS Simulation by Robert Corry)

5.3.2 Site-Scale Buffer Plans

The site-scale planning and design component blends the public goals identified in the landscape-scale assessments with individual landholder objectives and site conditions. The site-scale process is guided by the same questions used in the landscape-scale assessments but are applied to a specific landholder's site. The natural and social science principles described earlier are used to craft riparian buffer design alternatives that solve landholder resource issues and that are also acceptable to a landholder's set of attitudes, values, and perceptions. The design alternatives provide detailed recommendations on location, size, configuration, plant species and composition, and management practices.

An effective method for communicating and evaluating alternative riparian buffer designs is through photo-realistic simulations (Fig. 5.7). The communicative and non-threatening nature of simulations encourages stakeholders to actively participate in the design process and to offer feedback on the alternatives. Using simulations in participatory planning greatly increases a sense of ownership in the plan, which leads to enhanced acceptance and adoption of the proposed action (Al-kodmany 1999). If there is no regulation requiring riparian buffers, landholders maintain the right to decide if they want to implement a riparian buffer or not on their landholding. Resources and tools for planning, designing, and managing riparian buffers, including GIS-based methodologies and visual simulation software are listed in the Restoration Planner's Toolbox (Box 5.4).

Box 5.4 Restoration Planner's Toolbox

Natural and Social Science Principles

Landscape ecology principles in landscape architecture and land-use planning. Dramstad WE et al. (1996) Island Press, Wash DC

Conservation buffers: design guidelines for buffers, corridors, and greenways. Bentrup G (2008) US For Serv South Res Sta, Asheville, NC http://bufferguidelines.net

With people in mind: design and management of everyday nature. Kaplan R et al. (1998) Island Press, Wash DC

Planning, Design, and Management Resources

Riparia: ecology, conservation, and management of streamside communities. Naiman RJ et al. (2005) Elsevier Academic Press, New York

Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers. Palone, R, Todd, A (1998) US For Serv Northeast Area, State & Private For, Nat Res Conserv Serv, Coop State Res Educ Ext Ser http://www.treesearch.fs.fed.us/pubs/10519

Conservation corridor planning at the landscape level: managing for wildlife habitat. Johnson CW et al. (2000) US Dep Agric, Nat Res Conserv Serv, Wash DC ftp://ftp-fc.sc.egov.usda.gov/WHMI/NBHpdf/nbh613.pdf

Designing greenways: sustainable landscapes for nature and people. Hellmund P, Smith D (2006) Island Press, Wash DC

The community visioning and strategic planning handbook. Natl Civic Leag Press http://www.ncl.org/pdfs/community%20visioning.pdf

Regional Reconnaissance: Online Atlas

National atlas of the United States. http://www.nationalatlas.gov/index.html

Landscape-Scale Assessments: GIS-based Methodologies

Improved indexes for targeting placement of buffers of Hortonian runoff. Dosskey M et al. (2011) J Soil Water Conserv 66:362–372

Where should buffers go? – modeling riparian habitat connectivity in northeast Kansas. Bentrup G, Kellerman T (2004) J Soil Water Conserv 59:209–213 http://www.unl.edu/nac/research/2004riparianconnectivity.pdf

Agroforestry: mapping the way with GIS. Bentrup G, Leininger T (2002) J Soil Water Conserv 57:148A–153A http://www.unl.edu/nac/research/2002agroforestrygis.pdf

(continued)

Box 5.4 (continued)

The role of GIS in selecting sites for riparian restoration based on hydrology and land use. Russell G et al. (1997) Restor Ecol 5(4S):56–68

Site-Scale Design: Resources and Tools

CanVis visual simulation kit. Software and guidebook for creating photo-realistic visual simulations http://www.unl.edu/nac/simulation/index.htm

**Buffer$**. An economic tool for analyzing the costs and benefits of buffers. http://www.unl.edu/nac/buffer$.htm

Riparian buffer design guidelines for water quality and wildlife habitat functions on agricultural landscapes in the Intermountain West. Johnson C, Buffler S (2008) US For Serv Rocky Mtn Res Sta, Ft Collins, CO http://www.treesearch.fs.fed.us/pubs/29201

A design aid for determining width of filter strips. Dosskey M (2008) J Soil Water Conserv 63:232–241 http://www.unl.edu/nac/research/2008bufferwidth.pdf

PLANTS. An online plant database for the U.S. and its territories. http://plants.usda.gov/

Productive conservation: growing specialty forest products in agroforestry plantings. Josiah S (2001) U of Nebraska Ext, Lincoln NE http://www.unl.edu/nac/morepublications/sfp2.pdf

5.4 Management Considerations to Achieve and Maintain Goals

Since restored riparian forests are features in an agricultural landscape that are designed to yield specific ecosystem services, some level of active management will be required to optimize and maintain these services. The type and intensity of management will depend on which services and the desired level of attainment of those services (Box 5.5). For example, obtaining a 30% reduction in sediment and nutrient transport through a riparian zone will require some harvesting and some sediment removal to achieve and maintain this level of functioning. Higher levels of sediment and nutrient reduction may require more frequent actions. Other services, like forest habitat creation, may require minimal management activity, such as occasional pruning and weed control to maintain the necessary vegetation structure. Management activities may extend into existing riparian stands to enhance their function for those services as well.

Management needs to be coordinated so that a treatment activity used to achieve one goal does not inadvertently compromise the accomplishment and sustainability of another goal. For example, harvesting biomass for fuel could negatively impact forest habitat. Temporal and spatial considerations should also be factored into the development of a management plan. Management activities may need to be restricted during certain times of the year or limited to a part of the riparian zone each year to ensure some portions remain undisturbed at all times. Management must ultimately respond to the farmer's or landholder's attitudes, values, and perceptions so that the riparian restoration compels sustained management attention over time and gains in ecosystem services will not be lost (Nassauer et al. 2001).

5.5 Conclusions

Restoring forest ecosystem services to agricultural landscapes is a daunting challenge that stems from the unfeasibility of converting large tracts of food-producing land back into forest, and, of converting farmers and farming communities to forestry. Resolving these issues requires finding a balance between public goals for food and ecosystem services as well as landholder and community goals which often include continued farming. Natural science principles suggest that an appropriate balance may be possible through the use of riparian forest buffers. Riparian areas occupy a small portion of landscapes and can produce high levels of multiple ecosystem services. Principles for guiding riparian restoration for water pollution reduction and for terrestrial wildlife enhancement are used to illustrate how natural and social science information can influence design and management. Additional ecosystem services also can be effectively restored by applying similar sets of basic scientific principles. Achieving those services, however, will require that landholders and communities accept and adopt riparian forest buffers. Coordinated and cumulative action on several farms or other landholdings is often necessary to achieve desired levels of ecosystem services. A multi-scale planning process is important for integrating both natural and social science principles in a way that produces effective restoration plans and encourages their implementation and maintenance.

5.6 Management Implications

Restoration of forest ecosystem services in agricultural regions involves many challenges and tradeoffs. Successfully navigating these difficulties and achieving success often requires careful planning that includes:

- Recognition that the ultimate goal of forest restoration is improved social well-being. Forest restoration is a means for restoring ecosystem services toward achieving that goal.

- Riparian zones can be particularly effective and efficient for restoring a wide variety of forest ecosystem services.
- A restoration plan must be based on sound natural science principles.
- A restoration plan must accommodate the needs of the farmers and landholders who will implement and maintain the restored areas.
- The optimum size, shape, and level of connectivity to which riparian zones must be restored will depend on the specific objectives, opportunities, and constraints presented by each landscape and social setting.

Box 5.5 Principles for Managing Riparian Forest Restoration for Water Quality and Terrestrial Wildlife Habitat Enhancement

- Remove any accumulated sediment that prevents runoff from flowing directly into the riparian zone (Fig. 5.8).
- Periodic harvest of green vegetation will remove nutrients captured in the riparian zone and promote vigorous new growth for sustaining nutrient uptake.
- Some overstory vegetation removal may be necessary to maintain dense herbaceous cover to sustain filtering processes.
- Avoid vehicle traffic in the riparian zone which can cause compaction and reduce infiltration capacity.
- Manage vegetation to create the vegetative structure to support the desired wildlife species.
- Avoid working in the riparian zone during peak breeding season.
- Harvesting of vegetation should occur on a rotational basis to ensure that some portion of the riparian zone remains undisturbed at all times.

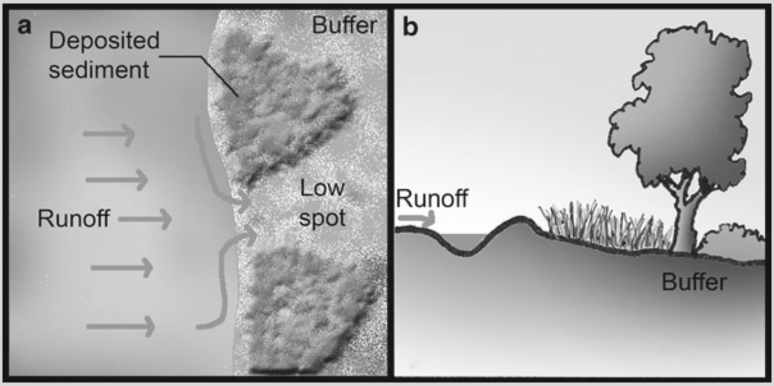

Fig. 5.8 Remove deposited sediment that concentrates runoff flows (**a**). Remove any ditch or berm that prevents runoff from flowing directly into the buffer (**b**)

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