GUEST EDITORIAL

WORKING TREES: SUPPORTING AGRICULTURE AND HEALTHY LANDSCAPES

JR Brandle[1] & MM Schoeneberger[2]

[1]*School of Natural Resources, University of Nebraska, 407 Hardin Hall, Lincoln, NE, USA 68583-0974; jbrandle@unl.edu*
[2]*Research Program Lead, US Forest Service, USDA National Agroforestry Center, 1945 N. 38th St. Lincoln, NE, USA 68583-0822*

By 2050 the population of the earth will approach 9 billion, give or take a few 100 million individuals. Many of these people will be in tropical regions and all will need food, clothing, shelter and fuel. For many, that fuel will continue to be wood. For some, the choice to burn wood will be by necessity; for others, the choice may be selecting a renewable energy source. In either case woody species and agricultural lands will be in demand, atmospheric carbon concentration will continue to rise, wilderness areas will be reduced and carbon stored over the past several hundred years will be released.

As countries struggle to provide food, fibre and fuel for their citizens, land clearing for agricultural purposes is likely to expand dramatically, putting additional stress on forests and grasslands of the world. This stress will most likely be greatest in tropical areas where vast expanses of native forest and grassland still exist. As the extent of these natural areas diminishes, biodiversity and associated ecosystem services will be threatened to a level never seen before. Much has been written about this dilemma but little has been done to mitigate human impacts. Societies must begin to recognise the demands being placed on natural and agricultural ecosystems and develop practices that can provide for the needs of people while protecting the very biodiversity upon which our future rests.

The traditional definition of a native forest (or grassland) is a large extensive ecosystem dominated by a distinct community of species. These ecosystems exist around the world and are primarily composed of an array of species adapted to the specific site conditions of the region. In the case of forests, most people hold a traditional view of these ecosystems as producing various wood and non-wood products, from traditional timber products such as lumber and pulp to fruits, fibres, resins and fuelwood. Some will recognise the many services provided by forests, from clean water, wildlife habitat and recreation to, more recently, serving as a sink and storehouse for carbon and a source of oxygen. In addition to these traditionally recognised services, society is beginning to assess the inherent value of the potential genetic resources contained within the biodiversity of these systems. While the societal needs—production of food, feed, fibre and fuel and conservation of natural resources—are clearly linked, their attainment tends to be antagonistic rather than complementary. The challenge for resource managers is to develop management strategies that support both sets of needs and that lead to an optimal balance among the demands of production, natural resource conservation and, ultimately, the health and sustainability of both forest and agricultural ecosystems.

Two approaches for meeting these competing demands, originally proposed by Waggoner (1996), were recently discussed by Green et al. (2005) and more recently by Fischer et al. (2008) and Quinn et al. (2012)—land-sparing agriculture and wildlife-friendly agriculture. In the former, agriculture is intensively practised on highly productive lands while native forest stands and grasslands are protected from development. A wildlife-friendly farm uses practices that minimise the environmental impacts of farming and incorporates non-crop areas within the farm landscape. Both approaches have value for linking future food production and protection of wild areas. The roles that forest science and assistance can play in the former approach are readily apparent. However, less recognised are the roles they can and perhaps should play in the latter—in essence, the use of forest science and assistance on the farm. Here we discuss a series of specific management options for wildlife-friendly farming systems collectively known as agroforestry—the integration of woody species into the farming system in order to enhance overall productivity, biodiversity and resilience to disturbance and climate shifts.

The term agroforestry means many different things depending on where it is being practised. According to Nair (1993), agroforestry is the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals. This definition implies:

1. two or more plant/animal species, one of which is woody,
2. two or more outputs,
3. a cycle of more than one year and
4. an ecological and economical complex system.

We suggest a more broadened and applied approach to integrating woody plants on the farm—the idea of *Working Trees*—a term coined by Gerald Bratton, a forester with the USDA National Agroforestry Center about 20 years ago. *Working Trees* are defined as woody plants integrated into the agricultural production system to provide various environmental services to cultivated ecosystems and the people who manage them. Under this broadened context, there are obviously a number of different categories or types of woody-based practices that might be used, from management of small, naturally occurring plantings within the farming landscape to a number of more 'designed' tree-based plantings. For the purposes of this commentary, we are focusing just on the 'designed' tree-based plantings and specifically only on two practices within this group: windbreaks (also called shelterbelts) and riparian forest buffers. In both of these practices, the main benefits flow from the ecosystem services which they provide and not necessarily from any marketable products they are capable of producing.

Windbreaks are defined as linear barriers of trees and shrubs purposely planted to protect crops, animals and people from strong winds. Riparian forest buffers are curvilinear barriers of trees and shrubs located along streams and waterways purposely established in many regions to protect and enhance surface water quality properties. These two practices are effective worldwide (Brandle et al. 1988, Garrett 2009).

There are three main types of windbreaks providing direct economic benefits to commercial agricultural production systems: field windbreaks to protect crop fields, livestock windbreaks to protect grazing animals and farmstead windbreaks to protect the farmyard and working area of the farm. In all of these cases, planting less than 5% of the land base to windbreaks results in direct economic returns to the farmer because of increased production and/or reduced input costs that generally exceed any revenue loss from land removed from active production. All three types can be viewed as small 'designer' tree-based features that, with the correct use of forestry science and assistance, can provide 'forest-derived' services in support of agricultural goals.

Field windbreaks are instrumental in controlling wind erosion, a service that we may well expect to grow in demand based on predictions for increased frequencies and intensities of weather extremes, including droughts. Within the protected zone of a windbreak, wind erosion is reduced or completely controlled. Controlling wind erosion helps maintain the productivity of the site; reducing both future input costs and immediate damage to crops. Further, the benefits from reducing wind erosion extend far beyond the farm boundaries. According to Huszar and Piper (1986), off-site costs associated with blowing dust are far greater than on-site costs. In this case, the environmental costs of agriculture are borne by society and not the producer. Controlling wind erosion with windbreaks on the farm can therefore be used to create a service valued by the producer, by the surrounding population, and by those who will be reliant on the future productive capacity of this system.

Livestock already faces periods of temperature extremes that affect their productivity and survival. Climate projections suggest livestock will be facing even greater frequencies and intensities of these thermal extremes. Windbreaks designed to protect livestock improve the living environment of the animals through microclimate modification. Placed correctly, shelter can lead to increased feed efficiency, reduced feed inputs, faster weight gain, improved animal health, protection of newborn animals and extended growing windows of forage production. In addition, protection of livestock buildings by windbreaks for microclimate control can help producers ameliorate odour problems, thereby reducing potential conflict with neighbours while at the same time adding diversity to the agricultural landscape.

While the economics and many of the non-market values of windbreaks are relatively straight forward, putting a value on benefits flowing from riparian forest buffers is more difficult. The ecological values of these systems, especially the biological diversity they add at the land–water interface are well recognised. However, how much a producer or society values or is willing to pay for these environmental services is difficult to discern. Runoff from agricultural fields and pastures often contains sediment from the field, pesticides, fertilisers and livestock manure. Environmental costs of sediment and chemical transport from agricultural fields are externalised, in this case falling to society and not necessarily the producer. Installation of a properly located and constructed riparian forest buffer within a farm can provide water quality benefits by intercepting and bio-filtering of runoff from adjacent areas. Again, putting the proper forest science to use, riparian forest buffers designed for water quality purposes can also be designed and managed to lower in-stream water temperatures, provide food for numerous aquatic invertebrates and generally improve in-stream habitat for other aquatic species. One should expect that as accessibility to farm chemicals and pressures to expand production on farmlands increase, the need for these services will likewise increase.

So far, we have focused predominantly on what might be considered the direct benefits of windbreaks and riparian forest buffers. However, incorporating *Working Trees* into agricultural production systems for purposes of supporting agriculture will, regardless of intent, also provide numerous ecosystem services of value to society. Our discussion here will consider two additional services of growing significance that *Working Trees* can provide to society while producing those other services mentioned above: carbon sequestration and wildlife habitat. These services are provided at little or no cost to the vast majority of beneficiaries and, in most cases, are taken for granted by the public.

Protection of existing forest lands and planting new forests are two important actions for addressing atmospheric carbon dioxide levels. Small *Working Tree* plantings that augment forest-derived services for fuel or other wood products should result in reducing pressures on existing forests, thereby protecting the vast stores of carbon these systems have already captured. Afforestation or the planting of trees where trees have not been recently, holds particular promise as a significant activity for capturing new carbon. Where new plantings should go is a question that may require interdisciplinary discussions. The largest amounts of non-forest land capable of supporting significant rates of tree growth are agricultural lands. However, these lands are required now and, even more so in the future, for food production. Use of *Working Tree* practices, such as windbreaks and riparian forest buffers, provide a means of sequestering carbon on agricultural lands while maintaining the agricultural productivity of these sites and enhancing other ecosystem services of value. Trees on farms are able to do this as the amount of carbon sequestered per unit area is much greater than the majority of other practices available to agriculture. Therefore, just the 3–5% of area put into a windbreak for services other than carbon sequestration can provide a contribution to sequestration within agricultural lands.

This conversion of 3–5% of the land area to *Working Trees* also means that fewer hectares are actually farmed. Depending on the farming system, this can translate into reduced fossil fuel use, thereby reducing carbon dioxide emissions. Similarly, fewer inputs such as seed, herbicide and fertiliser will be required, further reducing overall input costs, improving overall profitability and reducing agriculture's contribution to greenhouse gas emissions.

Agricultural expansion and urban sprawl are already adding to the high level of fragmentation of natural areas and loss of diversity required to support wildlife. *Working Trees* on farms, especially the linear plantings such as windbreaks and riparian forest buffers, can provide many critical wildlife services from feeding, migration stopover and roosting habitat to creating vital travel corridors. In the larger societal sense, this can contribute to species conservation, but at the local sense, it can provide habitat to foster natural enemies of crop pests. Studies have demonstrated the value of woody habitat for various insectivorous bird species (Puckett et al 2009) and predatory insects (Dix et al. 1995). Due to the growing decline in bee colonies worldwide and the concern that shifting climate may further exacerbate this decline, researchers are evaluating the design and use of *Working Tree* plantings to contribute to the protection and enhancement of pollinators, especially for native bee species. Considerations may be as simple as locating a small refugia of woody plants within a large expanse of a crop monoculture, to specific selection of species to serve as a food source for pollinators or management practices to maintain ground-dwelling habitat. The importance of these wildlife services from *Working Tree* plantings in agricultural lands will increase as weather extremes and climate shifts occur.

Society expects agriculture to produce greater amounts of food and fibre while maintaining the vast array of ecosystem services. The potential benefits from trees on farms are many and include practices beyond just the windbreak and riparian forest buffer practices described here. Realising the potential of *Working Trees* is a function of integrating trees into agricultural productions systems in ways that valued services can be achieved. Regardless of the approach, we must recognise that many questions remain. What are the specific pros and cons of the various approaches? What are the habitat requirements for local and migrant wildlife? Are working tree plantings inherently stable as a long-term contribution to landscape multifunctionality, including effective biodiversity conservation? Is society, especially farmers, willing to face the challenges of changing paradigms? We do not have answers to these questions with regard to management of our agricultural operations and lands but we do know that these questions need to be comprehensively addressed soon. *Working Trees* have the potential to play a vital role in building more climate-resilient and profitable agriculture that also supports the many other services we value from these lands. However, realising this potential means both foresters and forest science will need to be involved in helping to build the tools needed in the climate–smart agricultural toolbox.

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James R Brandle *Professor of Agroforestry at the University of Nebraska–Lincoln (UNL) since 1975 and leads the program in windbreak ecology at UNL.* ***Michele Schoeneberger****, a US Forest Service researcher since 1985, is Research Program Lead and Soil Scientist at the National Agroforestry Center in Lincoln, Nebraska.*