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# Agroforestry as an Integrated, Multifunctional Land Use Management Strategy



Agriculture is in the midst of a 21st century technological revolution, and we are well into the digital age of farming. The development of agriculture over 10,000 yr, including the technological advancements of the 20th century, has helped push the world population to 7.5 billion, with projections of 9.8 billion by 2050 (Searchinger et al., 2018). While the Green Revolution has helped to feed billions of people, the global environmental footprint of modern agriculture threatens the very existence of the socio-ecological system in which we live (Funabashi, 2018). The natural resource base, including soil and water, that supports agriculture is experiencing immense pressure. The world is looking for sustainable solutions not only for food security but also for environmental security for the burgeoning population (Searchinger et al., 2018).

The United States led the agricultural revolution with a massive commitment to enhancing food and fiber production capabilities. The overall strategy was to become self-sufficient with respect to agricultural crops and timber while improving the health and welfare of rural Americans. Obviously, this was successful within well-defined limits—today, food remains plentiful and relatively inexpensive, the timber famine was averted, and forest and farm lands abound. Such gains, however, did not come without some high environmental costs, and by the 1970s the public was demanding more environmentally benign land use practices (Laurence, 1987).

As a consequence of the environmental transgressions committed during the construction of our industrialized nation, new criteria for defining successful land use management strategies were identified during the late 1980s (Turner, 1988). Sustainability, stability, and equability have now joined increased production efficiency as objectives for agriculture (Conway, 1987), and forestry is developing new management strategies that optimize the yield of many products and multiple uses rather than merely maximizing the production of one—timber (Coufal & Webster, 1996; Gillis, 1990; Maser, 1994). But what about the hybrid between agriculture and forestry that is practiced worldwide—integrative management systems far more common than the developed world's often myopic approach to the production of a limited number of monocultures? Many professionals believe that agroforestry is a strategy for sustainable land use management that might be useful throughout North America (Garrett et al., 1994; Gold & Hanover, 1987; Kremen & Merenlender, 2018; Wiersum, 1990).

As we have moved into the 21st century, concerns have been raised about our dependence on foreign sources of fossil fuels, and the $CO_2$ emissions from our past and continued

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use of fossil fuels have increasingly been linked to global warming issues. The production of biofuels and energy from herbaceous and woody biomass has become a major interest with increasing amounts of research funding and private investment. Agroforestry practices combining herbaceous and woody species could play an important role in both the production of biomass for biofuels and energy as well as systems that enhance the ability of agricultural cropping to sequester and store carbon without the ecological problems of currently utilized agricultural systems (Downing, Volk, & Schmidt, 2005; Feliciano, Ledo, Hiller, & Nayak, 2018; Gruenewald et al., 2007; Holzmueller & Jose, 2012; Peichl, Thevathasan, Huss, & Gordon, 2006; Schoeneberger, 2005; Volk et al., 2006; White et al., 2007).

Because of its diversity, defining agroforestry could easily occupy an entire article—in fact on a number of occasions, it has (see Atangana, Khasa, Chang, & Degrande, 2013, pp. 35–47; Elevitch, Mazaroli, & Ragon, 2018; Lundgren, 1982; Nair, Viswanath, & Lubina, 2017). Presently, the concepts and practices of agroforestry in the United States are reasonably well understood within most professional circles to include ". . . intensive land management that optimizes the benefits (physical, biological, ecological, economic, social) arising from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock" (revised from Garrett et al., 1994). In identifying a niche for domestic agroforestry, emphasis must be directed toward a practice meeting the requirements of the four I's–that is, it must be intentional, intensive, integrative, and interactive. As discussed below, the options available under this definition are many (also see Chapter 2; Gold & Hanover, 1987; Campbell, Lottes, & Dawson, 1991; Schultz, Colletti, & Faltonson, 1995). Agroforestry practices in the North America involve more than the production of single products (e.g., monoculture field crops, livestock feedlots, forest plantations, biomass plantings, etc.), the extensive collection of special forest products (e.g., floral greens, mushrooms, wild game, etc.), or the extensive grazing of livestock in woodlots or on open ranges. This is not to minimize the importance of such land uses, but each one is already well supported by an established knowledge base and a well-educated group of practicing management professionals. Combining such practices into agroforestry arrangements that are ecologically sound and economically viable is a totally different story!

Intensive production of agricultural and forestry monocultures is found in both advanced, developed countries (e.g., corn [*Zea mays* L.], soybean [*Glycine max* (L.) Merr.], pine [*Pinus* spp.], fruit and nut orchards, vineyards) and many tropical regions in the form of woody perennial tropical tree, shrub, and vine crops including oil palm (*Elaeis* spp.), rubber [*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.], tea [*Camellia sinensis* (L.) Kuntze], coffee (*Coffea* spp.), pepper (*Piper nigrum* L.), and vanilla (*Vanilla planifolia* Jacks.) (Chambers, Pacey, & Thrupp, 1989; Jha et al., 2014; Liu, Kuchma, & Krutovsky, 2018; Pacheco, Gnych, Dermawan, Komarudin, & Okarda, 2017; Richards, 1985). On the other hand, agroforestry has remained the primary land use approach most common throughout the developing world (King, 1987; Mercer, 2004), where complex indigenous farming systems for food, fiber, and forage production have operated effectively for centuries (Nair, 1993). Not only have such agroforestry systems produced a variety of commodities for home use and/or sale, it is likely that they have offered a level of environmental protection unmatched by most modern land use technologies. Such dual features—production and protection—have become the basis for the concept of sustainability, which is now central to international development activities aimed at breaking the negative feedback relationship between intensive land use and progressive environmental degradation. Similarly, concepts such as "productive conservation" and "multifunctional agriculture," which combine production agriculture with conservation by introducing more sustainable agricultural practices, are increasingly being discussed as options in more developed countries and could easily incorporate agroforestry principles (Jordan, et. al., 2007). For example, the five principles of sustainable food and agriculture defined by the FAO (2018) include: (a) increase productivity, employment, and value addition in food systems, (b) protect and enhance natural resources, (c) improve livelihoods and foster inclusive economic growth, (d) enhance the resilience of people, communities, and ecosystems, and (e) adapt governance to the new challenges.

About four decades ago, agroforestry was "discovered" by the international scientific community as a practice in search of a science (Steppler, 1987). Since that time, an increasingly extensive research base has been developing to help understand, improve, and apply indigenous agroforestry practices in developing nations of the world (Nair, 1996; Garrity et al., 2010; van Noordwijk et al., 2019). Around the same time, academics started asking how such practices might be applied in more developed countries (e.g., Campbell et al., 1991; Gold & Hanover, 1987; Lassoie, Teel, & Davies, 1991). However, agroforestry practices were not new in the temperate context either. Native Americans, across what is now the United States and Canada, have been practicing indigenous forms of what could be termed landscape-scale agroforestry for millennia (Rossier & Lake, 2014). In the early decades of the 20th century, agroforestry plantings were done in the United States and Canada in the form of windbreaks and shelter belts as a response to the Dust Bowl of the 1930s. In the temperate zone, science-based agroforestry biophysical and socioeconomic research and practice gained attention in the1980s and has strongly increased in the past 40 yr. Interest in domestic agroforestry has continued to grow, particularly as the dual needs for enhanced environmental protection and new economic opportunity have increased in importance (Brown, Miller, Ordonez, & Baylis, 2018; Garrett et al., 1994; Jose, 2009; Jose, Gold, & Garrett, 2018). The realization that agroforestry systems are well suited for diversifying farm income while providing environmental services and ecosystem benefits has increased receptivity on the part of landowners (Rois-Díaz et al., 2018) Agroforestry systems offer great promise for the production of biomass for biofuel, specialty and organic crops, pasture-based dairy and beef, among others. Agroforestry also offers proven strategies for carbon sequestration, soil enrichment, biodiversity conservation, and air and water quality improvement not only for the landowners or farmers but for society at large (Dollinger & Jose, 2018; Holzmueller & Jose, 2012; Scherr & McNeely, 2007, 2008; Udawatta & Jose, 2012).

In this chapter, we demonstrate the linkages among emerging integrated management systems for agriculture and forestry and indicate possible roles that agroforestry could play in the continuing development of these new land use strategies. Opportunities for the development of domestic agroforestry practices are identified and progress toward meeting them highlighted. Possible approaches to overcoming constraints limiting the development of agroforestry in the United States are suggested. It is our purpose to provide a framework for the chapters that follow and to stimulate creative thinking and proactive behavior by scientists and management professionals responsible for developing and implementing new land use management strategies that are environmentally, socially, and economically sustainable.

## Land use Management Systems in North America

Here we provide thoughts on new management systems that are emerging to help account for the complex demands currently being placed on the nation's rural lands. Specifically, agricultural and forestry land use practices are examined relative to certain biophysical and socioeconomic principles basic to natural resources management. We also provide a historical perspective for the evolution of forest management and agricultural production practices and for the development of domestic agroforestry activities.

### Basic Principles Influencing Management Systems

Management can be considered as the planned intervention into natural processes to assure predictable outcomes of benefit to the health and welfare of humans. Hence, sociological factors often become the driving principles determining many land use decisions. For example, a stewardship ethic that places long-term social good above short-term personal gain can move people to spend time, effort, and money assuring the ecological integrity of land they currently own. In contrast, a pioneer ethic emphasizing the immediate needs of the individual can promote destructive activities that negatively impact future generations (Nash, 1982). This anthropocentric focus for management has been challenged for decades (Stone, 1996). Obviously, different user groups can hold very different views concerning the utilization, conservation, and preservation of our natural resources, often making the social context in which land use decisions are made highly contentious.

The social context for land use decision-making is also subject to increasingly rapid change as the pace of social evolution quickens in response to increased knowledge and technological advancements. For example, this century has witnessed major changes associated with the transition from a rural to an urban society, shifts in ethnic and age structures, a move to an information-based society, and periodic resurgence in the public's interest and concern about the environment and the use of the nation's farm and forest lands. Hence, management decisions socially acceptable in one generation may not be accepted in another (e.g., clear-cutting old-growth forests, eradicating predators, or indiscriminate pesticide use).

The United States is a capitalistic society, and the economic bottom line continues to drive many decisions concerning the production of food, forage, livestock, and fiber. We have been so successful in creating a higher order of socioeconomic organization through our effective harnessing of energy that subsistence living remains for only a few in North America. Agriculture and forestry are now big businesses operating in a dynamic world economy. Fortunately, there is a sound theory base supporting our understanding of the economic variables driving capitalism, such as cost/benefit ratios, supply–demand interrelationships, and marketplace dynamics. Unfortunately, much of this neoclassical theory simplifies or neglects critical issues, such as the long-term values associated with externalities arising from sound management practices, often making it inadequate for explaining the current realities of the land use and environmental decision-making process (Daly & Cobb, 1989; Tisdell, 1990).

Nonetheless, during the past two decades there has been increased interest in internalizing the environmental costs and benefits not necessarily reflected by our market system (Mann & Wustemann, 2008; Wang & Wolf, 2019). Payments for environmental or ecosystem services have entered the discussion of policymakers at both the federal and state levels in the United States (Mercer, Cooley, & Hamilton, 2011; Potter & Wolf, 2014). We have a voluntary market for carbon offsets in the United States and a developing market for water quality credits, both patterned after what has been considered to be a successful cap-and-trade system to control sulfur dioxide emissions (Börner et al., 2017; Gordon, 2007; Jack, Kousky, & Sims, 2008; Lowrance, 2007; Palma, Graves, Burgess, van der Werf, & Herzog, 2007b; Wang & Wolf, 2019).

Land use management is inherently interdisciplinary because of the multitude of interrelated factors that must be considered when deciding how best to optimize the use of land for realizing its multiple values (Ferraz-de-Oliveira, Azeda, & Pinto-Correia, 2016; Savory, 1988; Stankey, 1996). The extent to which scientific knowledge is useful in such a decision-making process depends on its ability to deepen managers' understanding of complex systems and how to adjust them to achieve specific objectives. An interdisciplinary approach is essential to the development of such knowledge (Chubin, Porter, Rossini, & Connolly, 1986). The study of interdisciplinary land use management systems, while previously overlooked (Stankey, 1996), has become a major topic of interest in the research and development community (LaCanne & Lundgren, 2018). The "tyranny of the disciplines," while still the norm in creating institutional obstacles to effective integration (Campbell, 1986), is no longer the only paradigm being promoted and is actively being superseded during the past decade by a shift toward increased diversification of landscapes and cropping systems (Geertsema et al., 2016; Liebman & Schulte, 2015). The theoretical base for the management of complex agroecosystems often does not meet the practical needs of the field-level manager (Wezel & Bellon, 2018). This can result in mismanagement by those owning land or controlling its use—unacceptable behavior in a society that is increasingly demanding sound ecological management of its natural resources.

## Evolution of Management Systems

The United States inherited its forest management practices from Europe during the latter part of the 19th century and modified them to accommodate its large, sparsely populated country, which was rich in natural resources (Perlin, 1991; Williams, 1989). Prior to settlement by Europeans, Native Americans derived a variety of food, forage, and fiber products from forests while manipulating them primarily through the use of fire in what could be termed landscape-scale agroforestry (Carroll, 1973; Cronon, 1983; Rossier & Lake, 2014; Russell, 1982). European pioneers also derived most of their energy and construction materials from the forest (Carroll, 1973).

The Industrial Revolution brought with it new harvesting and milling technologies, which greatly enhanced the efficiency with which the nation's forest resources were exploited (Williams, 1989). Such forest practices accelerated as the population grew and became more urbanized. Around the turn of the 19th century, continuing over-exploitation stimulated public concern and the birth of America's conservation movement (Jordan, 1994), which included the development of professional forestry management agencies and academic institutions (Skok, 1996; Spencer, 1996). In 1905, the U.S. Forest Service was formally established to promote sustained-yield forestry, designed to provide wood fiber from the nation's forests forever (Steen, 1976). Conflicts over the single-purpose use of public forest lands led the U.S. Forest Service to develop its multiple-use approach to the management of national forests, which assured that, given a large enough and diverse enough land base, a full complement of forest uses could be enjoyed without conflict. Eventually, however, this approach also led to problems once the public began to question decisions being made about individual pieces of land, especially with respect to tradeoffs between wilderness preservation and timber production (Nash, 1982). Such concerns, together with a growing understanding of the impacts that plantation forestry has on biological diversity and the natural functioning of forest ecosystems, have stimulated the forestry profession to consider a new management strategy—ecosystem management—based on a holistic, integrative approach to land use (Coufal & Webster, 1996; Maser, 1994; Nunez-Mir, Iannonne, Curtis, & Fei, 2015; Probst & Crow, 1991; Stankey, 1996). Parallel to those efforts and because of the growing interest in preserving our national forests free from production activities, national forests are increasingly off limits to harvest, shifting production forestry and harvesting to private lands (Adams, Haynes, & Daigneault, 2006). Simultaneously, there is a growing public cry for less governmental regulation and a return to a conservation ethic embodied in the idea of sound stewardship (Jordan, 1994). Likewise, it took a century and a half for American agriculture to develop to the level of complexity that required an integrated management approach (National Research Council, 1989). Native Americans were hunter-gatherers, subsistence farmers, and also practiced indigenous forms of landscape-scale agroforestry (Rossier & Lake, 2014), while early immigrants were primarily hunter-gatherers and subsistence farmers (Russell, 1982). With population growth and industrial development came a growing need to improve food production capabilities and economic livelihoods of farmers to feed an ever-increasing urban society. The mid-1800s brought the development of the land grant university system and the initiation of an agricultural experiment station infrastructure that eventually built the world's greatest system for the intensive cultivation of commercial food products (National Research Council, 1996; Russell, 1982).

Domestic and global marketing uncertainties, high costs for equipment, seed, chemical and energy inputs, high interest rates, and regional identity and security issues are forcing many modern farmers to develop integrated farming systems involving the production of a variety of products. More recent public concerns about the environmental impacts of modern farming practices and food safety are prompting the development of a new management approach based on agroecology principles: alternative or sustainable agriculture (LaCanne & Lundgren, 2018; Liebman & Schulte, 2015; National Research Council, 1989, 1991, 1996) More recently, eco-agriculture and regenerative agriculture—integrating production and conservation at a landscape scale with the deliberate inclusion of perennial crops—have been put forth as new paradigms for linking production and conservation in our agricultural landscapes (Elevitch et al., 2018; Scherr & McNeely, 2007, 2008). Perennial trees and shrubs, and hence agroforestry practices, can serve important functions in such sustainable agricultural systems (Elevitch et al., 2018; Prinsley, 1992).

## Evolution of North American Agroforestry

Although not defined as such until recently (Garrett et al., 1994; Gold & Hanover, 1987; Gordon & Newman, 1997; Rossier & Lake, 2014; Sinclair, 1999; Torquebiau, 2000), agroforestry-like practices have been part of North America's heritage. Native Americans and European pioneers practiced subsistence lifestyles based on integrated land use strategies that were similar in principle to the agroforestry being practiced by indigenous populations in today's developing countries (Carroll, 1973; King, 1987; Rossier & Lake, 2014; Russell, 1982). The widespread use of these strategies, however, largely disappeared during the last century with the concurrent development of separate agricultural and forestry research and management infrastructures. Today, an integrated, subsistence lifestyle is the chosen standard of living for a few independent, free-spirited individuals and an unfortunately necessary one for the economically marginalized rural poor. A few agroforestry practices survived into the mid-20th century associated with long-established organizations (e.g., the Northern Nut Growers Association) or as culturally acceptable complements to traditional farming enterprises (e.g., maple syrup production).

Periodic agricultural disasters have stimulated unique forestry activities that can also be considered agroforestry practices. In the 1930s, the Great Depression combined with the drought-induced Dust Bowl in the Great Plains caused severe economic and environmental perturbations throughout the agricultural community and the nation. The formation of the Civilian Conservation Corps promoted many conservation activities including the planting of millions of trees as windbreaks and plantations to help protect eroding farmlands (Hudson, 1981). Such ecological problems also stimulated interest in the use and genetic improvement of nut trees to reclaim and promote production from lands marginal for conventional farming practices (Smith, 1950). The farm crisis of the 1980s was less dramatic on a large scale, but it had devastating economic and social impacts on many rural communities (Fitchen, 1991). In response, congressional actions established alternative agricultural programs such as the Conservation Reserve Program, Low Input Sustainable Agriculture (renamed the Sustainable Agriculture Program), and the Integrated Pest Management Program.

In the first decade of the 21st century, there was an increased interest in the production of biofuels and a concerted government effort to develop the technologies to make biofuels a reality. One unintended impact of the interest and support for biofuels, and particularly corn-based ethanol, has been periodic increases in corn prices in the United States and around the world, igniting a "food versus fuel" debate. High commodity prices linked to the demand for biomass feedstocks for biofuels coupled with huge demand from China also resulted in farmers opting out of conservation programs and replacing conservation acres with commodity crops, with environmental consequences including increasing sediments and chemicals entering surface and ground waters (Jordan et al., 2007).

Simultaneously, spurts of environmental consciousness by the American public have promoted alternate land use practices, often involving unique mixes of trees, food crops, and livestock by non-traditional rural landowners. For example, the 1960s spawned a group of "back-to-the-land" environmentalists desiring low-impact communal lifestyles. Although most of these groups eventually disappeared, individuals committed to integrated land use practices remained to practice their more ecosystem-friendly forms of agriculture and to develop such organizations as the Land Institute, Rodale Research Center, and Wallace Center. The fact that the Northern Nut Growers Association was founded in 1910 is a testimony to the existence of such individuals for many years.

The past 40 yr have witnessed a growing understanding of the potential usefulness of agroforestry practices in addressing today's concerns over the economic and environmental sustainability of forest and farm lands. Gold and Hanover (1987) discussed two such practices: managing conifer sawlog with cattle grazing practices (silvopasture) and multi-cropping valuable hardwoods with agricultural crops (alley cropping). There are five widely recognized agroforestry practices in the United States today: (a) alley cropping, (b) riparian and upland buffers, (c) windbreaks, (d) silvopasture, and (e) forest farming. In addition to the five recognized practices, there is an emerging agroforestry practice called *urban food forests* that has gained considerable attention in the past decade (Bukowski & Munsell, 2018). The specifics concerning these six practices are examined later in this volume. In addition, with the growing interest in terrestrial carbon sequestration and alternative fuels provided by woody and herbaceous growth, there has been increasing interest in the role of agroforestry practices to sequester and store carbon as well as systems that produce biofuels. The National Agroforestry Center has continued to add support to those practices, providing publications and guidance to landowners and practitioners (Schoeneberger, 2005; USDA, 2015, 2019). Much progress has been attained toward the building of research, education, and application for domestic agroforestry that will foster the development of these practices (Gold, 2007; Gold, Hemmelgarn, & Mendelson, 2019; Gold & Jose, 2012). However, before discussing these concepts relative to the challenges still facing the development of agroforestry in the United States, we must first provide an appropriate context by considering opportunities for its development.

## Opportunities for Agroforestry

There is a range of opportunities for the development of agroforestry in the United States, a topic first addressed relative to nut-tree crops in 1989 (Lassoie et al., 1991) and then more comprehensively by Lassoie and Buck (1991) and more recently by Jose et al. (2018). What follows is a consideration of the importance of agroforestry to the development of newly emerging (a) land use systems, (b) institutional arrangements, (c) scientific opportunities, and (d) knowledge systems. It is important to note that many of the following statements are in the process of ongoing validation and are areas under active evaluation by agroforestry professionals.

### Opportunities for Practical Application

The possibilities for developing agroforestry for use in rural and urban areas of the United States is encouraging. It did function extensively at one time throughout North America (Carroll, 1973; Cronon, 1983; Russell, 1982), and refugia of such practices still exist today (e.g., see Campbell et al., 1991; Gold & Hanover, 1987; Schultz et al., 1995). Agroforestry is currently working effectively in many other developed (Burgess & Rosati, 2018; Gordon, Newman, & Coleman, 2018; Mead, 1995; Von Maydell, 1995) as well as developing (Hillbrand, Borelli, Conigliaro, & Olivier, 2017; Nair, 1989, 1993) countries. The political and social climate in the United States is rapidly changing, which is likely to allow the development of the new land use strategies that include agroforestry (Jose et al., 2018; Lovell et al., 2018; National Research Council, 1996; USDA, 2019). Opportunities for the development and application of domestic agroforestry practices can be separated into ecological, economic, and social components for discussion purposes; however, one needs to keep in mind that these components are interrelated, interlinked, and interactive.

### Ecological

One of the primary advantages of agroforestry in the United States probably rests in its ecological benefits and resultant environmental protection characteristics (Garrett et al., 1994; Jose, 2009; Jose & Gordon, 2008; Jose, Walter, & Kumar, 2019; Kremen & Merenlender, 2018; Udawatta & Jose, 2012). As an ecologically based land management strategy, agroforestry practices help maintain ecosystem diversity and processes that are important to the long-term sustainability of any extractive land use practice such as agriculture and forestry. This approach offers the opportunity to maintain and possibly improve the quality of the soil resource by reducing erosion, enhancing nutrient capital, and improving water infiltration and retention rates (Dollinger & Jose, 2018; Udawatta, Gantzer, & Jose, 2017). Trees also moderate microclimatic extremes, assuring cooler summers and warmer winters. Such conditions are beneficial to the production of certain food crops and livestock under severe environmental conditions as well as to human comfort. Agroforestry practices can also result in decreases in chemical (e.g., fertilizers and pesticides) and energy inputs of farming systems, all important to an environmentally sensitive society (Jose, 2019; Lerch, Lin, Goyne, Kremer, & Anderson, 2017). There is a growing movement to value some of the environmental services provided by agroforestry practices, allowing their benefits to be translated into economic incentives for landowners.

### Economic

Agroforestry offers financial opportunities associated with enhancing the profitability of traditional farming systems (Alavalapati & Mercer, 2004; Campbell et al., 1991; Nair, 1993; Van Vooren et al., 2016). One option is to reduce production costs by decreasing the need for external chemical, water, energy, and/or labor inputs. Another is that agroforestry might increase the net value of production from the nation's farmlands through optimizing mixtures of primary (e.g., corn, sawlogs, nuts, cattle, etc.) and secondary crops (e.g., mushrooms, Christmas trees, silvopasture-raised chickens, etc.) as well as ecological services (e.g., carbon sequestration and water quality credits) for which specialty markets have been or are being developed (Van Vooren et al., 2016; de Jalon et al., 2018). Total production might also be enhanced by increasing production from highly erodible or frequently flooded fragile lands without causing severe environmental degradation, for example through the use of tree crops as suggested by Smith (1950).

### Social

The development of agroforestry in the United States has social ramifications that will be realized at the individual, community, and national levels. As a sustainable land use strategy, agroforestry practices can further the land stewardship concept (Jordan, 1994; Montambault & Alavalapati, 2005; Roesch-McNally, Arbuckle, & Tyndall, 2017; Udawatta et al., 2017; Weber, 1991) by providing assurance to landowners that they are meeting their ownership responsibilities to provide healthy ecosystems for future generations. If agroforestry proves to enhance the production capabilities of rural lands, such practices will help revitalize rural communities, which have become socially depressed because of recent economic problems (Jose et al., 2018). Farmers with limited land and immigrant populations interested in farming provide an important audience as well as a population that may be more interested in the more labor-intensive practices common to agroforestry (Faulkner, Owooh, & Idassi, 2014). Understanding the role that agroforestry might play in modern land use systems will also help individuals appreciate that people from developing countries have experiences, insights, and knowledge potentially helpful for solving many problems currently plaguing modern societies (Coulibaly, Chiputwa, Nakelse, & Kundhlande, 2016; Jose & Dollinger, 2019). Such an appreciation for the value of human capital and indigenous (i.e., local) knowledge (Rossier & Lake, 2014) will help reduce ethnocentric and educational biases that form barriers between individuals who must work together to successfully address today's environmental crises. Also important is the impression that the United States must make on the rest of the world with respect to its concern about the management of its own natural resources. Developing agroforestry practices and integrated agricultural and forestry land use systems will set international standards for ecologically sound management by example. Our concern about deforestation, desertification, and soil erosion in developing countries will gain more credibility once our own "ecological house" is in order.

## Opportunities for Institutional Development

The continued development of a domestic focus on agroforestry offers unique opportunities for various organizations responsible for supporting the nation's food, forage, livestock, and fiber-producing networks. These include academic institutions, state and federal government agencies, non-governmental organizations (NGOs) that include conservation-oriented organizations, and the private sector. Such opportunities enhance the ability of these groups to provide support to rural communities while responding to public demand for more sustainable and environmentally benign land use practices (National Research Council, 1996; USDA, 2019). Previous experience in both developed and developing countries clearly demonstrates the need for institutional collaboration in developing effective agroforestry policies (Biggs, 1990). Domestic agroforestry has reached the point where new, interdisciplinary, and interagency approaches to integrated land use management are underway (USDA, 2019), thereby serving as a design methodology for reuniting the fields of agriculture and forestry in a common quest for sustainability.

### Academic Institutions

The development of a domestic agroforestry program is especially important to the nation's land-grant institutions, and specifically their state land-grant colleges of agriculture and forestry. After successfully achieving the goal of enhanced scientific rigor (USDA, 1987), these institutions are now being criticized for moving away from their original applied missions, thus becoming less directly responsive to the needs of the public (National Research Council, 1996). In spite of this trend, the development of comprehensive agroforestry programs and multiple partnerships focused on helping private rural landowners is well underway across the United States (USDA, 2015).

Land-grant institutions are also responsible for educating future professionals. The teaching of agroforestry courses offers the opportunity to help meet the interests of students for an interdisciplinary, problem-solving education, which is difficult to provide due to the demands for scientific rigor within discipline-based curricula (Gold & Jose, 2012; Lassoie, 1990; Lassoie, Huxley, & Buck, 1994). More specifically, agroforestry can provide a model for teaching holistic approaches to land use management and may attract students from a wide variety of disciplines within the agricultural and natural resource sciences. Likewise, agroforestry provides an intersection between major fields of study, and reconnecting agriculture and forestry will certainly strengthen these fields as they move to develop a scientific basis for new management paradigms. In addition, new opportunities for funding and program development will arise as the importance of domestic agroforestry increases, thereby providing new areas for professional advancement by young academics.

Land-grant institutions are emphasizing interdisciplinary and transdisciplinary research to deal with real-world problems that cross disciplines. This approach also recognizes that many of the problems we face today require solutions that require an interdisciplinary and/or transdisciplinary approach (Stock & Burton, 2011). Agroforestry, with its roots as an applied science, provides ample opportunities for research across biophysical and social science disciplines to address applied problems.

Lastly, a domestic focus on agroforestry will further emphasize the importance of developing and maintaining a strong international component within the land-grant university system (Globalizing Agricultural Science and Education Programs in America Task Force, 1997) as many of the examples of successful agroforestry activities come from projects in developing countries (Nair, 1989, 1993; Garrity et al., 2010; Pinho, Miller, & Alfaia, 2012). Hence, a comprehensive agroforestry program from the nation's land-grant institutions could recommit and recharge the intellectual energy necessary to address the needs of the peoples of the world, a much broader mission than originally identified for these institutions (National Research Council, 1996). Online offering of degrees and certificates is another avenue by which land-grant institutions could offer much needed agroforestry training both nationally and globally. Such a program was initiated in 2013 at the University of Missouri, offering graduate degrees or certificates in agroforestry entirely online (Gold & Jose, 2012).

### Government Agencies

State (e.g., departments of natural resources, environmental conservation, agriculture, and markets) and federal (e.g., U.S. Forest Service, USDA Natural Resources Conservation Service (NRCS), USDA Agricultural Marketing Service (AMS), USDA Agricultural Research Service (ARS), USDI Bureau of Land Management, and U.S. Environmental Protection Agency) agencies are gaining from the development of a domestic agroforestry program. The existing domestic program depends on, and promotes, interagency cooperation and effectiveness, areas always in need of improvement. Agroforestry provides a unique opportunity to foster new approaches to helping the farming and forestry communities with incentive programs, promoting needed rural development (Schoeneberger, Bentrup, & Patel-Weynand, 2017; USDA, 2019). This is especially important to small, independent farmers and nonindustrial forest landowners. While presently there is a trend toward rapid consolidation of small farms into larger corporate structures, with large and super-large farms controlling most of the fiber and food production in the country, there is growing recognition and appreciation for the important roles that small farms play in producing not only foodstuff but also a variety of economic, social, and environmental products and services (Schoeneberger et al., 2017). There is also a growing sector of beginning small farmers and immigrants entering rural areas interested in more diverse systems and organic options that adapt well to agroforestry management. This same population is often more open to the labor-intensive options associated with agroforestry production practices.

A report of the USDA National Commission on Small Farms (USDA, 1998) identified policy measures that are needed to enhance and preserve the important values of small farms; they recommended specifically that agroforestry offers small farm operators a means for economic diversification, windbreaks, biological diversity, and habitats for wildlife. The original publication was followed by another that offered specific legislation to support agroforestry (USDA, 2003). The report suggests that the USDA, through its extension, conservation, and forestry services, should make greater efforts to promote and support agroforestry as part of an economic and ecological strategy for a healthy agriculture. Of particular significance in establishing agroforestry policies and programs at the national level was the USDA Agroforestry Strategic Framework (USDA, 2011), which signified a major shift in the USDA's position on the value of agroforestry in today's agriculture. The strategic framework created a "road map" for advancing the science, practice, and application of agroforestry, broadening the USDA's role in agroforestry beyond that of just the National Agroforestry Center. For "buy-in" purposes, five USDA agencies and two non-USDA partners (The National Association of Conservation Districts and the National Association of State Foresters) were brought together to develop the framework in collaboration with stakeholders across the United States. In 2019, the USDA updated its Agroforestry Strategic Framework based on current agency needs and priorities, as well as additional input from partners and stakeholders (USDA, 2019). Within the farming and forestry sectors there is a growing trend toward the fragmentation of lands and expanded ownership by a larger group of small landowners, particularly in the eastern part of the country. Agroforestry can enhance the economic viability of owning and managing these units through the production and marketing of comparatively short-rotation, high-value specialty items in forest farming practices (e.g., see Chapter 9). Highly visible agroforestry programs that specifically address pressing environmental problems could greatly improve the public's image of agriculture and forestry as well as the agencies responsible for them. This could have important implications for their political futures.

### Private Organizations

There is a wide variety of private groups—environmental organizations (e.g., Audubon, A Greener World, The Nature Conservancy, Trees Forever, the Sierra Club), foundations (e.g., Kellogg, McKnight, Pew Charitable Trust, Walton, Winrock), and institutions (e.g., the Land Institute, Rodale Research Center, Wallace Institute, Green Lands Blue Waters)—that are dedicated to finding alternative solutions to environmentally damaging land use practices and to rural development problems. Their diversity of interests often hinders collaboration as well as their meaningful interaction with governmental agencies and private individuals, organizations, and corporations. Because of its integrated approach, agroforestry might provide an opportunity for various audiences to develop a common agenda and approach for conservation and sustainable land use, particularly at a landscape level. Such cooperation could help everyone better understand divergent perspectives, thereby helping alleviate some of the constant pressures that exist between organizations with different concerns and goals. The Savanna Institute, formed in 2013, is a 501(c)(3) nonprofit organization working to lay the groundwork for widespread agroforestry in the U.S. Midwest. The Savanna Institute works in collaboration with farmers and scientists to develop perennial food and fodder crops within multifunctional polyculture systems grounded in ecology and inspired by the savanna biome. Private foundations also initiate new innovative programs that support agroforestry and enhance public agency competitive grant programs (e.g., Agroecology Fund, Cedar Tree Foundation).

## Opportunities for the Scientific Community

The development of a domestic agroforestry program for the United States offers unique opportunities for the scientific community that embraces forest and agricultural sciences and can provide the opportunity for focusing issue-based science to address some of today's most complex problems. The scientific community currently is being challenged to search for viable solutions to complex environmental problems that are beyond its capabilities to address with customary precision and certainty (Burke et al., 2017). Consider the environmental and economic problems facing farmers and foresters today compared with the relatively simple production needs of the last century (National Research Council, 1996; Sampson & Hair, 1990). Agroforestry research experience in developing countries has shown it to be an effective means for interdisciplinary research teams to approach land use issues, in particular diagnosis and design methodologies (Murray & Bannister, 2004; Raintree, 1987, 1990). Similar work in Europe and North America now emphasizes the universality of ecological and socioeconomic issues, thereby blurring the distinction often made between domestic and international problems (Buck, 1995; Lovell et al., 2018). Agroforestry in developing countries is progressing with a combination of support from the research community (e.g., the World Agroforestry Center) and from the development assistance community (e.g., Heifer International) in promoting such practices. This is also beginning to unfold in the United States, in which both the underlying biophysical and socioeconomic science and broader knowledge infrastructure for agroforestry is beginning to reach critical mass, combining "bottom up, high touch" farmer-to-farmer approaches and "top down, high tech" scientific breakthroughs.

There is a growing interest in landscape level research on more sustainable land use systems that provide both income for farmers and ecological services for society (Lovell et al., 2010). Agroforestry concepts and applications provide ample opportunity to do just that (Brown et al., 2018; Palma et al., 2007a, 2007b). Research is now underway that demonstrates how those two objectives can be combined, providing opportunities for the scientific community to explore and identify new integrated land use options (Brown et al., 2018). Agroecology, eco-agriculture, and regenerative agriculture principles integrate biophysical, social, and economic factors at the landscape level and represent promise for moving agroforestry to the landscape level (Altieri, Nicholls, & Montalba, 2017; Geertsema et al., 2016; LaCanne & Lundgren, 2018; Liebman & Schulte, 2015; Scherr & McNeely, 2007).

Domestic agroforestry falls along the continuum of agroecology and regenerative agriculture, presenting a need for new types of information—a challenge that breeds creativity and vitality within the research community. Regardless of the scope, domestic agroforestry offers many opportunities for professional development arising from new research projects, education and training programs, and cooperative ventures with public agencies and private organizations.

## Opportunities for the Development of New Knowledge Systems

In his review of the science of agroforestry, the director general of ICRAF argued that the key challenge posed by this field to the agricultural and forestry research communities is to develop a predictive understanding of the competition, complexity, profitability, and sustainability aspects of agroforestry practices (Sanchez, 1995). This would appear to hold true for the United States as well as developing, tropical countries. To evaluate these four key criteria for the performance of agroforestry, a sound understanding is needed of ecological processes (Ong & Huxley, 1996) as well as socioeconomic and policy conditions that affect agroforestry practices (Buck, 1995; Garrett & Buck, 1997) and how they can be optimized through management.

Innovative agroforestry practices in the United States encompass numerous characteristics and unique associations of component species as landowners experiment with various perennial and annual species, often in unconventional niches. Most of these associations have not been studied, thus significant knowledge gaps exist. A recently completed national assessment provides a science-based synthesis on the use of agroforestry for mitigation and adaptation services in the face of climatic variability and change. It serves as a framework for including agroforestry systems in agricultural strategies to improve productivity and food security and to build resilience in these landscapes. It also provides technical input on the need for innovative strategies to address significant climatic variability challenges faced by U.S. agriculture (Schoeneberger et al., 2017). Furthermore, the assessment reviews the social, cultural, and economic aspects of agroforestry and the capacity of agroforestry systems to provide multifunctional solutions. In addition, it presents a comprehensive North American perspective on the strengths and limitations of agroforestry through U.S.

regional overviews along with overviews for Canada and Mexico (Schoeneberger et al., 2017).

The challenges to generating practical, broadly useful knowledge about agroforestry are well documented (Sanchez, 1995), revolving around the comparative complexity and site specificity of various applications and thus the difficulty of generalizing from studies of particular practices. Each practice involves multiple components and processes, the dynamics of which change with time as the perennial components mature and assume different ecological and biological roles. Similarly, profitability, social acceptability, and regulatory incentives for practicing agroforestry vary and change as a function of complex interactions among a host of intended and unintended socioeconomic and policy factors (Van Vooren et al., 2016). These are exceptionally complex to untangle (Buck, 1995), but in recent years researchers have been working on new tools to deal with this complexity. For example, Hi-sAFe is a novel tool for exploring agroforestry designs, management strategies, and responses to environmental variation (Dupraz, Wolz, et al., 2019). Added to this are the institutional problems of dispersed, often uncoordinated resources that combine to influence the generation and use of new knowledge—mainly researchers, information, infrastructure, and financial support. Relevant and broadly encompassing scientific research in this context becomes prohibitively expensive—particularly in the current economic climate of the United States where agricultural research resources are increasingly scarce and often monopolized by "big business" interests whose central focus is on generating profitable products. Although there is some dedicated funding for integrated research on sustainable agriculture through the Sustainable Agriculture Research and Education (SARE) program of the USDA, and a variety of related funding opportunities through the USDA National Institute of Food and Agriculture (NIFA), funding is limited, extremely competitive, and relatively short term. Concerns about integrating conservation and sustainable development goals through agroforestry are likely to continue to receive limited priority.

We propose a complementary strategy for advancing understanding of the conditions under which the desired attributes of agroforestry practice may be achieved and how well various systems can be expected to perform. This involves harnessing the experience and learning processes of numerous, dispersed agroforestry practitioners into purposive knowledge networks. During the past decade, a series of regional agroforestry networks have been established (e.g., Mid-American Agroforestry Working Group [MAAWG], Northeast/Mid-Atlantic Working Group [NEMA], Pacific Northwest Agroforestry Working Group [PNAWG], Southwest Agroforestry Action Network [SWAAN], etc.). In addition, a number of regional specialty crop cooperatives have formed (e.g., Midwest Elderberry Cooperative, multiple chestnut cooperatives, etc.). What is still needed is to challenge these regional working groups to share and evaluate their experience with others about specific activities along integrative themes. Facilitators, who might come from universities, federal agencies such as the National Agroforestry Center, and/or NGOs including the Savanna Institute, would help to link landowners with one another and with other key actors from production, trade, NGOs, professional associations, land-grant universities, national agency research laboratories, the markets that are essential for viable systems, and various policy units. They would document individual and collective learning processes with an aim to move knowledge from the particular, context-specific state to a more global and predictive one integrating knowledge across landscapes.

Workshops and study tours designed to help participants recognize and evaluate the informal experimental design and evaluation processes in which landowners engage, and how they inform these processes through their respective learning networks, would serve to sharpen and focus the collective expert judgment that develops. In recent years, many such workshops have been established. For example, in 2013, the Center for Agroforestry, in conjunction with MAAWG and via initial funding from SARE, established an annual Agroforestry Academy to help address this need. As of 2019, 175 individuals (farmers and educators alike) have been trained across seven academies, and a longitudinal study is ongoing to extract lessons learned and to create a learning network among the trainees (Gold et al., 2019). The Savanna Institute is also very active in hosting workshops and study tours and linking farmers together in networks. These activities overlap with conventional extension roles in agriculture and forestry, helping to provide a dual purpose and justification for funding.

Numerous trainings, workshops, and study tours have been very successful in attracting agroforestry practitioners. These individuals, varying widely in age from their 20s to their 60s, are typically curious, open-minded landowners, many of whom come from an understanding of permaculture, who believe there may be a better or different way to manage agricultural and forestry resources than conventional land use approaches. They are also likely to have a multigenerational vision for the development of their production system, while at the same time adopting a willingness to compromise it in practical terms to the realities of today's transient society. Agroforestry attracts individuals who value hard work and understand the critical role of management in generating multiple outputs in as complementary and noncompetitive a manner as possible. They are likely to experiment with various components of their evolving production system and to have created a diverse network of information resources to assist their efforts to design new systems and informally test new hypotheses. Such people can be found in the membership of numerous organizations throughout the United States and Canada (e.g., the Association for Temperate Agroforestry [AFTA], the Appalachian Beginning Forest Farmer Coalition [ABFFC], etc.) that are concerned with the development and marketing of alternative crops and enterprises or the management of natural resources. In a highly connected world of social media, they can easily reach out to existing organizations, anticipating their role in satisfying their needs for learning, improving their practices, and addressing important social issues. Once they are part of such networks, they attract others to join.

Implementation of the proposed strategy is well underway, and critical perceptual and institutional barriers to improving the capacity for knowledge and information generation about agroforestry are being addressed. Scientific knowledge about agroforestry is rapidly being integrated into practice via the host of organizations previously mentioned (Gold, 2019).

The important implication is that landowners have now become an integral part of the knowledge generation process. This requires careful examination of the processes they use, the products they develop, and the various learning groups with whom they interact. In doing so, the research and development community now acknowledges and participates in the dense networks of informal learning about agroforestry that they understand and appreciate. As stated, numerous organizations are now playing important roles in developing generalizable knowledge if adequately recognized and organized to do so. Actions are being taken to link them. In this way, agroforestry now offers important opportunities fostering innovation in land use management.

## Progress to Date and Challenges Ahead

The potential for domestic agroforestry and the constraints to its development that were first identified in 1989 (Lassoie et al., 1991) and then reexamined 2 yr later (Lassoie & Buck, 1991) are dramatically different from those facing us today (Gold, 2019). Agroforestry practices are becoming part of the repertoire of management strategies that are emerging from the research and development community to address complex land use sustainability issues within interdisciplinary forums.

As mentioned above, however, agroforestry is a hybrid of the established fields of agriculture and forestry, closely aligned with the science of agroecology and regenerative agriculture. Therefore, each new approach will face its own set of challenges as it moves from theory into practice. Practical application of these approaches also will face different challenges and offer different opportunities to the research and development community. These challenges and progress to date in meeting them are discussed here as well as specific recommendations to further advance agroforestry research, development, and practice in the United States.

### Basic Challenges and Progress

Agroforestry in the United States has faced some unique challenges as an emerging land use strategy, many of which are being overcome. First, concepts and methodologies were originally obtained from international experiences primarily in developing, tropical countries with very different ecological and socioeconomic contexts. In recent decades, agroforestry in the United States and Canada (and Europe) has made huge strides to refine relevant concepts and methodologies that fit the temperate zone and the Western, industrialized realities in which we live. As such, domestic agroforestry has evolved at the intersection of the well-established fields of agriculture, horticulture, and forestry. As an emergent applied science, agroforestry has aligned with agroecology and established a research–education–development infrastructure that integrates across these well-established but separate disciplines.

#### Inherent Constraints Being Overcome

Because domestic agroforestry has evolved within a modern society primarily located in a temperate region of the world, it has faced inherent constraints not found in most developing countries. First, the climate in much of North America is not conducive to fast plant growth, especially by long-lived woody perennials. In addition, some of our indigenous tree species are naturally slow growing and yield only one primary product—usually timber. As a consequence, the use of trees for timber in many types of agroforestry practices do not directly yield useful or marketable products for many years—often after the life of the persons who planted them! Knowing this, domestic agroforestry has instead focused on overstory nut- and fruit-bearing trees and shrubs that come into economic production in 3-15 yr (e.g., elderberry [*Sambucus nigra* L. ssp. *canadensis* (L.) R. Bolli], aronia [*Aronia* sp.], eastern black walnut [*Juglans nigra* L.], pecan [*Carya illinoinensis* (Wangenh.) K. Koch], Chinese chestnut [*Castanea mollissima* Blume]). Furthermore, fast-growing species of the genus *Populus* (hybrid poplar, cottonwood, etc.) and *Salix* (clonal willow) (Robertson et al., 2017; Volk et al., 2006) are being used for biomass (MacPherson, 1995) and as woody florals (Gold, Godsey, & Josiah, 2004) and are integrated into riparian forest and upland buffer production systems to provide multiple products and environmental services. Finally, native perennial grasses (e.g., switchgrass [*Panicum virgatum* L.]) are also being used for biomass and other ecosystem services within a variety of agroforestry practices (Gamble, Johnson, Current, Wyse, & Sheaffer, 2016; Schulte et al., 2017)

The United States is a modern, industrialized nation with an increasingly large educated, urban population. Therefore, agroforestry practices are being developed to simultaneously address the market opportunities in urban areas while also meeting specific interests, needs, and problems of rural landowners. Currently, obstacles to agroforestry adoption exist but are in the process of being overcome (de Jalon et al., 2018; Wilson & Lovell, 2016). Barriers include the expense of establishment, landowners' lack of experience with trees (Faulkner et al., 2014), the time and knowledge required for management and marketing (Valdivia, Barbieri, & Gold, 2012), and a lack of understanding by extension and state and federal agency professionals.

Agroforestry practices also have to compete with commodity crops, which have well-developed government support systems providing insurance and price guarantees that significantly reduce landowner risk. Agroforestry practices do not, at present, have the same level of support, requiring that the landowner take on significant risk in adopting agroforestry practices. That said, the support structure and knowledge network for agroforestry is growing rapidly, addressing many of the issues constraining agroforestry adoption (Schoeneberger et al., 2017).

### Evolving Infrastructure

The depth and breadth of the agroforestry research–education–application infrastructure has come a long way in the past 40 yr, developing most rapidly in the past decade. Coupled with an acceleration of biophysical and socioeconomic research, there are now positive changes in federal policy and positive market trends. The USDA–NRCS formally recognized temperate agroforestry practices in their cost-share Environmental Quality Incentives Program (EQIP), helping promote agroforestry through national policy. Further support for growth of the agroforestry sector comes from positive consumer and market trends: increased demand for and promoting of "buy local"; growth of direct-to-consumer farmers markets; continued growth in the organic sector; and strong interest in pasture-based livestock production.

Formally accredited online graduate certificate and master's degree programs have been established; numerous extended-duration training programs have been created and designed to train educators and landowners; NGOs (e.g., the Savanna Institute) and private sector (e.g., Iroquois Valley Farmland REIT, PBC Farms Beef) engage with landowners in agroforestry; multiple specialty crop and livestock cooperatives (e.g., elderberry, chestnut, hazelnut [*Corylus* spp.], aronia) have been formed; and robust financial decision support tools have been developed.

As it matures, this infrastructure must provide an interconnected feedback–feedforward knowledge system of researchers, teachers, extension personnel, and field practitioners to promote and support the development, refinement, and implementation of new ideas and practices (Gold, 2007).

## Agroforestry as an Applied Science

The ongoing challenge is the continued development of domestic agroforestry practices along with the development of more discipline-based land use strategies of sustainable agriculture and forestry. Almost 30 yr ago, Lassoie and Buck (1991) called for a major national commitment similar to the one mounted near the turn of the 20th century for agricultural production and forest conservation. As we begin 2021, large-scale refocusing of the nation's resources and professional energies has yet to fully materialize owing to the strength and ingrained structure of our current institutions and steady stream of state budget tightening. Nonetheless, concerns about the environmental impacts of current land use practices and the deterioration of the land base and water are increasingly being recognized as important problems to address (e.g., hypoxia, soil health). In spite of institutional and fiscal limitations, steady development efforts are underway to move domestic agroforestry from concepts to practices. During the past decade, steady progress has been underway at many different levels toward building a research–education–practice infrastructure involving a unique partnership including academia, state and federal governments, NGOs, the private sector, and agroforestry practitioners.

## Research and Development

Since the second North American Agroforestry Conference (NAAC) (Garrett, 1991), there has been a dramatic increase in the amount of biophysical and socioeconomic agroforestry research in the United States and Canada. This is directly reflected in the chapters within this third edition of *North American Agroforestry* along with other recently published works and edited volumes (Gordon et al., 2018; Mosquera-Losada & Prabhu, 2019; Schoeneberger et al., 2017). The 16th NAAC was held in 2019 and showcased a substantial amount of interdisciplinary research focused on specific opportunities where agroforestry practices can be applied. Temperate agroforestry research is regularly being reported at workshops and special sessions sponsored by professional societies, e.g., see recent abstracts of sessions at the American Society of Agronomy, Ecological Society of America, Society of American Foresters, and government agencies (e.g., USDA, 2019), along with active international conferences and symposia in Europe and elsewhere (Dupraz, Gosme, & Lawson, 2019). More scientific publications are appearing in a wider variety of scientific journals in addition to *Agroforestry Systems* (e.g., *Forest Ecology and Management*; *Society and Natural Resources*; *Agronomy Journal*; *Plant and Soil*; *Sustainability*; *Agriculture, Ecosystems, and Environment*; and the *Journal of Environmental Quality*).

Previously considered to be a new, interdisciplinary, applied science, agroforestry used to be equated with being professionally “vague” and “non-rigorous” by many working in more narrow scientific disciplines. However, the biennial NAAC, European Agroforestry conferences (EURAF), and the breadth and depth of the scientific literature are helping to change this situation by raising the professional recognition of those working in domestic agroforestry.

The volume of quality agroforestry research has increased dramatically in the past four decades, helping to support the application of agroforestry domestically. While the science of agroforestry lacks the full spectrum of understanding necessary to assure the successful widespread implementation of most agroforestry practices (e.g., information about specific species’ responses to site characteristics, economics of production through time), a substantial body of research information has been developed and is increasing annually. Advances in both the biophysical and socioeconomic understanding of agroforestry practices is helping to reduce both biological and financial risks for producers.

Agroforestry scientists have found grant support through the many programs within the Agriculture and Food Research Initiative (AFRI), the nation’s leading competitive grants program for the agricultural sciences. The NIFA awards AFRI research, education, and extension grants to improve rural economies, increase food production, stimulate the bioeconomy, mitigate the impacts of climate variability, address water availability issues, ensure food safety and security, enhance human nutrition, and train the next generation of the agricultural workforce. Multiple federal agencies and programs including NIFA, the USDA–AMS, USDA–ARS, Farm Service Agency, U.S. Forest Service, NRCS, SARE, U.S. Environmental Protection Agency, National Science Foundation, and National Institutes of Health all support facets of the science and application of agroforestry.

Agroforestry researchers have had particular funding success through USDA SARE grants and USDA–AMS Specialty Crop Block Grants. With rare exceptions, grant funding opportunities are competitive and, in light of constantly diminishing support for higher education, the competition for federal grant dollars is fierce—often funding <10% of submitted proposals. In this light, what is currently lacking is a dedicated research funding program specifically targeted to support agroforestry.

## University Education

In 1997, 36 universities in 28 different states reported teaching at least one course dealing with agroforestry (Rietveld, 1997). As of 2017, 27 U.S. institutions reported current agroforestry course offerings (Wright, 2017). However, due to the presence of online agroforestry programs, educational access for those interested in studying agroforestry has increased (Gold, 2015; Gold & Jose, 2012). In addition, the breadth and availability of the relevant literature and up-to-date textbooks has continued to increase. In addition to this text, another recently updated text is dedicated to temperate agroforestry (Gordon et al., 2018), and other similar compendiums have been published (Mosquera-Losada & Prabhu, 2019). Agroforestry education is reviewed in detail in Chapter 19.

Within universities, agroforestry courses are most often offered through forestry, natural resources, or agriculture departments (Wright, 2017). In addition, agroforestry is often addressed within courses on sustainable agriculture, agroecology, integrated forest management, international agriculture, or sustainable development. Typically, courses dedicated solely to agroforestry consider both domestic and international aspects. Although many universities offer agroforestry courses, few offer comprehensive curricula, and most agroforestry courses are used to supplement disciplinary degree options at the undergraduate level and to help build interdisciplinary programs at the graduate level.

Few institutions possess the complement of faculty to offer the selection of courses believed necessary for a major in agroforestry or, if they have the faculty, it is difficult to bring them together to offer an integrated agroforestry curriculum (Gold & Jose, 2012; Lassoie, 1990; Lassoie et al., 1994). Agroforestry is not a discipline but rather an interdisciplinary field of study. Therefore, a comprehensive agroforestry curriculum (or even a single course) demands expertise from a wide variety of professionals, often from different academic units across campus. Such individuals are often fully committed to teaching responsibilities within their respective disciplines, making it difficult for them to engage in a new curriculum or team-taught course. This means that not only are their numbers relatively small, but there is also a widespread lack of extensive training and experience in agroforestry within the academic community, especially related to its application to North American conditions. Fortunately, this situation is changing as faculty gain relevant experience, more graduate students pursue agroforestry studies, and universities begin to hire those with such an education.

Agroforestry curricula tend to be carried by a limited number of faculty members (often one) and their graduate students working within either an agriculture or forestry academic unit (e.g., college, school, or department). Unfortunately, the decision typically is made by default: who has the interest and commitment to deal with an interdisciplinary topic like agroforestry, especially when considering its application to a modern, production-oriented society? This means that the administrative support for agroforestry can be quite weak, existing only at the margin of more commonly understood traditional teaching programs.

In the United States and Canada, notable exceptions to the general trend include agroforestry programs at the University of Missouri, Virginia Tech, and Laval University in Canada. These and a handful of other universities (e.g., the University of Florida, University of Minnesota, Cornell University) are actively training agroforestry professionals who are now filtering out to other schools in temperate North America, creating the human and applied research base that can be used to grow the discipline in the United States. The University of Missouri has had a sustained funding base for more than two decades and has developed increasingly robust agroforestry research, teaching, and outreach programs. In addition to its on-campus agroforestry graduate program, the University of Missouri established an online master of science program and an online graduate certificate in 2013. These fully online programs have provided access to agroforestry education regardless of geography (Gold & Jose, 2012). Between 2013 and 2018, more than 70 students have been admitted into these programs and 30 have received graduate credentials in agroforestry.

Despite the current limitations, agroforestry courses typically attract highly qualified students who often come with extensive international agroforestry experience, including the Peace Corps (Gold & Jose, 2012), or are familiar with permaculture, agroecology, and sustainable or regenerative agriculture. In the past, such interest was limited to graduate students seeking careers in international development. More recently, however, both undergraduates and graduate students have been attracted to agroforestry courses, probably reflecting their growing interest in courses dealing with issues of sustainability. Employment opportunities where agroforestry credentials are a definite plus are increasing. Many federal agencies (e.g., the NRCS), global, national, and regional conservation organizations (e.g., Heifer International, The Nature Conservancy, National Wild Turkey Federation, Trees Forever), along with NGOs specifically dedicated to agroforestry (e.g., Savanna Institute) are hiring individuals with agroforestry backgrounds.

### Professional and Practitioner Training

The need for continuing education and training in agroforestry for both professionals and practitioners was recognized in the early 1990s. Specific needs for such training were identified for various regions of the United States (Merwin, 1997), and scattered regional trainings were held across a broad range of topics (Josiah, 1999); however, active professional training programs did not become commonplace until the early 2000s. Agroforestry training programs are reviewed in more detail in Chapter 19.

The first USDA agroforestry strategic framework (USDA, 2011) discussed the need for education and training of natural resource professionals, including training needs, methods, tools and certification, to effectively deliver agroforestry assistance. General recommendations included pursuing partnerships and cross-training opportunities with special interest groups and nontraditional partners and seeking training opportunities such as landowner-to-landowner, peer-to-peer, local organizations, and professional training of different audiences.

In 2019, the USDA released an updated Agroforestry Strategic Framework (USDA, 2019), revisiting priorities for professional education. Their primary objective was to increase the availability of information and tools that help natural resource professionals to provide technical, educational, financial, and marketing assistance. The outlined strategies included support for university efforts to develop agroforestry curricula and to offer a major, certificate, or area of expertise in agroforestry, providing natural resource professionals with an array of options for receiving and providing training and technical assistance in agroforestry technologies and landowner outreach, including professional meetings and conferences, stand-alone training activities, and online courses, and developing recognition mechanisms for professionals that have gained expertise in agroforestry through completion of a recommended set of agroforestry training requirements (e.g., agroforestry certification).

In spite of significant advances in both the science and practice of agroforestry during the past 35 yr, adoption has been limited. Up to about 2010, the situation persisted in which natural resource professionals and other educators were not well equipped to help landowners adopt agroforestry and benefit directly from an intensive immersion into agroforestry. Without being able to observe and understand the benefits of agroforestry, professionals lacked interest and, without interest, agroforestry practices were not being promoted or adopted. One of the most important contact points between landowners and natural resource professionals is the local county agent, often working for university extension, the USDA–NRCS, or a Soil and Water Conservation District. These are the professionals who help farmers as they adopt practices receiving local or federal government support. Although many of these professionals administer programs to which agroforestry practices might apply, the lack of knowledge or interest in those options by agents means that they are not suggesting agroforestry options to landowners, severely limiting the dissemination and demonstration of agroforestry practices.

One concrete step designed to help rectify this knowledge gap was created back in 2013. The University of Missouri and MAAWG collaborated to create a week-long intensive crash course in agroforestry planning and design: the Agroforestry Academy (Gold et al., 2019). The Agroforestry Academy, initially funded for 2 yr through an North Central Region–SARE Professional Development Program grant, was originally designed for professional development of natural resource professionals, extension agents, and other educators to advance the adoption of agroforestry as a cornerstone of productive land use in the Midwest. After the academy's second year, it was also opened up to landowners with a particular focus on opportunities for resource-limited farmers and military veteran farmers. Through other grant funding, scholarships have been provided to support military veterans. Up through 2021, the Agroforestry Academy has been offered for 7 yr with 175 educators and landowners trained in agroforestry. During the past decade (i.e., 2010–2020), many other spinoff trainings, offered throughout the United States, have evolved from or in parallel with the Agroforestry Academy.

Advanced training on the five agroforestry practices includes options for marketing, economic, social dimensions, and environmental services benefits and, coupled with practice in agroforestry planning and design, facilitates the development of an agroforestry knowledge network. In turn, this has helped to build the infrastructure needed to enhance landowner adoption of agroforestry, resulting in increased sustainability of rural communities and the food and agricultural system. As a result of the Agroforestry Academy and other training programs offered across the United States, educators and landowners are gaining an improved understanding of the design and implementation of agroforestry practices, including documented changes in awareness and knowledge and on-the-ground adoption (Gold et al., 2019).

## Identification and Support of Practitioners

It is important to recognize the level of risk a practitioner takes on in adopting or practicing agroforestry. The predominant agricultural crops and, to a lesser extent, specialty nut and fruit crops often have extensive research bases that help reduce uncertainty. That research base, coupled with government-sponsored insurance and price support programs for many crops, significantly reduces the risk to landowners. The research base for agroforestry practices has grown substantially since 2000. While agroforestry practices do not enjoy the same level of support as commodity crops, both biophysical and socioeconomic research has been conducted to help reduce landowner risk. Government programs, especially USDA SARE grant programs directed to farmers, support the adoption and demonstration of sound agroforestry practices and are helping to address questions of risk for agroforestry adoption.

During the past decade (2010–2020), in addition to the National Agroforestry Center and the Association for Temperate Agroforestry, a number of regional agroforestry working groups have been established to bring agroforestry practitioners together. These informal networks are serving as venues for the exchange of knowledge and experiences among practitioners, cooperatives, researchers, outreach professionals, and NGOs. The growing list of key regional agroforestry working groups includes:

Northeast/Mid-Atlantic Agroforestry Working Group (NEMA) https://www.capitalrcd.org/nema-about-us.html
Mid-American Agroforestry Working Group (MAAWG) http://midamericanagroforestry.net/
Pacific Northwest Agroforestry Working Group (PNAWG) http://pnwagro.forestry.oregonstate.edu/
Southwest Agroforestry Action Network (SWAAN) https://aces.nmsu.edu/aes/agroforestry/southwest-agroforestry-w.html
Appalachian Beginning Forest Farmers Coalition (ABFFC) https://www.appalachianforestfarmers.org/
Savanna Institute http://www.savannainstitute.org/

In addition, many practitioners prefer to affiliate with associations or cooperatives involving like-minded individuals, and a number of these organizations support agroforestry specialty crop production (e.g., Northern Nut Growers Association, Chestnut Growers of America, Maple Producers Association, North American Ginseng Association, ABFFC, Northeast Organic Farmers Association, Nebraska Woody Florals). The Savanna Institute, as discussed above, is a nonprofit organization created to reap the full benefits of the experiences and knowledge emerging from the diversity of agroforestry practitioners.

At the federal level, the Cooperative Extension System has developed eXtension (eXtension.org), and within eXtension there are Communities of Practice. One such community of practice, created through a grant to Virginia Tech, is the Forest Farming Community (https://forest-farming.extension.org/). The Forest Farming Community includes forest farmers, university faculty, and agency personnel working together to provide useful farming information. The Forest Farming Community shares information about growing and selling high-value non-timber forest products. Members are from across the country and have experience farming and studying edible, medicinal, decorative, and craft-based products in woodlands. The community provides woodland owners and managers with information about startup, best practices, and markets and policies.

Because of the growing wealth of organizational resources and knowledge networks, agroforestry is becoming a more realistic and practical options for thousands of landowners.

## Future Needs

In a short span of four decades, agroforestry in the United States has transitioned from a little-used name and practice to a science-based technology that is widely recognized. While the United States lacks a consistent national policy on agroforestry, the establishment of the USDA Agroforestry Strategic Framework for 2011–2016 (revised in 2019) has advanced agroforestry from a fragmented effort on the part of a few to an area of focus on the part of many. The question is no longer, do we need agroforestry, but rather what will agroforestry look like in the United States over the next four decades? The professional community continues to be focused on providing the biophysical and socioeconomic specifics needed to implement agroforestry on the ground. Such details comprise the rest of this volume, showing strong promise for the further development of agroforestry in the United States as well as for other developed, temperate regions of the world.

Although progress has been good, specific challenges still face the development of domestic agroforestry. First, we must continue to increase the amount of research being conducted, and this work must be interdisciplinary and focused on specific opportunities where agroforestry practices can be applied. Second, we must educate and train professionals who are capable of applying agroforestry research methodologies and results to real-world situations and, of course, assure employment opportunities for them at the end of their schooling. Third, we must cultivate and support a group of practitioners willing to work with researchers to test and evaluate new technologies. Fourth, we must educate the general public to understand the need to support the development of sustainable land use management systems like agroforestry and to appreciate the unique value of products from such systems. Lastly, collaboration must be stimulated among key individuals and organizations to further the ideals and practice of domestic agroforestry: extension personnel, researchers, and practitioners; different disciplines, departments, and colleges; and different public and private organizations, agencies, and institutions. In practice, the development of these technological and organizational components of a domestic agroforestry program should occur simultaneously and proceed in parallel rather than in series. Hopefully, an emerging national policy on agroforestry will provide the framework needed to address these challenges.

It is important that the research, extension, federal and state agencies, NGOs, associations, cooperatives, and the private sector continue to build and develop the knowledge network and infrastructure to support the growth of agroforestry. With dedicated, collaborative efforts, agroforestry practices will become increasingly important within North America's food, forage, and fiber production systems. It is hoped that this text provides support for innovative approaches to maintaining the long-term ecological integrity and productivity of the nation's farm and forest lands. Such is the essence of our society's quest for sustainability.

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# Study Questions

1. Throughout Chapter 1, the authors attempt to make a case for agroforestry's importance as a viable land use practice in North America. What are three major issues identified by the authors that agroforestry can be used to address in a cost effective manner?

2. To understand why agroforestry began in the United States, one must study the evolution of forest management. Of particular significance was a decision made by the U.S. Forest Service to manage public forest lands for multiple uses. What led to this decision?

3. Why has agroforestry always been the primary land use approach throughout the developing world, but is relatively new in developed nations?

4. In the late 1980s, Steppler (1987) suggested that agroforestry was "a practice in search of a science". What do you think was meant by this phrase? Has research in the past nearly four decades changed its validity?

5. Does agroforestry have a role in helping address global warming and dependence on foreign oil? Explain.

6. Do you agree that the importance of agroforestry in North America relates more to ecosystem services and resulting environmental protection than to production and economic gain? Justify your answer.

7. What role does state and federal policy play in the adoption of agroforestry? Has agroforestry policy development kept abreast of agroforestry technology development? Why or Why not? What do we need to do as agroforestry community to ensure the development of sound agroforestry policy?