Chapter 1
Introduction

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Enhancing food security and preserving vital ecosystem services from agricultural lands are critical issues for the United States and have become increasingly important globally. Addressing these issues requires that forestry and agricultural systems become even more productive while ensuring that the other environmental services provided by these landscapes are available to future generations. To achieve higher levels of productivity and ensure long-term sustainability, these landscapes and production systems will need to use inputs more efficiently; have less variability and greater stability in outputs; and be more resilient to risks, shocks, and long-term climatic variability (Tilman et al. 2011). To achieve these goals will require a major shift in the way land, water, soil nutrients, and genetic resources are managed. In general terms, agroecological principles and practices that capitalize on greater multifunctionality also build in greater resiliency within the agricultural operations and landscapes in which they are applied (Beddington et al. 2012, Tomich et al. 2011).

As a multifunctional management strategy, agroforestry provides an intentional blending of forestry and agricultural practices that can address food security and stability in managing for other ecological and environmental services provided by these landscapes. As an agricultural management option, agroforestry is unique in that it is tree based, adding strategic diversity at various scales in ways that can reduce threats and build resiliency under changing conditions. Agroforestry, as defined within the United States, is "intensive land-use management that optimizes the benefits (physical, biological, ecological, economic, and social) from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock" (Gold and Garrett 2009). Better recognized within tropical agricultural strategies (Verchot et al. 2007), agroforestry is now emerging as a viable resiliency strategy for the United States and other temperate regions, especially in regards to helping producers deal with the impacts from the increasing erratic and extreme weather events (Delgado et al. 2011, Jose et al. 2012, Schoeneberger et al. 2012, Smith et al. 2013). A brief overview of the five main categories of agroforestry practices used in the United States, with a growing sixth category—special applications—for agroforestry technologies being adapted to address emerging needs across rural/urban landscapes, is presented in figure 1.1 and table 1.1.

Although practice categories offer a useful frame of reference for describing agroforestry, in application it can take on many variations and combinations—from only a few trees within a crop field to highly integrated, multistoried food forests—depending on the products and functions being sought. The permutations and the terminology used to describe them are often quite varied, especially for agroforestry within tribal and island communities. To illustrate the large continuum of agroforestry practices, examples in box 1.1 show the different combinations of practices in greater detail. Additional information on these agroforestry practices within North America can be found in Garrett (2009).

Agroforestry has been identified as a multifunctional land-use approach that can balance the production of commodities with noncommodity outputs such as environmental protection and cultural and landscape amenities (McIntyre et al. 2009). Evidence suggests that agroforestry can sustainably increase production per unit of land area while maintaining or enhancing other economic, social, and environmental services (Asbjornsen et al. 2014, Olson et al. 2000, Smith et al. 2013). Evidence also suggests that agroforestry can build adaptive capacity within agricultural operations and support greenhouse gas (GHG) mitigation (CAST 2011, FAO 2013b, Matocha et al. 2012, van Noordwijk et al. 2014, Watson et al. 2000).

Like many other management options for building resiliency, agroforestry needs to be implemented proactively to reduce vulnerability to weather extremes and other climatic variability-driven impacts when they occur. Tree-based practices have

Figure 1.1. Five main categories of agroforestry practices are used in the United States: (A) alley cropping, (B) windbreaks, (C) riparian forest buffers, (D) silvopasture, and (E) forest farming. An emerging sixth category is (F) special applications (e.g., short-rotation woody crops). (Photos by USDA Forest Service and USDA Natural Resources Conservation Service [A, B, C, D, F], and Catherine Bukowski, Virginia Tech [E]).

longer establishment periods, requiring planting several years before large-scale disturbances occur. The potential benefits currently valued by farmers and ranchers (e.g., enhanced yields and livestock production, water quality protection, biodiversity, productive soils, and diversification of production) are derived from the same agroforestry functions that are important for reducing threats and enhancing resiliency under changing conditions. These many benefits provide a mechanism for producers to offset any lost opportunity costs as they work towards building more resilient operations.

Agroforestry practices in the United States are not as well-studied and well-established as more conventional agronomic and forestry practices and will require some investment to further our understanding of the impacts of changing conditions on agroforestry health and performance (Luedeling et al. 2014). Most of our knowledge of agroforestry is derived from site- and field-scale studies at limited numbers of locations. Agroforestry systems are complex assemblages of ecosystem components, each of which may respond differently to climatic variability and other environmental changes. Although we

Table 1.1. Categories of agroforestry practices in the United States.

Practice	Description[a]	Primary benefits and uses[b]
Alley cropping (also called tree-based intercropping)	Trees or shrubs planted in sets of single or multiple rows with agronomic crops, horticultural crops, or forages produced in the alleys between the trees that can also produce additional products.	• Produce annual and higher value but longer term crops. • Enhance microclimate conditions to improve crop or forage quality and quantity. • Reduce surface water runoff and erosion. • Improve soil quality by increasing utilization and cycling of nutrients. • Enhance habitat for wildlife and beneficial insects. • Decrease offsite movement of nutrients or chemicals.
Windbreaks (also includes shelterbelts)	Single or multiple rows of trees or shrubs that are established for environmental purposes; depending on the primary use, may be referred to as crop or field windbreak, livestock windbreak, living snow fence, farmstead windbreak, or hedgerow.	• Control wind erosion. • Protect wind-sensitive crops. • Enhance crop yields. • Reduce animal stress and mortality. • Serve as a barrier to dust, odor, and pesticide drift. • Conserve energy. • Manage snow dispersal to keep roads open or to harvest moisture.
Riparian forest buffers[c]	An area of trees, shrubs, and herbaceous vegetation established and managed adjacent to streams, lakes, ponds, and wetlands.	• Reduce nonpoint source pollution from adjacent land uses. • Stabilize streambanks. • Enhance aquatic and terrestrial habitats. • Increase C storage in plant biomass and soils. • Diversify income either through added plant production or recreational fees.
Silvopasture	Trees combined with pasture and livestock production.	• Produce diversification of livestock and plant products in time and space. • Produce annual and higher value but longer term products. • Reduce nutrient loss.
Forest farming (also called multistory cropping)	Existing or planted stands of trees or shrubs that are managed as an overstory with an understory of plants that are grown for a variety of products.	• Improve crop diversity by growing mixed but compatible crops having different heights on the same area. • Improve soil quality by increasing utilization and cycling of nutrients. • Increase C storage in plant biomass and soil.
Special applications	Use of agroforestry technologies to help solve special concerns, such as disposal of animal wastes or filtering irrigation tailwater, while producing a short- or long-rotation woody crop.	• Treat municipal and agricultural wastes. • Manage stormwater. • Produce biofeedstock.

C = carbon.

[a] Descriptions follow USDA Natural Resources Conservation Service Practice Standards. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/ncps/.

[b] All agroforestry plantings add diversity within the agricultural landscape. In general, such plantings will enhance wildlife habitat in agricultural settings and are often designed or managed with doing so as a secondary benefit.

[c] Riparian forest buffer refers to the planted practice. This category does not include naturally established riparian forests.

capitalize on it to attain agroforestry's benefits, this inherent complexity makes it difficult to accurately predict, at this time, impacts from changing conditions. A broader understanding of how these agroforestry practices function is needed to enhance our ability to provide reliable regional and local assistance, and gaining that understanding will require an adaptive management approach.

This report offers a first-ever scientific assessment of agroforestry's potential in the United States to provide mitigation and adaptation services under changing conditions. Based on available scientific evidence, agroforestry can contribute to these services by sequestering carbon, reducing GHG emissions, enhancing resiliency, and reducing threats while facilitating migration of wildlife and aquatic species to more favorable conditions (table 1.2). One of the primary strengths of agroforestry that emerged from this assessment is the opportunity to provide integrated mitigation and adaptation services in a synergistic manner (Duguma et al. 2014) while also supporting expanding food security goals and limiting environmental impacts. Agroforestry-induced diversification of income streams and other ecosystem services can help safeguard agricultural production under the many uncertainties from climatic variability to shifting markets.

Box 1.1. The Practice of Agroforestry

Agroforestry represents a wide-ranging continuum of managed woody plant, herbaceous crop, and livestock combinations—from a few trees planted within industrial, commodity operations to stratified native forests manipulated for food and other products. This diversity can create some confusion regarding what agroforestry actually is and what it means.

As a general rule, when agroforestry is placed into a land use, it does not convert the land use. It is not considered afforestation (based on its small size); rather, it is the use of tree-based plantings in support of agricultural land use or, in the case of forest farming, in support of forest land use. Agroforestry within U.S. farm or ranch operations, in general, is only a few plantings, comprising a small portion of the land area.

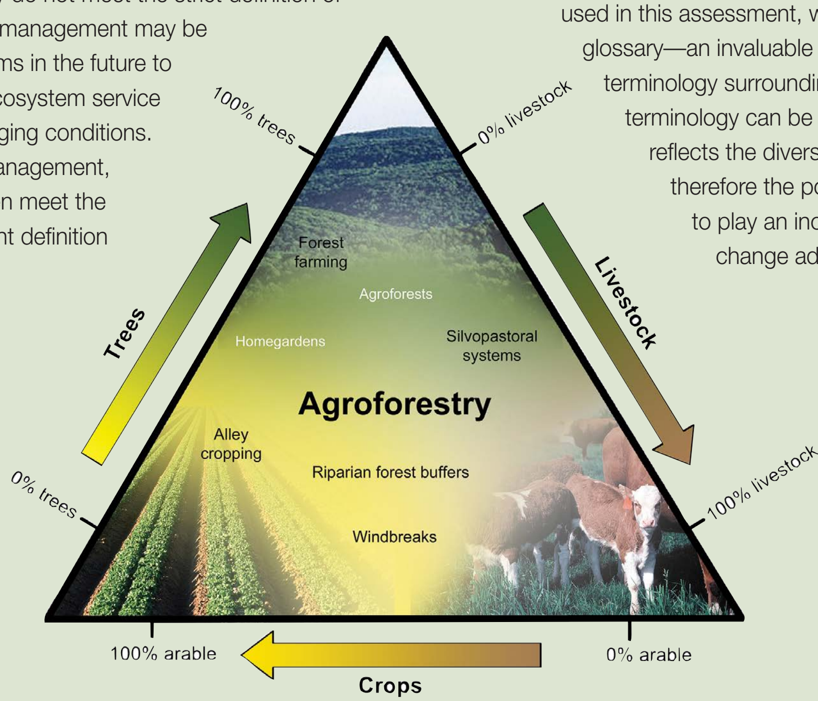
The definition of agroforestry implies deliberate and integrated management of tree, crop, and livestock components. Therefore low- to no-management applications, such as tribal and island plantings or Southwest woodland grazing, represent a gray area (see chapter 5 and box A.1). Some of these systems currently do not meet the strict definition of agroforestry. However, management may be required in these systems in the future to enhance or maintain ecosystem service production under changing conditions. With this addition of management, those systems may then meet the criteria under the current definition of agroforestry.

Is it an agroforestry system or practice?

Agroforestry is often described in many ways; as a *system*, a *practice*, and even a *management activity* and a *planting*. Although these terms are used interchangeably, a distinction between a system and a practice is worth mentioning. *System* connotes the many parts, arrangements, and interactions created by integrating these parts; it is a familiar term within the scientific community. In the agricultural community, however, the use of *practice* is better understood and more compatible with other agricultural practices (Gold and Garrett 2009).

Agroforestry category and practice, while also used interchangeably, can provide a means for acknowledging subgroups. In this case, the five main agroforestry *practices* (table 1.1) can be referred to as *categories*, allowing some groups, like windbreaks, to be further defined based on specific use (e.g., field windbreaks, farmstead windbreaks, livestock windbreaks).

Additional terms such as *agroforest* and *homegarden* are used in this assessment, which also includes a glossary—an invaluable tool for navigating the terminology surrounding agroforestry. The terminology can be confusing; however, it reflects the diversity, the versatility, and therefore the potential of agroforestry to play an increasing role in climate change adaptation strategies.



Agroforestry represents a fluid continuum among trees, crops, and livestock, ranging from a few trees established within a field or pasture to multistory forests managed for a variety of products. The five agroforestry categories are well-established terms in the conterminous United States, with each practice having the potential to vary depending on its design within these continuums. Terms, such as *homegarden* and *agroforest*, which are more commonly used and recognized outside the conterminous United States (e.g., the islands and Mexico), are slowly growing in use in the United States. (Figure adapted from den Herder et al. 2015.)

Table 1.2. Agroforestry functions that support climate change mitigation and adaptation.

Climate change activity	Major climate change functions	Agroforestry functions that support climate change mitigation and adaptation
Adaptation		
Actions that reduce or eliminate the negative effects of climate change or take advantage of the positive effects.	Reduce threats and enhance resilience.	• Alter microclimate to reduce impact of extreme weather events on crop production. • Alter microclimate to maintain quality and quantity of forage production. • Alter microclimate to reduce livestock stress. • Provide greater habitat diversity to support organisms (e.g., native pollinators, beneficial insects). • Provide greater structural and functional diversity to maintain and protect natural resource services. • Create diversified production opportunities to reduce risk under fluctuating climate.
	Facilitate plant species movement to more favorable conditions.	• Assist in plant species migration through planting decisions.
	Allow species to migrate to more favorable conditions.	• Provide travel corridors for species migration.
Mitigation		
Activities that reduce GHGs in the atmosphere or enhance the storage of GHGs stored in ecosystems.	Sequester C	• Accumulate C in woody biomass. • Accumulate C in soil.
	Reduce GHG emissions	• Reduce fossil fuel consumption: o with reduced equipment runs in areas with trees. o with reduced farmstead heating and cooling. • Reduce N_2O emissions: o by greater nutrient uptake through plant diversity. o by reduced N fertilizer application in tree component. • Enhance forage quality, thereby reducing CH_4.

C = carbon. CH_4 = methane. CO_2 = carbon dioxide. GHG = greenhouse gas. N = nitrogen. N_2O = nitrous oxide.

Source: Modified from Schoeneberger et al. (2012).

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