Agroforestry

Preparers

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Introduction

Adapting to climate change requires a comprehensive approach that involves public and private lands. Agroforestry is the intentional mixing of trees and shrubs into crop and animal production systems to create environmental, economic, and social benefits. This private land management approach provides opportunities for shared stewardship on agricultural and forested lands, including those adjacent to public lands. Agroforestry allows land managers to integrate productivity and profitability with environmental stewardship that will contribute to healthy and sustainable landscapes.

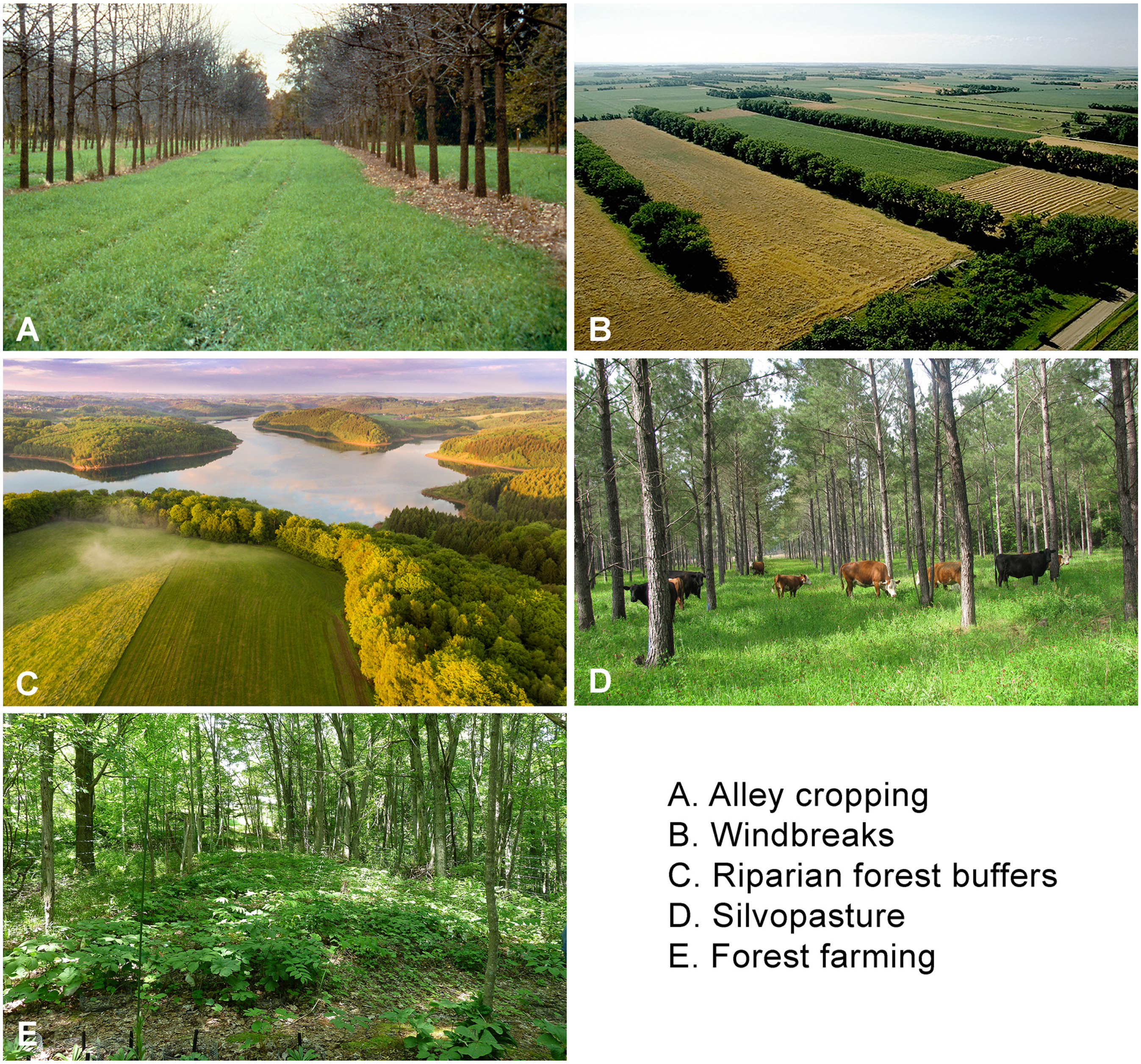
The five widely recognized categories of agroforestry in the United States are 1) alley cropping, 2) windbreaks, 3) riparian forest buffers, 4) silvopasture, and 5) forest farming (also called multistory cropping) (Figure 1 and Table 1) (1). These agroforestry practices are used to enhance crop and livestock production; protect soil, air, and water quality; provide wildlife habitat; and diversify income sources.

Figure 1. Categories of common agroforestry practices used in the United States. Modified from (1).

Table 1. Description of agroforestry practices used in the United States. Modified from (1).

Based on a recent scientific assessment, agroforestry can contribute to climate change adaptation and mitigation by 1) reducing threats and enhancing agricultural landscape resiliency, 2) facilitating species movement to more favorable conditions, 3) sequestering carbon, and 4) reducing greenhouse gas emissions (1).

As an agricultural management option under climate change, agroforestry is unique in that it is a woody-plant based approach that adds functional diversity at various scales (2). Perennial components can create microclimates that benefit crops and livestock. The use of agroforestry to enhance resiliency is not a new idea. To mitigate one of the largest North American wind-erosion events in history—the 1930s Dust Bowl— the Prairie States Forestry Project planted over 18,600 miles of windbreaks in the Great Plains (3). Windbreaks continue to be used by farmers and livestock producers across the US to enhance crop yields and protect soil health, while also



providing conservation benefits. Other agroforestry practices can play similar roles in different agricultural systems, delivering a range of functions to reduce threats and enhance landscape resiliency (Table 1).

Habitat fragmentation will likely impede the ability of many species to respond, move, and/or adapt to climate-related impacts (4). Agroforestry practices can function as forest corridors or stepping stones in agricultural landscapes that enhance habitat connectivity. For example, in the intensely farmed Tensas River Basin, Louisiana black bears (Ursus americanus luteolus) use riparian forest buffers to travel between forest patches to forage and breed (5).

One of the unique benefits of agroforestry is the opportunity to provide mitigation benefits along with adaptation in an integrated and synergistic manner (6). Agroforestry practices can reduce net greenhouse gas budgets by sequestering carbon in soil and biomass, decreasing fossil fuel usage by reduced equipment runs in fields, enhancing energy conservation around farm buildings, and enhancing efficiency of nitrogen fertilizer use (7). Agroforestry may offer valuable mitigation benefits in return for the amount of area in the agroforestry practice. For instance, woody riparian and

Practice	Description	Primary benefits and uses
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 • Increase C storage in plant biomass and soils
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 • Enhance habitat for wildlife and beneficial insects • Conserve energy • Manage snow dispersal to keep roads open or to harvest moisture • Increase C storage in plant biomass and soils
Riparian forest buffers	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 • Improve livestock health and productivity • Reduce nutrient loss • Reduce fuel load • Increase C storage in plant biomass and soils
Forest farming (also called multistory cropping)	Existing or planted stands of trees and/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

hedgerow habitats on a Central Valley farm in California stored 18% of the farmscape's total carbon (C), despite occupying only 6% of the total area (8).

Likely Changes

Changes in climate patterns and weather variability pose substantial hazards for current U.S. agricultural systems (9, 10). Table 2 describes anticipated changes in different regions of the country with implications for crops and livestock raised in agroforestry systems (11). For example, significantly more hot spells may cause a rancher to add a few silvopasture paddocks to their grazing rotation. Similarly, fewer freeze days may cause a producer using apple trees in their agroforestry system to select different varieties.

Table 2. Observed and expected changes in weather by U.S. Region. Expected changes are the A2 scenario at mid-century (2041–2070 average). Modified from (11).

	Annual Temperature	Annual Precipitation	Growing Season	Hot Spells	Freeze Days
Northwest	↑ Greatest summer increase in the interior	↑ Increase in most seasons; decrease in summer	**+25-30 days** Greatest increase west of the Cascades	**+6-10 days** Greatest increase in south ID	**-30-40 days** Greatest change at high elevations
Southwest	↑ Warming likely in all seasons, with greatest increase in summer	↓ Largest decrease in the Sierra Nevadas & southern AZ. and NM	**+10-38 days** Least change in CA & greatest change in the interior far west	**+8-16 days** Increase of 20 days or more in the south	**-25-35 days** Greatest change at high elevations
Southern Great Plains	↑ Greatest increase in the summer and fall, & least in spring	↑ ↓ Increase in the north & decrease in the south	**+15-30 days** Greatest increase in southeast TX	**+8-24 days** Greatest increase in north TX & OK	**-0-20 days** Greatest decrease in the west
Northern Great Plains	↑ Greatest increase in winter & summer	↑ ↓ Greatest increase in winter & fall; greatest decrease in summer	**+20-30 days**	**+0-12 days** Greatest increase in winter & fall	**-15-21 days** Greatest decrease in the northwest
Midwest	↑ Greatest summer increase in the south	↑ Increase in winter, spring & fall; no change to a decrease in summer	**+22-30 days** Greatest increase in northern MI	**+5-20 days** Change increases moving south	**-18-23 days** Greatest increase in the east
Northeast	↑ Both annual & seasonal temps increase with latitude	↑ Seasonal increase greatest in winter Summer rain expected to decline	**+19-27 days**	**+1-7 days** Greatest change in WV Least change in NY & New England	**-18-26 days** Smaller changes likely along parts of the Atlantic coast
Southeast	↑ Seasonal increase greatest in summer, esp. in the NW	↑ Greatest increase in winter	**+0-30 days** Least change in southern FL Greatest change in the LA & AL	**+4-20 days** Least change in the Appalachians Greatest change in the west	**-0-25 days** Change increases moving north

Options for Management

For farmers and ranchers, agroforestry practices provide perennial living structure that can offer adaptation strategies for different climate change risks depending on the specific practice (Table 3). While the mitigation services of agroforestry are valuable, they are rarely the driver of design and implementation by producers. Because most farmers and managers do not make management decisions primarily to mitigate climate change, hence these options for management are focused on adaptation.

Table 3. Climate change risks and associated adaptation services provided by agroforestry practices. Source (12).

Risk	Adaptation	Agroforestry Practice
Intense precipitation events	Slow water runoff to reduce flooding, soil erosion, and water pollution	Riparian forest buffers; alley cropping
Increased temperatures	Reduce heat stress on animals by providing shade	Silvopasture
Increased frequency and intensity of drought	Reduce evapotranspiration by reducing windspeed	Windbreaks
Increased storm intensity (wind & precipitation)	Protect crops from wind damage	Windbreaks; alley cropping
Changes in growing season due to temperature and precipitation	Protect crops by creating microclimates	Windbreaks; alley cropping; forest farming
Winter storms and cold temperature extremes	Reduce cold stress on animals by providing shelter	Silvopasture; windbreaks
Increased insect and disease problems	Control pests by providing habitat for beneficial insects	Windbreaks; riparian forest buffers; alley cropping
Increased possibility of crop failure due to other risks	Reduce total crop loss by increasing crop diversity.	All agroforestry practices

Intense Precipitation and Flooding

Agroforestry can help landowners adapt to increasing intense precipitation events and lessen the negative impacts by expanding forest and tree cover that intercept rainfall, increase the amount of rain that infiltrates into the ground, and reduce the quantity, speed, and peak flows of runoff (2, 13). When compared with no till, cover crops, crop and livestock integration, and crop rotation, adding perennials increased water infiltration the most compared with annual crops (an increase of 59%) (14). In Missouri, fields planted with agroforestry contour buffers had a 28 to 30% reduction in annual soil loss (15).

Heat and Drought

Increasing humidity and higher day and nighttime temperatures pose a significant challenge for livestock and crop production systems (9, 10). Silvopasture and windbreaks can mitigate these challenges by reducing animal heat stress and maintaining quantity and quality of forage production under increasing temperatures (2). For instance, cattle provided with shade reached their target body weight 20 days earlier than those without shade (16). In cropping systems, agroforestry practices can reduce agricultural demand for water during dry periods. Windbreaks reduce crop water stress and conserve soil moisture by reducing windspeed across adjacent crop fields, thereby reducing evaporation losses from soil and transpiration by crops (17) and may be particularly valuable under water-stressed conditions (18).

Longer, hotter drought periods will reduce soil cover by crop and pasture vegetation and leave the soil increasingly vulnerable to accelerated erosion (8). Permanent vegetative cover in the form of drought-hardy agroforestry practices can maintain soil protection by complementing annual vegetation cover practices like cover crops which may face establishment challenges in times of drought (2, 19). Windbreaks, through a variety of physical processes, can reduce wind speed over the land surface and thereby reduce the mobilization and transport of dust and associated particulates (20, 21). The zone of reduced wind speed typically extends a distance equivalent to 10 to 20 tree heights downwind of a windbreak, so in large agricultural landscapes multiple barriers are often required to effectively control wind erosion (21).

In areas where rising stream temperatures may affect cold-water aquatic habitat, shade from riparian forest buffers can help maintain cooler water temperatures (22). Riparian forest buffers can maintain lower maximum summer stream temperatures by 3.3 °C compared with streams without buffers and lower summer mean stream temperatures by 0.6 °C based on a meta-analysis of 10 studies (23).

Winter Storms and Cold Temperatures

The consequences of extreme winter events can create challenges to producers, exemplified by the October 2013 storm that resulted in the deaths of more than 45,000 livestock in South Dakota (24). Reducing wind speed in the winter by using agroforestry practices, particularly windbreaks, can also lower livestock stress, improve feeding efficiency, and enhance survival during lambing and or calving season (2). Field windbreaks can help capture the moisture available in snow by slowing the wind and distributing the snow across the field. Snow capture and protection of crop plants from winter desiccation by windbreaks can increase wheat yields by 15% to 20% (25, 26).

Diversification

Agroforestry systems are multispecies mixes of perennials and annuals that are inherently more resilient to environmental stresses than annual-only cropping systems (27, 28). They have a higher degree of species diversity, larger root systems that hedge against climate extremes, and the ability to tolerate increased disturbance (Figure 2) (29). Where winter chilling requirements do not become limiting, food-producing perennial crops such as fruits, nuts, and berries can provide resilience to climate extremes. Species mixes spread biological and financial risks across crops and seasons. By providing continuous living cover, perennial crops may offer more resilient and sustainable options on marginal lands than annual crops that often require more soil disturbances (30).

Figure 2. The willows in this alley cropping system provided a harvestable product during an extremely wet year when the annual crop was lost due to flooding. Credit: Josh Gambel

Plant Adaptation

Successful agroforestry practices depend on the ability of the trees and shrubs to survive and grow well enough to provide the benefits sought. Local climate is a major factor in determining which woody species can be effective in an agroforestry practice, and a great deal of variability in this regard exists among different species. As climate changes, local climate can shift beyond tolerable thresholds for some species or varieties and move to within tolerable thresholds for other species or varieties. In a changing climate, agroforestry species must be able to survive and grow under both current and future climatic conditions. If species that are currently used cannot adapt to future climate, risk is high that the desired functional lifespan of the agroforestry practice will not be achieved (31).

When selecting plants for an agroforestry application, consider the multiple points of climate vulnerability: winter chilling requirements, springtime freeze risk, heat and water stress, pollination constraints, and disease and pest damage (32). Tools that model future local climate shifts can be useful when considering the suitability of species or varieties based on anticipated changes in temperature, precipitation and extreme weather. Reviewing plant material lists in nearby ecoregions that have a current climate similar to the predicated future climate of your planting area can be one way to identify species that may be potentially suitable for the changing conditions. Another effective

adaptation strategy is simply increasing the plant diversity within a planting, which broadens the mix of genetic, phenological, and biophysical attributes (33).

How to cite

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Recommended Reading

Bentrup, Gary; Cernusca, Ina; Gold, Michael. 2018. Supporting U.S. agricultural landscapes under changing conditions with agroforestry: An annotated bibliography. Bibliographies and Literature of Agriculture 137. Washington, DC: U.S. Department of Agriculture Forest Service. 63 p.

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Related Links

USDA National Agroforestry Center (NAC) – Climate Change Topic Page – A page dedicated to NAC resources on agroforestry and climate change.

USDA Climate Hubs – The Climate Hubs link USDA research and program agencies in their regional delivery of timely and authoritative tools and information to agricultural producers and professionals.

Northeast Climate Hub 'As If You Were There' 360° Demonstrations – This demonstration site website offer a way to virtually see how farm and forestry practices work in the real world. Three sites feature agroforestry operations.

Research

Livestock performance in silvopasture systems Shade provided by silvopasture may play an important role in reducing heat stress on livestock from lambs to poultry. Research at Virginia Tech is investigating animal well-being and performance in hardwood silvopasture systems. Contact: Gabe Pent

Tree leaf fodder for livestock: transitioning farm woodlots to 'air meadow' for climate resilience
Historically Europeans relied on established 'air meadows' of pollards heavily pruned in 3 to 5 year cycles, to overwinter cows, sheep, goats and hogs. This project will investigate previously established pollards and document findings, to guide development of climate resilient fodder tree systems. Contact: Shana Hanson

Measuring soil health and carbon sequestration in an emerging chestnut agroforestry system
This project will document changes in soil health and carbon sequestration in chestnut agroforestry systems that incorporate regenerative agricultural practices. Contact: Keith Zaltzberg

Tools

COMET-Farm™ – This tool enables farmers and ranchers to estimate carbon sequestration and greenhouse gas emissions related to annual crop production, livestock, and on-farm energy use and includes a module on agroforestry.

Agroforestry and Climate Change Bibliography – This online library contains scientific literature on agroforestry's role in adaptation and mitigation under climatic change, as well as the effects of these stressors on agroforestry from the period of 1992 to the present.

Conservation Buffers – Illustrated guidelines for designing multipurpose buffers based on over 1,400 scientific publications.

AgBufferBuilder – A GIS-based tool for planning water quality buffers.

Chapter 6: Agroforestry Resources – Examples of decision-support tools to support planning, design, and management of agroforestry systems.

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