Southeast and Caribbean

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Description of the Region

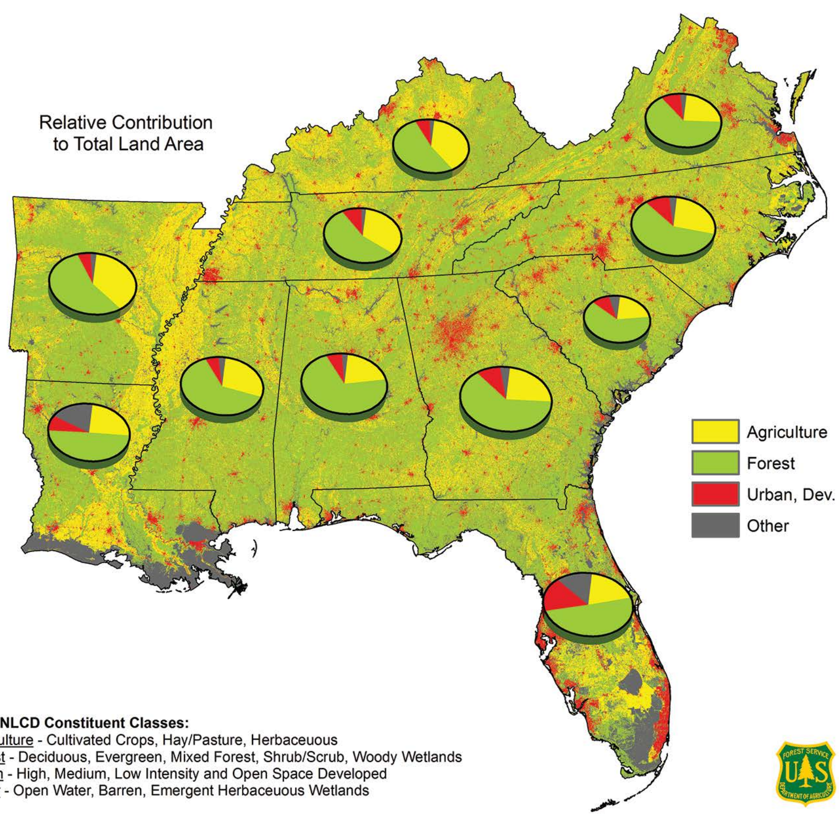
Cropland and pastureland occupy significant portions of land area in the Southeastern United States. Forests occupy from 50 to 69 percent of the land within each State in the region (fig. A.15). All of these land uses provide significant productivity and income. The Southeast encompasses physiographic provinces, or ecoregions (Wear and Greis 2012), that have unique climate, fire history, and composition of vegetation. From the physiographic province of the Appalachian Mountains

Figure A.15. Acres of land-use categories of the 11 Southeastern States. (Map and table prepared by William M. Christie, Eastern Forest Environmental Threat Assessment Center, USDA Forest Service, Southern Research Station, Asheville, NC).

Percent Agriculture and Forest for 11 Southeastern States

Source: 2011 National Land Cover Database

State	Agriculture	% of Total	Forest	% of Total	Urban, Dev.	% of Total	Other	% of Total	*State Total*
Alabama	6,821,453	21%	22,580,332	69%	2,388,761	7%	931,798	3%	32,722,344
Arkansas	11,988,555	36%	18,727,329	56%	2,019,953	6%	934,239	3%	33,670,075
Florida	7,127,234	20%	18,066,765	50%	5,232,627	15%	5,458,966	15%	35,885,593
Georgia	8,850,379	24%	23,103,176	62%	3,740,669	10%	1,565,959	4%	37,260,183
Kentucky	9,451,253	37%	13,555,903	53%	1,910,059	7%	652,578	3%	25,569,793
Louisiana	7,136,092	24%	14,680,875	50%	2,071,030	7%	5,713,188	19%	29,601,185
Mississippi	8,343,911	28%	18,886,290	63%	1,941,509	6%	1,022,707	3%	30,194,417
North Carolina	8,160,063	26%	18,516,853	59%	3,414,561	11%	1,158,195	4%	31,249,672
South Carolina	4,208,803	21%	12,175,005	62%	1,883,596	10%	1,334,596	7%	19,602,000
Tennessee	8,601,207	32%	14,805,674	55%	2,586,309	10%	684,328	3%	26,677,518
Virginia	5,980,234	23%	16,214,224	63%	2,499,889	10%	876,702	3%	25,571,049
SE Total	86,669,185	26%	191,312,424	58%	29,688,962	9%	20,333,255	6%	328,003,826



2011 NLCD Constituent Classes:
Agriculture - Cultivated Crops, Hay/Pasture, Herbaceuous
Forest - Deciduous, Evergreen, Mixed Forest, Shrub/Scrub, Woody Wetlands
Urban - High, Medium, Low Intensity and Open Space Developed
Other - Open Water, Barren, Emergent Herbaceuous Wetlands

Source: Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., and Xian, G. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sensing of Environment, 132: 159 – 175.

to the alluvial plains of the Mississippi River Basin, within deciduous forests of Kentucky and Tennessee and the Interior Highlands of the Ozarks, to the Piedmont, Flatwoods, and Coastal Plains, a large portion of the land area is appropriate for implementing several types of agroforestry, integrating either crops or livestock, or both, with trees and woody crops. All these Southeastern ecoregions have land area capable of supporting agroforestry as a tool for climate-smart agriculture to meet priority elements of the U.S. Department of Agriculture (USDA) Climate Change Science Plan (USDA 2010a). Diversified landscapes using agroforestry practices in the Southeast can help enhance rural prosperity; restore and conserve the Nation's forests, farms, ranches, and grasslands; and help protect and enhance America's water resource—all elements of strategic goals stated in the plan.

As part of the Lesser Antillean archipelago, the U.S. Caribbean islands consist primarily of Puerto Rico and the U.S. Virgin Islands, along with disputed Navassa Island, Bajo Nuevo Bank, and Serranilla Bank. Puerto Rico is the largest island of a group of cays and islands that includes Mona, Monito, and Desecheo to the west and Culebra and Vieques to the east. Of the island of Puerto Rico, 53 percent is mountainous (three ranges), with nearly 12 percent of the landscape in ridges, 25 percent in plains, and 20 percent in hills. Dry climatic conditions prevail on nearly 30 percent of the island and, of the 57 landscape units of the islands of Puerto Rico, the most abundant landforms are moist and wet slopes, primarily on volcanic soils (Gould et al. 2008, Martinuzzi et al. 2007, PR DNER 2009). Six subtropical Holdridge life zones are on the island (Ewel and Witmore 1973). The island also has diverse terrestrial, wetland, coastal, and marine ecosystems and also agroforest and urban systems (Miller and Lugo 2009).

The U.S. Virgin Islands has three large islands—St. Croix, St. John, and St. Thomas—and includes nearby Water Island along with 68 smaller islands and cays. The topography is characterized by central mountain ranges and small coastal plains. The uplands are rocky, rugged slopes; e.g., 50 percent of St. Croix's land area contains slopes of 25 to 35 percent. Natural influences such as landslides, hurricanes and tropical storms, and fire are key to shaping the environment and the marine and terrestrial communities of the islands (Chakroff 2010).

From the viewpoint of suitability, the Caribbean islands provide a diversity of tropical species and a variety of options for agroforestry-based land management. Puerto Rico consists of 49 percent forest, 33 percent agriculture/pasture, and 14 percent developed land. Forest cover is approximately 90 percent on St. John (two-thirds national park), 70 percent on St. Thomas, and 55 percent on St. Croix (fig. A.16). Loss of forested landscapes to development is perhaps the greatest land-use pressure for Puerto Rico; this places critical stress on watersheds and results in a fragmented and increasingly urbanized landscape. Also, land use outside developed zones is perhaps best viewed in terms of the nature of woody plant cover and whether animals are excluded or allowed access. Both Puerto Rico and the U.S. Virgin Islands are experiencing a trend toward an increase in woody cover with the loss of agricultural land and pastureland (Brandeis and Turner 2013a, 2013b; Brandeis et al. 2009). With informed management, this cover could be suitable for return to production or conservation use and less prone to the establishment of invasive plants.

Agroforestry practices are viable for both larger acreages and for small land holdings for mitigation and adaptation to climate change and resilience under climate variability in the Southeast United States-Caribbean. The economics of risk and value of diversified systems bode well for production in the region. Riparian forest buffers and conservation buffers with trees are the most widely used practices across the Southeast (Lowrance and Sheridan 2005, Trozzo et al. 2014b, Twilley et al. 2001). Buffers may be more popular, because they typically can meet objectives of the landowner and help maintain environmental health and ecosystem services without active management. More interactive and intensified practices, such as energy, food, fiber, floral, or medicinal crop production, could be implemented in many of these buffer zones, increasing their overall utility and productivity.

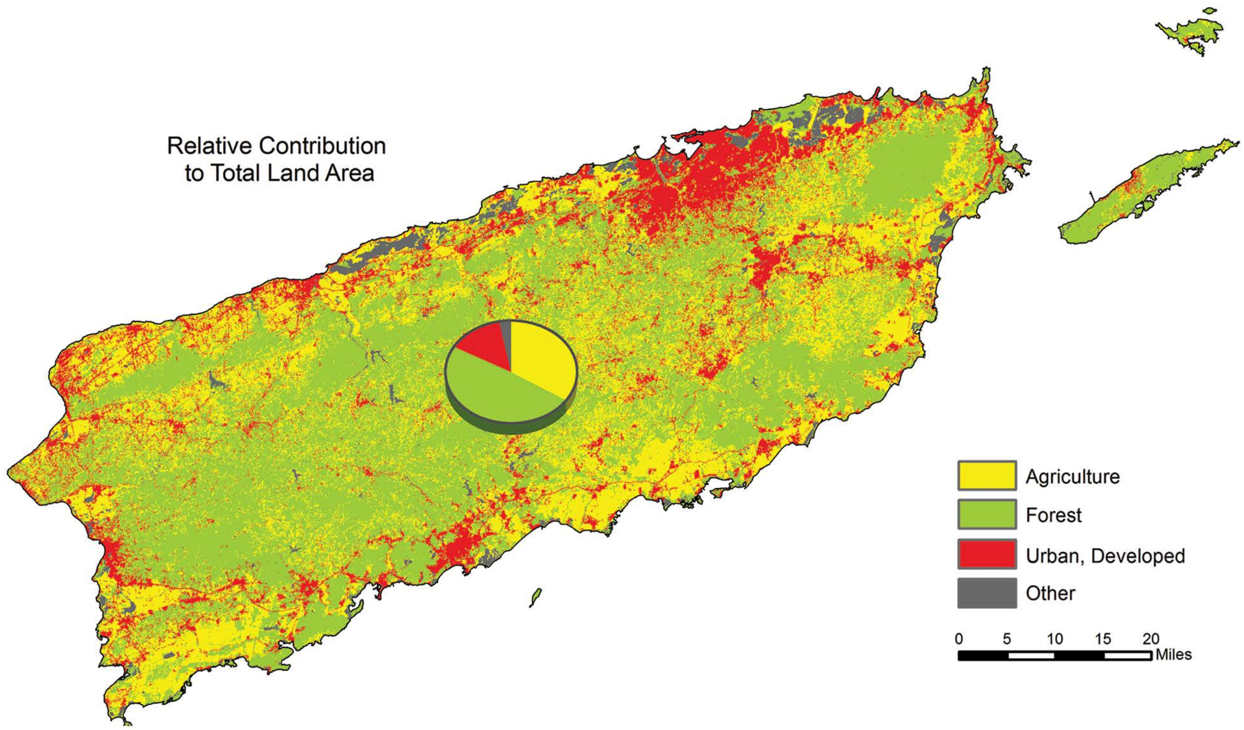
The diversity of farms and forest tracts in the region offer many opportunities to integrate trees with crop or pasture systems. Such systems would benefit many of these lands beyond their value for addressing climate change. Sloping lands of the Interior Highlands, the Blue Ridge Plateau, and the Caribbean, for example, are good candidates for integrating contoured swale practices with silvopasture or alley cropping, using nut, fruit, fodder, or timber trees to better harvest water and reduce erosion (fig. A.17) (Hill 2010, Smith 1929).

In a similar way, forest farming is possible on extensive areas of forest and woodland, and people of the southern mountains have a long tradition of harvesting and, more recently, of cultivating nontimber forest products (NTFPs) (Chamberlain et al. 2009, Persons and Davis 2007). Two-strata or multistrata land management options—whether with crop and timber trees or NTFPs—can offset seasonal risks associated with monocultural production systems and buffer the suite of effects driven by a shifting climate. That tree crops provide protective functions (e.g., soil and water conservation) especially on marginal lands or steeper slopes, is becoming more widely recognized (Delgado et al. 2011). These diversified agroforestry systems can offer reduced risk and greater economic stability under climate variability with both short- and long-term income sources (CIER 2008, Cubbage et al. 2012). Recent census data confirm producers are identifying and using these practices, although current adoption rates are low (table A.5).

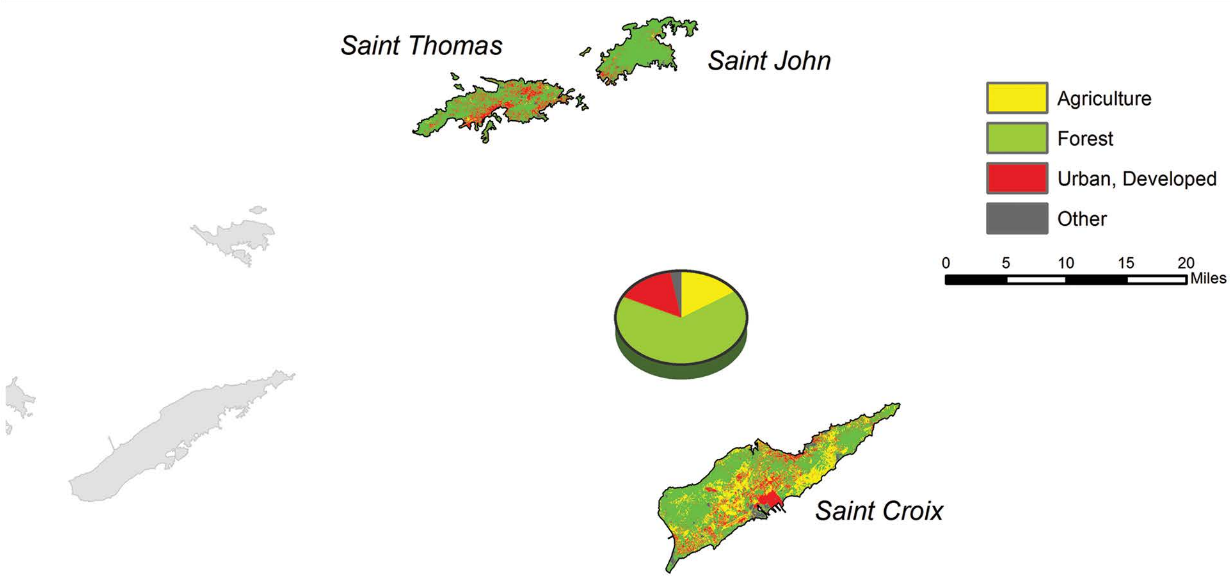
Figure A.16. Acres of land-use categories of the Caribbean islands—U.S. territories. (Map and table prepared by William M. Christie, Eastern Forest Environmental Threat Assessment Center, USDA Forest Service, Southern Research Station, Asheville, NC).

Percent Agriculture and Forest for Puerto Rico and the U.S. Virgin Islands

Territory	Agriculture (ac)	% of Total	Forest (ac)	% of Total	Urban, Dev. (ac)	% of Total	Other (ac)	% of Total	TOTAL
Puerto Rico	725,911	33%	1,079,709	49%	320,806	15%	77,568	4%	2,203,994
US Virgin Islands	14,382	17%	54,259	64%	13,246	16%	2,836	3%	84,724



Source: The National Map, 2013 (data 2007). USGS Small-scale Dataset: 100-Meter Resolution Land Cover of Puerto Rico and the U.S. Virgin Islands 201301.



Source: Kennaway, T., E. H. Helmer, M. A. Lefsky, T. A. Brandeis and K. R. Sherrill. 2008. Mapping land cover and estimating forest structure using satellite imagery and coarse resolution lidar in the Virgin Islands. Journal of Applied Remote Sensing 2:023551, DOI:10.1117/1.3063939. The Department of Forestry Rangeland and Watershed Stewardship, College of Natural Resources at Colorado State University in cooperation with the USDA Forest Service International Institute of Tropical Forestry.

Table A.5. Selected agroforestry practices, 2012 Census of Agriculture—State Data.

State	Farms practicing alley cropping or silvopasture (farms in State)	Percent of farms practicing agroforestry
Alabama	119 (43,233)	0.28
Arkansas	47 (45,071)	0.10
Florida	137 (47,740)	0.29
Georgia	99 (42,257)	0.23
Kentucky	96 (77,064)	0.13
Louisiana	37 (28,093)	0.13
Mississippi	65 (38,076)	0.17
North Carolina	119 (50,218)	0.24
South Carolina	51 (25,266)	0.20
Tennessee	51 (68,050)	0.08
Virginia	74 (46,030)	0.16
Total farms	**895 (511,098)**	**0.18**

Nationwide, 2,725 farms report using agroforestry practices. Thus, one-third of the reporting farms nationwide which use these practices are in the Southeast United States.

Source: Adapted from Table 43; USDA National Agricultural Statistics Service.

Along with agroforestry's potential in agricultural and forested systems, incorporating agroforestry practices may provide many benefits on lands that could be classified as mixed land cover (after Riitters et al. 2000). These benefits would be at the interfaces of agricultural lands with forests or with either of these cover types with urbanized areas. At these interfaces, agroforestry practices hold the potential to help buffer against the effects of forest fragmentation, to provide or mimic natural corridors for species movement (wildlife) or maintenance (biodiversity), and to increase options for provision of ecosystem services in these dynamic land-use landscapes (e.g., Douglas and Jennings 2014, Morgan and Zimmerman 2014).

Threats and Challenges to Agricultural Production and Other Ecosystem Services

Land-use change (e.g., due to urbanization and market forces), climate change, and environmental policies affecting land-use choices are the largest potential challenges or uncertainties facing agricultural and forested landscapes in the Southeast (e.g., Keyser et al. 2014). Under current climate change scenarios, the Southeast faces increasing temperatures and frequency of extreme weather events, reduced precipitation, and land area losses due to rising sea levels. Increased disturbances such as drought (Pederson et al. 2012, Seager et al. 2009, Sun et al. 2013), insect infestations (Brandle et al. 2004, Doblas-Miranda et al. 2014, Poch and Simonetti 2013), hurricanes (Mitchum 2011, Philpott et al. 2008), and fire (Liu et al. 2014, Mitchell et al. 2014, Stanturf and Goodrick 2012) may also occur as a consequence of climate change (Vose et al. 2012). These responses are likely to be magnified by the changes in land use and cover, which are occurring at some of the most rapid rates nationwide.

The main threats to the production and supply of ecosystem services in Puerto Rico include lack of resource management, lack of incentives, lack of valuation of forested land, threats from invasive species and nonnative grasses, wildfire, and climate change. In the U.S. Virgin Islands, primary threats include lack of effective forest management strategies, lax enforcement of existing statutes, and too few technical professionals with adaptation/mitigation knowledge. The Caribbean archipelago is a global biodiversity hotspot, and species manipulation and unregulated species introductions are threats to local ecological systems (vegetation, wildlife, and hydrological

Figure A.17. Swale system on a hillslope, St. Croix, U.S. Virgin Islands, before (A) and after (B) installation of contour tree rows and horticultural crop. The hedgerows are planted with fruit trees and fodder trees that are periodically coppiced for leaf material to serve as animal feed. The crop fields are rotated seasonally and annually to diversify and manage production. Soil and water conservation are a valued ecosystem service on these slopes. (Photos by Nate Olive, Ridge to Reef Farm).

processes). Despite these challenges, climate is the overarching influence on forest species composition when recovering from deforestation; all other factors are secondary to the influence of climate (Brandeis and Turner 2013a, 2013b). Based on the 2014 National Climate Assessment for the U.S. Southeast and the Caribbean (Carter et al. 2014), the region is exceptionally vulnerable to sea level rise, hurricanes, extreme heat events, and decreased water availability. Freshwater availability is already an issue in the region (CCCCC 2009).

On Caribbean islands, businesses, ports, and homes ring the coast and are extremely vulnerable to small rises in sea level. With 56 percent of the population living in coastal municipalities, Puerto Rico has one of the highest population densities in the world. As a result of current sea-level rise, the coastline of Puerto Rico around Rincón is being eroded at a rate of 3.3 feet per year (Carter et al. 2014). Temperatures for Puerto Rico under climate change with global warming are projected to increase 2 °F to 5 °F by the end of the century (Carter et al. 2014). The trend exhibited in the Caribbean since the 1950s is of increasing numbers of very warm days and nights, with daytime maximum temperatures rising above 90 °F and nighttime temperatures remaining above 75 °F. Increasing temperatures contribute to increased fire frequency, intensity, and size.

Also, since the early 1980s, the number of Category 4 and 5 hurricanes in the Atlantic basin has distinctly increased (Carter et al. 2014). Ocean warming could support species shifts, growth rate, migrations, and invasive species. Droughts are one of the most frequent climate hazards in the Caribbean, resulting in economic losses. Precipitation trends in the region are unclear, with some higher and some lower average rainfall areas noted. Most models show future decreases in precipitation are likely, with a few areas showing increases. Caribbean islands already have a high human and livestock health burden from climate-sensitive disease. In addition, either because of cyclical changes or climate change, more Saharan dust is being carried into the region by prevailing winds from Africa.

Agroforestry practices can play a key role in mitigating these threats by improving diversity, modifying microclimate to maintain production, and enhancing resilience. Although recognizing and monetizing the value of ecosystem services can be a key challenge, doing so has potential as a mechanism for furthering agroforestry implementation, because the value of these services may be worth more than the agricultural and forest products derived from agroforestry systems (e.g., Alam et al. 2014). Most managers perceive their cropland or forested land as most valuable when managed with traditional production practices. For this audience, greater government investments via cost-share payments may be needed to drive the adoption of agroforestry practices to levels that meet desired environmental outcomes under current market conditions (Martinuzzi et al. 2014, Stainback et al. 2004). Such support may be less important, however, for newer landowners and beginning farmers who have goals beyond production outcomes, and these systems may foster greater cross-generational ties if they provide ways to support intergenerational transfer. Although agroforestry practices offer opportunities to meet the challenges of growing global demand for natural resources, adaptation measures must go beyond technical solutions around single components; they must address human-institutional dimensions and the social and economic consequences of climate change (Seppälä et al. 2009), especially in support of poor and forest-dependent communities.

Policies to mitigate climate change likely will have both direct and indirect impacts on production systems of the region. For example, the Southeast is predicted to supply about one-half the biomass for U.S. bioenergy systems in the future (USDA 2010b). In this scenario, agroforestry practices could help meet demands for fuel and fiber, but policies driven strictly to bioenergy feedstock production may run counter to more integrated, agroforestry system development. Many private landowners do not actively manage their lands, and only some understand the connections between their lands and land use and the broader ecosystem. Thus, reaching new audiences of landowners with effective outreach (e.g., through trusted contacts) and partnering with diverse stakeholder groups for education and incentive programs will be critical components in meeting the demands for products and ecosystem services from these lands.

Agroforestry as an Opportunity To Build Resilience

In the Caribbean, agricultural lands were being abandoned by the mid-1800s due to the crash of the sugar market, emancipation and the loss of slave labor, and the difficulty of farming steep slopes. Agroforestry practices are part of the region's tradition and have commercial benefits that include development of NTFPs, such as medicinal plants, arts and crafts materials, food, animal forage, resins, and oils (Morgan and Zimmerman 2014). Landowners may grow row or orchard crops with windbreaks, or they may combine animal production within orchards. Forest farming of plants used for the floral industry, food/culinary uses, or health supplements is well documented (Chamberlain et al. 2009, Robinson et al. 2014, Vaughan et al. 2011).

On Puerto Rico, some local artisans are using native and other locally grown wood to produce musical instruments and crafts. Shaded coffee production is most developed in western Puerto Rico and silvopasture in the southern landscape on more level land and alluvial plains, where greater livestock and cropping exist. More so than in the Southeastern States, the implementation of practices in the islands is frequently based more on cultural identity and inherited knowledge than on technical assistance. Exceptions may be beekeeping and honey production or growing high-value crops such as mushrooms. Planting traditional varieties of fruits (e.g., indigenous fruits like guavaberry [*Myrciaria floribunda*] or West Indian avocado [*Persea americana* var. *americana*]) or mixtures of culinary crops under tree shade are practices with cultural roots that support a pride in the sense of place.

In the U.S. islands, patio or dooryard gardens—a form of multistrata agroforestry used in both urban and rural settings—vary in their potential for ecosystem service provisioning and buffering climate change. Zones of management and cultivation often ring rural family dwellings, from a zone near the home patio, with materials for both aesthetic and food sources along with fruit trees to the next zone, with less intensive management but similar species and some soil enrichment practices. Living fences and field border plantings are sometimes incorporated.

Farther away, fields with less or little shade are used for open grazing or market crops and usually have fewer inputs. Areas with higher rainfall have some bananas and plantain agroforestry. Some places use trees to isolate chicken farms and mitigate odor. In the islands, riparian buffers could be managed to increase cover by adding woody components to what now is a "grass only" practice (USDA Natural Resources Conservation Service [NRCS] standard). Some discussion was begun in 2012 regarding planting fruit tree crops, such as mamey (*Mammea americana*), açaí (*Euterpe oleracea*), and cacao (*Theobroma cacao*), in riparian zones (USDA Forest Service 2016) around El Yunque National Forest.

In the Southeast, frequent natural and sometimes human-caused fire created open presettlement woods and savannahs with grassy understories, where bison and elk once roamed. The Scotch-Irish who settled this region brought a tradition of grazing domestic stock, often with low stocking rates (5 to 10 acres per head) and limited management. This history is noted in Wahlenberg's 1946 book: "In accordance with age-old custom, southern landowners usually tolerate grazing on their forest lands by the livestock of numerous small famers. The typical forest range is open, no permits are required, no fees are charged, and usually no attempt is made to control fires set by stock owners" (Wahlenberg 1946: 309).

In a similar way, settlers to the Ozarks were grazing cattle on bluestem forage in the shortleaf-hardwood and hardwood forest as early as 1800. Graeber (1939) documented the effects of cattle, sheep, and pig "free range" woodland grazing on forest soils in North Carolina in the early 1930s in and around what is now the Great Smoky Mountains National Park (Lindsay and Bratton 2014). J. Russell Smith (1929), a formative advocate for soil and water conservation, outlined how to put trees to work as perennial crops to counter erosion, flooding, and "climatic peculiarities" to extend agriculture on hill slopes and marginal lands and also on level lands to create two-story agriculture (trees above and annual crops below). Raking pine straw for profit was also popular during this time (Mattoon 1930). In 1930, W.R. Mattoon noted that a landowner in North Carolina "…makes regular income selling pine straw (leaves or needles) from his 10-acre patch of pines. He sells the straw on the ground at a rate of 25 cents per cartload. As an acre produces three to five loads, his net income is from 75 cents to $1.25 per acre yearly" (Mattoon 1930: 12). Fencing laws enacted in the 1930s eventually precluded livestock from freely wandering open forests, thus the practices of woodland grazing and burning largely disappeared from the landscape.

Modern agroforestry techniques take us beyond free-ranging cattle to science-based land management. In the Southeastern United States, agroforestry practices can help address threats posed by global climate change. In this region, riparian buffers are used extensively as a best management practice for water quality, however, most land managers and landowners do not often view their use as an agroforestry practice (Trozzo et al. 2014a). Forest farming and silvopasture are other agroforestry practices that seem to have the most promise in the region (fig. A.18–A.22). Forest farming for medicinals or decorative and floral items provides additional income to landowners, thus improving livelihoods. North Carolina, Florida, and Georgia are considered to be pine-straw industry leaders (Mills and Robertson 1991). Estimates for market value range from a 1996 pine-straw value of $50 million in North Carolina (Rowland 2003) to a $79 million value for Florida in 2003 (Hodges et al. 2005). The State with the most detailed records regarding pine-straw production is Georgia, where data for pine straw is actually collected as a separate commodity. In 2012, pine straw

Figure A.18. Pine-based silvopasture managed with cattle is perhaps the most common type of silvopasture in the Southeast. Cattle benefit both in summer and winter from the buffered environment created by the tree canopy cover. (Photo by USDA National Agroforestry Center).

Figure A.19. Small ruminants may be an important means of managing silvopastures. Goats and sheep can be instrumental in removing invasive weeds and stump sprouts that often develop in thinned tree stands. Goat silvopasture, Dallas County, AL; McIntire Stennis Forestry Research Program. (Photo by Nar Gurung, Tuskegee University).

Figure A.20. While it is most often used as a landscape mulch, pine straw is a nontimber forest product that is highly sought after in floral, craft and decorative markets (A). Pine straw and nontimber forest products crafts; Alabama-Coushatta Tribe longleaf pine needle baskets (B). (Photo by Beverly Moseley, USDA Natural Resources Conservation Service).

Figure A.21. In the Southeastern United States, pine straw is usually harvested from the forest floor of longleaf, slash, or loblolly stands, and may be compatible with many land uses including silvopasture. The open understory of a silvopasture allows for pine straw to be bailed by machine (A) or hand (B), and can provide an additional source of income for landowners. (Photos by Becky Barlow, School of Forestry and Wildlife Sciences, Auburn University).

Figure A.22. Plants valued for traditional use and/or with high value in the supplements market are utilized in multistrata agroforestry systems. Cultivated in forest shade environments, these herbs provide an income stream and play a role in conservation of wild populations by reducing collection pressure. In this figure, goldenseal (*Hydrastis canadensis*) roots are ready for planting in Catawba, VA (A) and goldenseal cover under canopy (B). (Photos by Forest Farming Community of Practice).

accounted for 9.6 percent of Georgia's forest products market, at $58.7 million. Successful silvopasture management requires good grazing management practices, which improve cattle waste management and forage production, and it also limits the amount of commercial feed used. Integrated crop-livestock agriculture, including tree crop systems, all contribute to carbon dioxide (CO_2) sequestration and enhance soil fertility, water quality, and biodiversity (Sulc and Franzluebbers 2014). In the islands, these practices hold promise for the transition of abandoned pasture, shade coffee, or agricultural lands (Brandeis et al. 2009).

In Alabama, Florida, Georgia, Louisiana, and Mississippi, forest farming and silvopasture are common agroforestry practices. Of these 5 States, 4 were in the top 10 reported as participating in alley cropping or silvopasture in 2012 (table A.5). Harvesting pine straw is common and may actually motivate landowners to restore imperiled longleaf pine (*Pinus palustris*) ecosystems in the southern part of the Southeast. This restoration would accrue additional benefits, because longleaf pine forests are likely to be among the most resilient against the effects of expected future climatic changes, given their tolerance to wind, drought, fire, insects, and disease (Johnsen et al. 2009, Kush et al. 2004, Remucal et al. 2013).

Silvopasture is well suited to most southern pines and could benefit longleaf and shortleaf pine (*P. echinata*) restoration efforts across the region. With that restoration comes the opportunity to restore the understories of these systems, which were typically low and grassy, providing excellent habitat for native pollinators. Climate change, in turn, may benefit loblolly (*P. taeda*) and longleaf pine growth, which may respond positively to increases in atmospheric CO_2 and temperatures (Boyer 2001, Wertin et al. 2012, Whelan et al. 2013).

Opportunities and benefits for longleaf and shortleaf pine restoration on agroforestry sites west of the Mississippi River in States such as Arkansas are similar to those of other Southern States. Shortleaf and loblolly pine silvopastures may have the added benefit of mitigating the effects of ice storms (Burner and Ares 2003) in these States of the "Glaze Belt," which experienced a catastrophic ice storm event every 2 years in the period between 2000 and 2009 (Kovacik et al. 2010). For example, some Arkansas landowners are planting windbreaks along the edges of their pastures to provide shade and reduce the heat stress load for their stock and also to buffer other weather effects.

In the Upper Coastal Plain and Appalachian Highlands of Kentucky, North Carolina, South Carolina, Tennessee, and Virginia, all the agroforestry practices show promise for climate change mitigation and adaptation. Although the benefits of silvopasture and riparian buffers for soil stabilization, diffusion of animal waste, pollination, and plant diversity are similar to the benefits in other regions, the production of NTFPs and woodland medicinals is a customary focus (Vaughan et al. 2013). Silvopasture has the potential to benefit lands making the transition from the conservation programs (e.g., USDA's Conservation Reserve Program) to provide both annual and periodic income to landowners and to motivate them to actively manage their forests rather than converting them to pastureland or commercial/residential development.

Potential of and Limitations to Agroforestry

The ability to provide ecosystem services and mitigate the effects of climate change through agroforestry practices is great in the Southeast and Caribbean Region—provided adoption of agroforestry practices can be increased. The Southeast has among the highest potential for carbon (C) storage and sequestration, and adding trees to mixed cropping and integrated crop-livestock systems offers several options to help maximize this potential (Franzluebbers et al. 2014; Schoeneberger et al. 2012). Along with their potential use in cropland systems, agroforestry practices can be deployed on rugged or sloping grounds as a means for addressing climate change challenges and meeting ecosystem services needs (Dosskey et al. 2012a, Smith et al. 2013).

In addition to increasing C storage (Haile et al. 2010), agroforestry practices can conserve soil and water by reducing runoff (Smith et al. 2013) and buffering streams (Dosskey et al. 2012b) while improving site conditions for wildlife habitat (Bowling et al. 2014; Rittenhouse and Rissman 2012) and providing safety-net goods (e.g., NTFP and firewood). The improved delivery of ecosystem services may simultaneously be accompanied by increased diversity and productivity of agricultural systems in the Southeast and Caribbean. Such improvements also may enhance cashflows to farm families and provide good return for the labor invested. Inroads have been made in promoting agroforestry with small land holders, beginning farmers, and minority farmers in the Southeast that could serve as models for advancing agroforestry adoption in other regions of the country. Increasing interest from these groups and the potential for them to apply agroforestry are notable through products and activities of the 1890s Agroforestry Consortium (Idassi 2012). Compared with traditional plantation forestry or agricultural systems, agroforestry techniques provide opportunities to diversify incomes, expand production, and enhance nonmarket benefits such as soil and water conservation and wildlife habitat. Systems with perennial components with their influence on microclimate and potential reduction of inputs and costs, while diversifying outputs and conservation, hold promise. Thus, agroforestry practices are viable options to enhance farm livelihoods and increase resilience of food systems while providing C storage and other conservation benefits (Fike et al. 2004, Russelle et al. 2007, Steiner and Franzluebbers 2009, Workman et al. 2004).

Constraints to adopting agroforestry practices include lack of technical knowledge and management skills and high establishment or annual management costs for some practices. Incompatibility between multiple components, potential for weedy species and pest interactions, and potential negative impacts of livestock on tree seedlings and soil productivity can be obstacles. The more important constraint is the long-term investment required, coupled with limited economic analysis, which remains a liability in promoting the systems.

Economic data and planning assistance (for intensity and timing of inputs and outputs), along with institutional and policy support (including finances and incentives), are needed to drive early-stage implementation of agroforestry systems. Market development for agroforestry products has increased in the past decade, with landowner information and public education. The value of nonmarket benefits is evident to many practitioners and motivates many to design and implement practices (Bentrup 2008, Fraisse et al. 2009, Workman et al. 2005); however, it is often a constraint at higher levels of institutional and social policy (Lin et al. 2013, Merwin 1997). For example, at present no active market exists for carbon, though some industries may, in the future, be required to cap their emissions. Technology transfer needs for all agroforestry practices call for region- and situation-specific information to support design decisions based on research. Efforts to increase planting stock and improve genetic materials for tree resilience will help. More demonstration sites, training workshops, economic analysis, production budgets, marketing opportunities, and production effectiveness models are needed (fig. A.23). Technical designs must balance input availability and input quality and timing with production outputs and processing for various components and services.

Agroforestry practices have application potential over a range of land area sizes, from garden plots to total periphery of large park areas, from buffering and restoration of degraded sites to partitioning municipal landholdings, and, as envisioned for the Mississippi River and Chesapeake Bay watersheds, to serve as riparian buffer zones to guard against nonpoint source pollution and sedimentation. These integrated land-use practices can help bridge the gaps in the mosaic of land uses across a region and

Figure A.23. Site tour and hands-on activities at the Trainer's Training on Sustainable Agroforestry Practices in the Southeast Region, Atkins Agroforestry Research and Demonstration Site, Tuskegee University, Tuskegee, AL, conducted by the 1890s Agroforestry Consortium and funded by Southern Sustainable Agriculture Research and Education program. (Photo by Dr. Uma Karki, Tuskegee University).

serve as tools to strengthen the sustainable supply of goods and environmental services that society needs. Given that farming and plantation forestry have been rural economic mainstays compared with other development options in the region, ways that improve their value as a land use will continue to support rural communities and offer greater future land-use flexibility.

Agroforestry systems hold great potential in the Southeast and Caribbean Region and could likely be practiced in some form on more than 50 percent of the land area in most States and territories, with consideration of management intent, protected status, and limitations of soils and slope. Under good management, these systems can help provide increased resiliency and mitigation under changing moisture patterns and temperature extremes (Schoeneberger et al. 2012, Sulc and Franzluebbers 2014). The economic value of these systems, particularly in the event of climate change, has not been well defined, however. Realizing their potential likely will require more active management than commonly practiced. Greater understanding and capacity of service providers to promote agroforestry as an integrated approach, coupled with focused research and landowner innovation, is needed to push these systems forward in practical ways that will meet economic and environmental goals in the face of climate change foreseen for the region (Franzluebbers et al. 2014, Howden et al. 2007, Ingram et al. 2013, Kunkel et al. 2013, Vose et al. 2012).

Greater use of available scientific tools is needed for better decisionmaking, considering the complexity of agroforestry with its diversity of species, field conditions, and management options in use. Some policy and programmatic review (e.g., buffer practice sheets, forest health monitoring, resource inventory) would support decision tools and benefit the region. Landowners have to perceive the practices as valuable, whether in terms of income and livelihood, in terms of aesthetics and land ethics, or with belief in stewardship and resilience for the future. The U.S. Department of the Interior Southeast Climate Science Center (CSC) is one of eight regional CSCs and works with the USDA Caribbean Climate Sub Hub and Southeast Regional Climate Hub. These centers, along with their partners concerned with landscape conservation (e.g., http://lccnetwork.org/OurWork/DecisionTools) or social vulnerability (e.g., Oxfam), have tools to contribute to decisionmaking efforts. Development of models (such as Carbon Management Evaluation Tool for Voluntary Reporting [COMET-VR] from USDA NRCS), measurement protocols (such as GRACEnet from USDA ARS), and monitoring/reporting tools (such as the Forest Change Assessment Viewer [ForWarn] and Template for Assessing Climate Change Impacts and Management Options [TACCIMO] from USDA Forest Service) reflect the expertise and opportunity for climate mitigation and adaptation using agroforestry in the Southeast and Caribbean Region.

Key Information Needs

- Development of strategies to help transition lands coming out of Conservation Reserve Program contracts into sustainable agroforestry systems.
- Identification of appropriate forage species and their management in silvopasture systems over the range of tree species and densities that might be utilized in the diverse ecosystems of the Southeast.
- Better understanding of how to incentivize and integrate the development of silvopasture systems within a whole-farm (or whole-plantation) context in order to increase ecosystem services, sequester carbon, and other conservation goals.
- Development of tools to assist with nonmarket valuation and marketing of nontimber forest products sustainably harvested from agroforestry systems.
- Identification of strategies to spur innovation and adoption of alley cropping systems in the region.

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