Farming with Trees: Reforming U.S. Farm Policy to Expand Agroforestry and Mitigate Climate Change

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Agroforestry systems have enormous potential to mitigate climate change. These systems incorporate trees and shrubs into agricultural production, increasing both soil carbon sequestration and the amount of carbon stored in biomass. Even the most conservative estimates find that agroforestry sequesters two to five times more carbon per acre than the most effective—and better-known—climate-friendly practices for annual crops, such as no-till agriculture and cover crops. Agroforestry also offers substantial environmental and economic benefits: clean water, reduced fertilizer and pesticide use, greater resiliency, and higher profitability per acre. Yet there are significant legal and policy barriers to its expansion in the United States. For the first time in the policy literature, this Article reviews the emerging scientific research on agroforestry. The Article then analyzes how federal programs for agricultural loans, subsidies, research, and education favor annual monocultures over agroforestry practices. It concludes with a comprehensive set of reforms designed to expand agroforestry.

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"I see a million hills green with crop-yielding trees . . . from Boston to Austin, from Atlanta to Des Moines. The hills of my vision have farming that fits them and replaces the poor pasture, the gullies, and the abandoned lands that characterize today so large a part of these hills."[1]

"A healthy farm will have trees on it . . . for their usefulness: for food, lumber, fence posts, firewood, shade, and shelter . . . for comfort and pleasure, for the wildlife that they will harbor, and for their beauty[.]"[2]

INTRODUCTION

General Sherman is a giant sequoia in California—the world's largest tree and the oldest of its kind.[3] Reaching 275 feet above ground, its red bark gives way at the trunk to a small cavern that a child can walk under.[4] Some of its neighbors can accommodate entire cars.[5] General Sherman has sequestered 1,439 metric tons (MT) of carbon in above-ground biomass over its 2000-year lifetime,[6] an amount equivalent to the annual emissions of 311 passenger

1. J. RUSSELL SMITH, TREE CROPS: A PERMANENT AGRICULTURE 317 (1929).
2. WENDELL BERRY, THE UNSETTLING OF AMERICA: CULTURE AND AGRICULTURE 181–82 (1977).
3. *The General Sherman Tree,* NAT'L PARK SERV., https://www.nps.gov/seki/learn/nature/sherman.htm (last updated June 22, 2020).
4. *Id.*
5. FOREST SERV., U.S. DEP'T OF AGRIC., WHERE IS THE TREE YOU CAN DRIVE THROUGH?, *available at* https://www. fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_058751.pdf. (last visited June 22, 2021).
6. *How Much Carbon Dioxide Can a Sequoia Store?,* DEW HARVEST, https://www.dewharvest.com/carbon-dioxide-stored-by-general-sherman-giant-sequoia.html (last visited Mar. 8, 2021).

vehicles.[7] An acre of corn, the most planted crop in the United States,[8] stores approximately 0.008 percent the amount of carbon that General Sherman stores per year, much of which is returned to the atmosphere at the end of the year.[9]

While General Sherman's capacity to store carbon is extraordinary even for a tree, it reflects a fundamental biological reality: perennial plants, which live longer than one year, store substantially more carbon than annual plants.[10] In recent years, a growing number of scientists and farm operators have proposed integrating perennial crops into mainstream agricultural production in order to take advantage of their unrivalled ability to sequester carbon.[11] Agroforestry, the incorporation of woody plants into cropland or pastureland, in particular holds immense potential for rapidly increasing carbon storage. According to conservative estimates, agroforestry systems in temperate regions of the United States sequester two to five times more carbon per acre than the most promising climate-friendly practices for annual crops.[12] Perennial practices are not only vastly superior at reducing emissions on a per acre basis than other methods, but they also offer the greatest potential for system-wide reductions. Adopting

7. *See Greenhouse Gas Equivalencies Calculator*, EPA (Mar. 2020), https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (392.4 MT of "Carbon or Carbon Equivalent" was inputted under the "If You Have Emissions Data" tab).

8. Tom Capehart & Susan Proper, *Corn is America's Largest Crop in 2019*, U.S. DEP'T OF AGRIC.: RSCH. & SCI. (Aug. 1, 2019), https://www.usda.gov/media/blog/2019/07/29/corn-americas-largest-crop-2019.

9. Kurt Thelen, *Corn Fields Help Clean Up and Protect the Environment*, MICH. STATE UNIV.: MSU EXTENSION (June 7, 2007), https://www.canr.msu.edu/news/corn_fields_help_clean_up_and_protect_the_environment. Specifically, the giant sequoia stores 0.196 million metric tons (MMT) of CO_2 per year and an acre of corn stores 0.0000016 MMT of carbon per year. *Id.*

10. Perennial agriculture refers to the production of food, fiber, and forestry products with crops that do not need to be replanted each year. Annual crops such as corn, wheat, and soybeans, in contrast, can only be harvested once. Agroforestry, an agricultural system that intentionally incorporates trees, is the most common form of perennial agriculture (outside of perennial pasture), and therefore the focus of our Article. Other types of perennial agriculture include cultivation of a variety of herbaceous crops currently used commercially as feed or biofuel. In addition, researchers are developing perennial cereal crops, including perennial sorghum, rice, and kernza, which may be able to replace annual staple crops. *See* TOENSMEIER, *infra* note 133 (examination of perennial systems and their benefits).

11. *Drawdown*, a popular book researched by an interdisciplinary organization of climate scientists ranking the top 100 global solutions by gigatons of CO_2 sequestered, lists agroforestry practices in ninth (silvopasture), seventeenth (tree intercropping, or alley cropping), and twenty-eighth (multistrata agroforestry, or forest farming) on this list. Their estimates suggest that agroforestry, adopted globally, could draw down fifty parts per million (ppm) of CO_2 over the next century while improving food security and food justice for a growing global population. *See* DRAWDOWN: THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING (Paul Hawken ed., 2017); *see also* Ranjith P. Udawatta & Shibu Jose, *Agroforestry Strategies to Sequester Carbon in Temperate North America*, 86 AGROFORESTRY SYS. 225 (2012); Kevin J. Wolz et al., *Frontiers in Alley Cropping Transformative Solutions for Temperate Agriculture*, 24 GLOB. CHANGE BIOLOGY 883 (2018).

12. *See COMET-Planner*, U.S. DEP'T OF AGRIC., http://comet-planner.com/ (last visited Mar. 8, 2020).

agroforestry practices on just 10 percent of U.S. agricultural land could offset up to 30 percent of the country's annual emissions.[13]

Agroforestry practices transform carbon dioxide into biomass while filtering waterways and stabilizing the atmosphere we breathe and live in.[14] A 2019 review found that agroforestry systems, compared to conventional agricultural practices, reduced surface runoff, soil erosion, organic carbon, and related nutrient losses by an average of 58 percent, 65 percent, 9 percent, and 50 percent respectively, while lowering herbicide, pesticide, and other pollutant losses by 49 percent on average.[15]

Agroforestry can also offer farmers economic advantages, including greater resiliency to weather shocks and stresses, additional sources of income, lower agrochemical costs, and higher profitability on a per acre basis.[16] A 2019 study found that growing rows of black walnuts between rows of crops, an agroforestry practice known as "alley cropping," is more profitable for farmers than corn-soybean rotations in much of the Corn Belt.[17] However, many agroforestry practices face substantial policy barriers that impede their adoption.

Federal farm research and safety net programs were developed to support the production of annual crops—and livestock animals that eat annual crops—decades before the benefits of perennial agriculture became widely known.[18] As a result, billions of dollars flow to annual crop production each year in programs that are either ill-suited to perennial crops or exclude them altogether.[19] This Article proposes a comprehensive set of reforms designed to reduce this disparity and encourage the expansion of agroforestry, the most shovel-ready perennial system. The recommendations here are based on dozens of interviews with scientists, farm operators, policy practitioners, and advocates. During these

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13. Udawatta & Jose, *supra* note 11 (estimating that adopting silvopasture on 10 percent of pastureland and alley cropping, windbreaks, and riparian buffers on 10 percent of cropland will sequester 1,945 MMT of carbon dioxide (CO_2) equivalent (eq.) per year, whereas total United States emissions in 2019 were an estimated 6,558 MMT CO_2; *see also* Ranjith P. Udawatta et al., *Agroforestry and Biodiversity*, SUSTAINABILITY, May 21, 2019 (literature review finding that floral, faunal, and soil microbial diversity were significantly greater in agroforestry systems compared with monocropping systems and some forest systems).

14. Xiai Zhu et al., *Reductions in Water, Soil and Nutrient Losses and Pesticide Pollution in Agroforestry Practices A Review of Evidence and Processes*, 453 PLANT & SOIL 45 (2020).

15. *Id.* at 46.

16. Kevin J. Wolz & Evan H. DeLucia, *Black Walnut Alley Cropping is Economically Competitive with Row Crops in the Midwest USA*, ECOLOGICAL APPLICATIONS, January 2019, at 1, 7 (2019) (finding that alley cropping with black walnut would be more profitable than maize-soybean production on nearly a quarter of the cropland currently devoted to maize-soybean production in four Midwestern states); *see also* Kevin Wolz et al., *supra* note 11, at 886–87 (summarizing the climate change adaptation benefits of agroforestry).

17. Wolz & DeLucia*, supra* note 16, at 4.

18. Peter H. Lehner & Nathan A. Rosenberg, *Chapter 30 Agriculture, in* LEGAL PATHWAYS TO DEEP DECARBONIZATION IN THE UNITED STATES 772, 799–805 (Michael B. Gerrard & John C. Dernbach eds., 2019).

19. *Id.*

interviews a common set of barriers to agroforestry quickly emerged, which our recommendations are designed to address.

Agriculturalists have many options to incorporate woody plants: trees can be planted around cropland, in rows between crops, along rivers, and dotting pastures, while crops and livestock forage can be directly recovered from existing woodlots.[20] This Article focuses on practices that "farm with trees"[21]––agroforestry practices that integrate trees into a farm's core productive activities in the field, rather than those that use trees around field edges, such as buffers. All agroforestry practices have substantial climate benefits and should be encouraged through public policy. But when agroforestry practices are incorporated into a farm's primary crop- or grazing-land, they offer the greatest aggregate benefits due to their capacity to be implemented on a much larger area. However, to fully realize the societal, economic, and environmental benefits of agroforestry it will be critical to avoid replacing monocultures of annual crops with monocultures of perennial crops. Research has repeatedly shown that diversified agroforestry systems provide more environmental services and are more resilient than tree monocultures.[22] As a result, the recommendations in this Article are focused on facilitating the growth of *diversified* farms with trees.

This Article proceeds as follows. Part I discusses the background scientific and agronomic literature that explains the contribution of agriculture to climate change, the vulnerabilities of agriculture to climate impacts, and why agroforestry uniquely improves agriculture's climate resiliency. It then details five main agroforestry practices. Part II discusses three interconnected social barriers to agroforestry adoption, and identifies eleven concrete policy recommendations to address these barriers.

I. SCIENCE AND PRACTICE

A. Agriculture and Climate Change

Staying under 1.5 degrees Celsius of global warming will be necessary to avoid the harshest impacts of climate change, including more frequent and severe storms, flooding, droughts, longer times between rain events, depletion of freshwater sources, biodiversity loss, pollinator die-offs, sea level rise, and human displacement.[23] Achieving this goal will be impossible without reducing agricultural emissions and adopting agricultural practices that sequester carbon;

20. *See infra* Subpart I.B.2.

21. *See* TEMPERATE AGROFORESTRY SYSTEMS (Andrew M. Gordon et al eds., 2d ed. 2018).

22. *See* Zhu et al., *supra* note 14.

23. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), GLOBAL WARMING OF 1.5 C: AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5 C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS, IN THE CONTEXT OF STRENGTHENING THE GLOBAL RESPONSE TO THE THREAT OF CLIMATE CHANGE, SUSTAINABLE DEVELOPMENT, AND EFFORTS TO ERADICATE POVERTY 7–8 (Valérie Masson-Delmotte et al. eds., 2018).

agriculture currently contributes an estimated 19-29 percent of global anthropogenic emissions.[24] Unlike the energy and transportation sectors, which mostly emit carbon dioxide, agricultural emissions largely consist of nitrous oxide and methane.[25] This makes reducing agricultural emissions particularly urgent since methane will need to be drastically curtailed over the next ten to thirty years in order to avoid catastrophic climate change.[26]

The Environmental Protection Agency (EPA) estimates that emissions from agriculture account for 619 million metric tons of carbon dioxide equivalent or more than 9 percent of U.S. total emissions.[27] This share is likely underestimated, however. EPA's estimate does not include substantial parts of agriculture's footprint, such as emissions from the production of fertilizer and other inputs or fossil fuel combustion on farms. Further, it relies on an outdated formula for calculating the global warming potential of methane. EPA's estimate follows the International Panel on Climate Change's (IPCC) fourth assessment report in estimating that methane has twenty-five times the radiative impact of carbon dioxide.[28] The IPCC's fifth assessment report (published in 2018), however, puts the global warming potential of methane at twenty-eight to thirty-four times that of carbon dioxide,[29] and a more recent study has indicated that the 2018 estimate may still undercount methane's global warming potential by an additional 20-25 percent.[30] The study's authors predict that the IPCC's sixth report, due to be released in 2022, will revise methane's hundred-year global warming potential to 35 percent or higher, or at least 36 percent higher than the rate currently used by EPA.[31] Incomplete understanding of methane's full impacts only underscores the urgency of reducing emissions as much and as soon as possible.

While methane was responsible for 41 percent of U.S. emissions from agriculture in 2018, nitrous oxide contributed an even greater share, accounting

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24. *Id*. at 14.

25. Greenhouse gases are compared using the common unit, global warming potential. This unit considers both the radiative efficiency, how well the molecule absorbs energy and the lifetime of a gas, how long the molecule exists in the atmosphere. CO_2 is used as a reference against which other gases are compared, giving rise to the unit CO_2 equivalents. Using this system of unit conversion, methane is twenty-eight to thirty-six times as powerful and nitrous oxide is 265-298 times as powerful as CO_2. *See* EPA, EPA 430-R-20-002, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS 1990-2018, at 5-1(2020).

26. *Id*.

27. *Id*.

28. *Id*. at ES-3, ES-15.

29. Gunnar Myhre et al., *Anthropogenic and Natural Radiative Forcing, in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS 659, 714 tbl.8.7 (Thomas F. Stocker et al. eds., 2013).

30. *See generally* M. Etminan et al., *Radiative Forcing of Carbon Dioxide, Methane, and Nitrous Oxide A Significant Revision of the Methane Radiative Forcing*, 43 GEOPHYSICAL RSCH. LETTERS 12,614 (2016).

31. NATHAN ROSENBERG & PETER LEHNER, FARMING FOR OUR FUTURE: THE SCIENCE, LAW, AND POLICY FOR CLIMATE-NEUTRAL AGRICULTURE, Environmental Law Institute (forthcoming) (manuscript at 48) (on file with authors).

for 58 percent of emissions.[32] Carbon dioxide made up the remaining 1 percent.[33] Among U.S. agricultural activities, soil management is the single largest source of emissions.[34] Soil management makes up approximately half of all U.S. agricultural emissions and encompasses practices intended to improve crop yields, such as tillage, drainage, irrigation, and fertilization.[35] The second largest source of U.S. agricultural emissions is enteric fermentation, which results from the digestive processes of ruminants and releases an amount of methane responsible for 32 percent of the sector's footprint.[36] The last major category is manure management, which releases both nitrous oxide and methane that accounts for 15 percent of U.S. agricultural emissions.[37] Four additional categories (rice cultivation, field burning of crop residues, urea fertilization, and liming) together make up roughly 4 percent of agricultural emissions.[38]

1. Diversification of Agricultural Production

The increased uniformity of agricultural production has played an important role in the growth of agricultural emissions in the United States.[39] Between 1987 and 2012, the number of species of field crops grown by a single producer fell from four to six crops to two to three crops.[40] Geographic specialization of food production allows producers to exploit climates and soils best suited to particular crops. This system fundamentally relies on cheap agricultural products and inputs, like fertilizers, pesticides, and well-established transportation networks. For example, nitrogen fertilizer application in U.S. corn production nearly quadrupled between 1960 and 2015, while phosphate application almost doubled.[41]

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32. EPA 430-R-20-002, *supra* note 25, at 5-2.
33. *Id.*
34. *Id.*
35. *Id.*
36. *Id.*
37. *Id.*
38. *Id.*
39. *See* EMILE A. FRISON ET AL., INT'L PANEL OF EXPERTS ON SUSTAINABLE FOOD SYS., FROM UNIFORMITY TO DIVERSITY: A PARADIGM SHIFT FROM INDUSTRIAL AGRICULTURE TO DIVERSIFIED AGROECOLOGICAL SYSTEMS 17 (2016); JAMES M. MACDONALD ET AL., ECON. RSCH. SERV., U.S. DEP'T OF AGRIC., ECON. INFO. BULLETIN NO. 189, THREE DECADES OF CONSOLIDATION IN U.S. AGRICULTURE 9 (2018).
40. As farms become larger, they also tend to specialize in grain or beef cattle production. These types of production systems rely on practices that are particularly high in emissions. MACDONALD ET AL., *supra* note 39, at 38–39.
41. VACLAV SMIL, GROWTH: FROM MICROORGANISMS TO MEGACITIES 125, 387–88 (2019); *see also* Peter M. Vitousek & Pamela A. Matson, *Agricultural Nutrient Use and Its Environmental Consequences, in* THE EVOLVING SPHERE OF FOOD SECURITY 269, 269–84 (Rosamond L. Naylor ed., 2014).

Crop and livestock yield per acre have rapidly increased under this system.[42] Rapid yield increases also come with the creation of detrimental global and local waste streams. Production externalities, such as manure that might be fully utilized as fertilizer in a non-specialized system, are instead wasted, polluting global common-pool resources like the atmosphere and watersheds.[43] These negative externalities threaten the long-term viability of the current food production system.[44]

In 2018, almost half of the 14.4 million bushels of U.S. corn were grown in just three Midwestern states (Iowa, Illinois, and Nebraska), and approximately a third of all U.S. corn was transported to feedlots to fatten livestock.[45] Geographic separation of corn and livestock production breaks nutrient cycles, resulting in nutrient waste. Corn producers, in the absence of accessible cow manure, depend on synthetic fertilizers to ensure that local soil fertility does not limit corn yields. Market forces and inexpensive fertilizer pricing encourage producers to apply fertilizer in excess, which, combined with aggressive soil tillage, releases nitrous oxide from the soil into the atmosphere and nutrients into nearby watersheds.[46] Meanwhile, concentrated animal feeding operations (CAFOs) and poorly managed pastures saturate fields with manure, releasing methane into the atmosphere and leeching nutrient-rich runoff into nearby watersheds.[47]

Excessive discharge of nutrients into watersheds promotes growth of algal and cyanobacterial populations downstream, which contaminates drinking water and kills aquatic life and related fisheries.[48] Total annual damage from

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42. U.S. corn yields per hectare has skyrocketed from 1.8 tons in 1900 to 10.6 tons in 2015. In addition to increased mechanization and application of fertilizers, herbicides, insecticides, widespread use of hybrid and transgenic seeds has also contributed to the production increase. Expanded use of these technologies has also increased global food crop harvests six-fold during the twentieth century. *See id.*, at 122–23, 390; *but see* Anderson et al., *infra* note 61.

43. To avert widespread freshwater eutrophication, Steffen et al., propose updated global boundaries for phosphorus and nitrogen fertilizer application. A planetary boundary indicates the environmental threshold that humans can safely live within. Current global phosphorus application is double the proposed boundary. The Corn Belt is one of the "main contributors" to excessive phosphorus and nitrogen application. Will Steffen et al., *Planetary Boundaries Guiding Human Development on a Changing Planet*, 347 SCIENCE 1259855, 1259855-3, 1259855-6 (2015); Michael F. Chislock et al., *Eutrophication Causes, Consequences, and Controls in Aquatic Ecosystems*, NATURE EDUC.: KNOWLEDGE PROJECT (2013), https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/.

44. Steffen et al., *supra* note 43, at 1259855-8.

45. Capehart & Proper, *supra* note 8.

46. Allen G. Good & Perrin H. Beatty, *Fertilizing Nature A Tragedy of Excess in the Commons*, PLOS BIOLOGY, August 2011, at 1, 4 (2011) (reducing nitrogen fertilizer by 21-35 percent for major commodity crops from current rates would significantly lower nitrous oxide emissions without any reductions in crop yield).

47. *See* Gowri Koneswaran & Danielle Nierenberg, Correspondence, *Beef Production Koneswaran and Nierenberg Respond*, 116 ENVTL. HEALTH PERSPECTIVES A375, A375 (2008); Peter Lehner & Nathan A. Rosenberg, *Legal Pathways to Carbon-Neutral Agriculture*, 47 ENVTL. L. REP. (ENVTL. LAW INST.) 10,845, 10,847 (2017).

48. Decomposition of algae blooms leads to depletion of the dissolved oxygen in watersheds, while toxic algae blooms and cyanobacteria pollute drinking water. Chislock et al., *supra* note 43.

freshwater eutrophication in the United States alone was estimated to be $2.2 billion.[49] Moreover, marine dead zones are now found at the terminus of most U.S. river systems—the number of marine dead zones have approximately doubled each decade since 1960 when nitrogen fertilizer use began to skyrocket.[50] Their size and scope can be tremendous. For example, the dead zone at the mouth of the Mississippi River in the Gulf of Mexico was estimated to be 14,970 square kilometers in 2018, approximately the size of Connecticut.[51]

Many of these detrimental environmental impacts can be mitigated or altogether avoided by including diverse plants and animals within the same agricultural system. Integrating functionally diverse species can optimize nutrient use and avoid the creation of waste streams because different species utilize different nutrients.[52] Diversification of agricultural production also adds a natural form of insurance to a farm enterprise.[53] Seasonal differences from year to year will tend to favor one product over another; thus, including different crops within the same production system serves to hedge against annual variability in climate. Consolidation and specialization of agricultural production, along with other socioeconomic changes, have eroded genetic diversity in the food system. For example, 91 percent of maize varieties grown in the United States in the nineteenth century no longer exist.[54] Loss of this genetic reserve hinders adaptation to a new and changing environmental landscape.[55] Stewardship of diverse agroecosystems is one way to preserve healthy genetic pools.[56]

2. Vulnerability

The agricultural sector has a strong interest in mitigating climate change due to its vulnerability to extreme weather events and changes in climate patterns. Crop losses due to drought, heat waves, floods, and hurricanes, and

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49. Walter K. Dodds et al., *Eutrophication of U.S. Freshwaters Analysis of Potential Economic Damages*, 43 ENVTL. SCI. & TECH. 12, 18 (2009).

50. Climate models predict that increased precipitation may lead to higher river discharge, which will increase nutrient loading and expand oxygen-depleted areas in the Mississippi River Basin further. Robert J. Diaz & Rutger Rosenberg, *Spreading Dead Zones and Consequences for Marine Ecosystems*, 321 SCIENCE 926, 928–29 (2008); *see also* Steffen et al. and Chisock et al. *supra* note 43.

51. *Average Sized Dead Zone Forecast for Gulf of Mexico NOAA's Annual Prediction Based on USGS Data,* NAT'L OCEANIC & ATMOSPHERIC ADMIN. (June 7, 2018), https://www.noaa.gov/media-release/average-sized-dead-zone-forecast-for-gulf-of-mexico.

52. Yanfang Xue et al., *Crop Acquisition of Phosphorus, Iron and Zinc from Soil in Cereal/Legume Intercropping Systems A Critical Review*, 117 ANNALS BOTANY 363, 366 (2016).

53. *See generally* Stefan Baumgärtner, *The Insurance Value of Biodiversity in the Provision of Ecosystem Services*, 20 NAT. RES. MODELING 87 (2007).

54. COMM'N ON GENETIC RES. FOR FOOD & AGRIC., FOOD & AGRIC. ORG. OF THE UNITED NATIONS, THE SECOND REPORT ON THE STATE OF THE WORLD'S PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE 35 (2010).

55. José Esquinas-Alcázar, *Protecting Crop Genetic Diversity for Food Security Political, Ethical and Technical Challenges*, 6 NATURE REVS.: GENETICS 946, 947–48 (2005).

56. *Id.* at 948.

other extreme weather events are increasingly common.[57] The climate crisis is also reducing yields and crop viability independent of extreme weather.[58] Researchers estimate that corn yields in the United States will decline about 10 percent for every degree Celsius of warming.[59]

A 2018 review of climate impacts on specialty crops in California found dramatic yield losses among a variety of vegetables, fruits, and nuts due to rising temperatures, heat waves, increasingly variable precipitation, and earlier snow melt runoff.[60] Not only are crop yields diminished, but extended droughts in the region have stressed already limited freshwater resources.[61] Many crops are no longer viable in parts of the state where they were once commercially produced.[62] In 1950, for example, apricots, peaches, and plums, which require 700 chilling hours[63] through the winter to blossom, could be grown commercially throughout the Central Valley, California's main agricultural region.[64] Today, less than half of the valley is suitable for these crops and only 10 percent is expected to remain suitable by 2080-2095.[65] In addition to reducing fruit and vegetable availability, climate change will also affect nutrition by diminishing the nutritional value of crops. Studies have consistently found that elevated carbon dioxide levels substantially reduce levels of protein and micronutrients in a wide variety of crops.[66]

B. Agroforestry and Climate Change

Agroforestry curtails agricultural emissions by promoting production practices that regulate local and global carbon, nutrient, and water cycles. This Subpart explains how agroforestry sequesters carbon and enhances ecosystem resilience against the environmental stresses of climate change. First, it explains how incorporating trees with crops and livestock functions to sequester carbon.

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57. *See* Zhao et al. and Glotter & Elliott *infra* note 59.

58. Yield growth has also levelled off in the last few decades due to biophysical limits. Crop harvests in many regions have experienced greater variability due to the changing climate. Warming is slowing yield gains in most wheat-growing locations, while more agricultural regions have experienced greater yield variability overall. *See* SMIL, *supra* note 41, at 126–27.

59. Chuang Zhao et al., *Temperature Increase Reduces Global Yields of Major Crops in Four Independent Estimates*, 114 PROC. NAT'L ACAD. SCIS. 9326, 9327 (2017). Compounding the effects of warmer temperatures, a large-scale drought like the Dust Bowl is estimated to lead to an 80 percent loss in corn yields. Michael Glotter & Joshua Elliott, *Simulating U.S. Agriculture in a Modern Dust Bowl Drought*, NATURE PLANTS, Dec. 12, 2016, at 1, 2.

60. *See generally* Tapan B. Pathak et al., *Climate Change Trends and Impacts on California Agriculture A Detailed Review*, AGRONOMY, Feb. 26, 2018, at 1.

61. Martha Anderson et al., *Field-Scale Assessment of Land and Water Use Change over the California Delta Using Remote Sensing*, REMOTE SENSING, June 7, 2018, at 1, 24.

62. Pathak et al., *supra* note 60, at 14.

63. A "chilling hour" is when the temperatures dips between 32 and 45 degrees Fahrenheit.

64. Pathak et al., *supra* note 60, at 13.

65. *Id*. at 14.

66. *See, e.g.*, José C. Soares et al., *Preserving the Nutritional Quality of Crop Plants Under a Changing Climate Importance and Strategies*, 443 PLANT & SOIL 1 (2019).

Then, it defines and describes the five main agroforestry practices in the United States and their associated climate benefits.

1. Climate Benefits of Agroforestry

Agroforestry promises to deliver some of the highest carbon sequestration benefit of any agricultural practice, including other "climate-smart" practices focused on narrowly improving soil health (see Table 1).[67] While policymakers have primarily focused on incremental improvements to conventional cropping systems, like cover cropping and no-till,[68] agroforestry's potential to reduce net emissions is substantially higher. Adoption of no-till and cover crops on 63 percent of U.S. cropland would sequester an estimated 105 million metric tons of carbon dioxide (MMT CO_2) annually,[69] only about two-thirds of what agroforestry would sequester on the same amount of land.[70] Indeed, according to a 2012 estimate, incorporating trees on just 10 percent of all U.S. agricultural land could sequester 530 MMT CO_2 per year.[71] Moreover, the sequestration capacity of no-till practices is highly variable depending on soil type and, in some instances, studies actually suggests a net loss of soil organic carbon.[72]

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67. *See* Udwatta & Jose *supra* note 11.

68. USDA's most recent report on its efforts to mitigate climate change highlighted the department's myriad programs to expand common practices used to reduce emissions in annual systems, while only mentioning agroforestry to note that it was "considering [how it] can be incorporated into this initiative." U.S. DEP'T OF AGRIC., USDA BUILDING BLOCKS FOR CLIMATE SMART AGRICULTURE AND FORESTRY: IMPLEMENTATION PLAN AND PROGRESS REPORT 7–9, 56 (2016).

69. In addition, agricultural emissions would remain net positive under no-till management and cover cropping, while failing to meet hypoxia reduction goals in the Gulf of Mexico. Wolz et al., *supra* note 11, at 884.

70. *See* Lehner & Rosenberg, *supra* note 18, at 793.

71. *See* Udawatta & Jose, *supra* note 11, at 239; *see also* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), CLIMATE CHANGE AND LAND: AN IPCC SPECIAL REPORT ON CLIMATE CHANGE, DESERTIFICATION, LAND DEGRADATION, SUSTAINABLE LAND MANAGEMENT, FOOD SECURITY, AND GREENHOUSE GAS FLUXES IN TERRESTRIAL ECOSYSTEMS 5–72 (Valérie Masson-Delmotte et al. eds., 2019) (detailing global potential of agroforestry adoption and agroforestry's GHG sequestration benefits).

72. Researchers find that no-till does increase aggregate soil stability, which lowers the risk of soil organic carbon (SOC) loss through erosion. However, no-till also tends to compact the soil, which increases the fraction of SOC found in the soil surface but does not necessarily contribute additional SOC to deeper soil strata. Stephen M. Ogle et al., *Climate and Soil Characteristics Determine Where No-Till Management Can Store Carbon in Soils and Mitigate Greenhouse Gas Emissions*, SCI. REPORTS, Aug. 12, 2019, at 1, 2.

Table 1.[73]

	Farming Practice	Maximum applicable area (million acres)	Carbon Sequestration (MMT CO_2 eq.)	Rate of change per applicable acre (MMT CO_2 eq.)
Agroforestry	Silvopasture	173	114	0.66-1.34
	Alley Cropping	198	160	0.81-1.74
	Wind Breaks	11	12	1.09-2.09
	Riparian Buffers	2	2	1.08-2.47
Conventional	Cover Cropping	126-245	33	0.26-0.35
	No-Till Agriculture	232	72	0.31-0.33

Woody perennials such as trees and shrubs grow elaborate, durable root and branch systems that sequester significant stocks of atmospheric carbon before and after they die—unlike annual crops which are planted and harvested each year.[74] Moreover, when woody plant parts like roots and branches decay, soil microorganisms decompose the organic material over a long period to create humus, a stable form of carbon that can remain in the soil for up to 5,000 years if left alone.[75] In contrast, a smaller percentage of the non-woody leaf matter of annuals is transformed into soil humus. Most of this leaf material, like corn stalks, decomposes rapidly, releasing CO_2 back into the atmosphere. This difference is due to the higher lignin (the primary molecule that provides structure to the cell walls of vascular plants) content of the woody roots and branches of trees and shrubs.[76] The woody material is more difficult for bacteria

73. Adapted from *COMET-Planner*, *supra* note 14. There remain gaps in the research for carbon sequestration estimates. The purpose of this Article is not to execute an extensive review of these rates, rather to illustrate that, even some of the more conservative estimates show the sequestration potential for agroforestry is unmatched by other agricultural practices.

74. *See* Michael L. Pace & Gary M. Lovett, *Primary Production the Foundation of Ecosystems, in* FUNDAMENTALS OF ECOSYSTEM SCI. 27, 47 (Kathleen C. Weathers et al. eds., 2013). Genetic differences between perennials and annuals help explain their biological and physiological differences: Whereas annual crops use energy (from photosynthesis) to develop seeds and then die, perennials store energy in roots and stems late in the growing season after the annuals have died. Norberto E. Pogna et al., *Evaluation of Nine Perennial Wheat Derivatives Grown in Italy, in* PERENNIAL CROPS FOR FOOD SECURITY: PROCEEDINGS OF THE FAO EXPERT WORKSHOP 54, 55 (Caterina Batello et al. eds., 2013).

75. RAY WEIL & NYLE C. BRADY, THE NATURE AND PROPERTIES OF SOILS 543 (15th ed.).

76. Stuart E.G. Findlay, *Organic Matter Decomposition, in* FUNDAMENTALS OF ECOSYSTEM SCIENCE 75, 85 (Kathleen C. Weathers et al. eds., 2013).

to decompose compared to herbaceous annuals.[77] Thus, maintaining trees over a long period to allow for the growth and decay of woody plant materials is crucial to maximizing the carbon sequestration capacity of agroforestry. In sum, agroforestry's substantially higher climate benefits compared to no-till and cover cropping is due to the structure and lifecycle of trees and other perennial crops.

2. Five Agroforestry Practices

Trees can be incorporated on existing farmland in many configurations: at the borders of farmland and bodies of water, in strips between crops and grazing livestock, and interspersed throughout the landscape. Producers can harvest fruits, nuts, saps, mushrooms, timber, animal fodder and medicinal crops from these incorporated trees as well as from existing forests. The rich history of agroforestry around the world attests to its immense adaptability and diversity. For example, farmers and indigenous communities practice these methods on Spanish grazing lands,[78] in Indonesian home gardens,[79] and in Japanese woodlands,[80] among many other places.[81]

Below, we discuss the five main types of agroforestry practiced in the United States, their estimated carbon sequestration capacities, and associated economic and environmental benefits. These sequestration estimates are designed to illustrate potential rates of sequestration—actual rates will vary according to differences in climate, soil health, and crop species, among other factors.[82] Among the five practices described below, silvopasture and alley cropping have the greatest carbon sequestration potential, capturing approximately 97 percent of estimated carbon sequestration benefits from agroforestry in the United States, and thus are particularly promising policy targets for scaling-up agroforestry.[83]

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77. Jason S. Lupoi & Emily A. Smith, *Characterization of Woody and Herbaceous Biomasses Lignin Composition with 1064 nm Dispersive Multichannel Raman Spectroscopy*, 66 APPLIED SPECTROSCOPY 903, 905 tbl.1 (2012) (estimating that oak and pine have twice as much lignin compared to some herbaceous plants).

78. Written records of Spanish *dehesa* date from 924 A.D. L. Olea & A. San Miguel-Ayanz, *The Spanish* Dehesa*. A Traditional Mediterranean Silvopastoral System Linking Production and Nature Conservation*, 11 GRASSLAND SCI. IN EUR. 3, 3 (2006). They were documented and admired by American economic geographer Smith in *Tree Crops*. *See* SMITH, *supra* note 1, at 192.

79. Dilrukshi Hashini Galhena et al., *Home Gardens A Promising Approach to Enhance Household Food Security and Wellbeing*, 2 AGRIC. & FOOD SEC. 1 (2013).

80. Customary Japanese *satoyama* woodlands consist of terraced rice paddy fields and secondary forest, which provide food, fuel, timber, and ecosystem services like increased soil fertility from leaf litter amendments. B. Mohan Kumar & K. Takeuchi, *Agroforestry in the Western Ghats of Peninsular India and the Satoyama Landscapes of Japan A Comparison of Two Sustainable Land Use Systems*, 4 SUSTAINABILITY SCI. 215, 218–21 (2009); SMITH, *supra* note 1, at 137–38, 152 fig.7.

81. *See, e.g.*, SMITH, *supra* note 1; *see also* P.K.R. NAIR, AN INTRODUCTION TO AGROFORESTRY (Kluwer Academic Pub., 1993).

82. For consistency, rates are adopted from the optimistic review by Udawatta & Jose, *supra* note 11, and the more conservative *COMET-Planner*, *supra* note 14, unless otherwise noted.

83. *See* Udawatta & Jose, *supra* note 11, at 239.

a. Silvopasture: Trees on Grazing Land

Silvopasture incorporates trees on grazing land. Farmers or ranchers can convert existing pastures to silvopasture systems by planting and protecting trees, or can convert existing forests into silvopasture systems by thinning woodlots to allow for forage growth in the understory.

Silvopasture represents 82 percent of the carbon that agroforestry is capable of sequestering in the United States if fully implemented.[84] In 2012, pasture and rangeland accounted for the largest land use in the United States, or roughly 29 percent of the continental landmass.[85] Converting just 10 percent of pasture land and grazed forests to silvopastoral systems could sequester an estimated 1,703 CO_2 eq. per year according to one literature review, offsetting more than 25 percent of total U.S. emissions.[86] Grazing land in the Western and Southeastern United States is particularly ripe for silvopasture conversion—much of it is well-suited for trees.[87] Planting trees on pastures can sequester more carbon relative to forest conversion into silvopasture, but both methods have ecological and economic benefits relative to plantation forests and conventional livestock grazing systems.[88]

Silvopasture can increase economic diversity and profitability compared with open pastures or monoculture tree plantations.[89] Trees in silvopasture not only sequester carbon in biomass and prevent agricultural runoff from entering into watersheds,[90] but they can also require less fertilizer because livestock manure may be used in situ.[91] Enhanced tree habitat for birds and other natural pest predators reduces the need for pesticides, while providing additional farm revenue from hunting activities.[92] Rotating grazing animals regularly among trees can also benefit livestock production by providing more diverse forages

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84. *See* Ranjith P. Udawatta & Shibu Jose, *Carbon Sequestration Potential of Agroforestry Practices in Temperate North America, in* CARBON SEQUESTRATION POTENTIAL OF AGROFORESTRY SYSTEMS: OPPORTUNITIES AND CHALLENGES 17, 38 (B. Mohan Kumar & P.K. Ramachandran Nair eds., 2011). Some assumptions that are made in this review include the harvest age and tree density for some studies, as well as the calculated land area that can take agroforestry systems.

85. *See* Daniel Bigelow et al., U.S. DEP'T OF AGRIC., ECON. INFO. BULLETIN NO. 161, U.S. FARMLAND OWNERSHIP, TENURE, AND TRANSFER 36 (2016).

86. "Forestland" excludes forests in parks, wildlife areas, and other special uses. This estimate assumes a sequestration rate of 15.1 metric ton (MT) C hectare/year. *See* Udawatta & Jose, *supra* note 83.

87. *Id.* at 20.

88. O.U. Onokpise & J. Hamilton, *Silvopasture, in* PROFITABLE FARMS AND WOODLANDS: A PRACTICAL GUIDE IN AGROFORESTRY FOR LANDOWNERS, FARMERS AND RANCHERS 57, 57–71 (Joshua Idassi ed., 2012).

89. *See, e.g.*, S.H. Sharrow et al., *Silvopastoral Practices, in* NORTH AMERICAN AGROFORESTRY: AN INTEGRATED SCIENCE AND PRACTICE 105, 110–11 (H.E. Garrett ed., 2d ed. 2009).

90. V.D. Nair & D.A. Graetz, *Agroforestry as an Approach to Minimizing Nutrient Loss from Heavily Fertilized Soils The Florida Experience,* 61 AGROFORESTRY SYS. 269, 276 (2004).

91. *Id*.

92. *See id*.; S.C. Grado et al., *A Financial Analysis of a Silvopasture System in Southern Mississippi*, 53 AGROFORESTRY SYS. 313, 321 (2001) (finding that incorporating fee hunting management plan for silvopasture system enhanced land expectation value by 8.6 percent).

leading to healthier cows.[93] The shade provided by trees interspersed in pasture improves the welfare of the animals. Cows managed on silvopastoral systems experience increased calf weight, decreased stress from birthing, and higher retained weight over winter months.[94] In many places, silvopasture is more ecologically and economically sustainable than its monoculture counterparts.[95]

b. Alley Cropping: Trees between Crops

Alley cropping integrates trees in rows between other crops like cereals, grasses, fruit shrubs and vegetables to produce a variety of food crops and non-food products.[96] Up to half of cropland in the United States can be converted to alley cropping, primarily in the Midwest, according to one estimate.[97] At this scale, alley cropping could sequester approximately 192 MMT CO_2 eq. to 998 MMT CO_2 eq. per year—or up to 15 percent of total U.S. greenhouse gas emissions.[98]

Alley cropping offers numerous environmental, health and economic benefits. Trees can reduce fertilizer and mulch inputs by dropping leaves, sticks, and needles onto the soil, which increases soil organic carbon levels.[99] Additionally, tree shade can provide needed respite to farm workers harvesting field crops in hotter temperatures: a study conducted in Georgia found that regular shaded breaks have the greatest potential to reduce heat-related illness

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93. Sharrow et al., *supra* note 89.

94. Rob Kallenbach, *Integrating Silvopastures into Current Forage-Livestock Systems*, PROC. N. AM. AGROFORESTRY CONF., 2009, at 455, 460.

95. In a simulated pine-beef cattle system in the Southern United States Coastal Plains, silvopasture's net present value per unit area was 70 percent greater than a pure plantation forestry operation. C.W. Dangerfield Jr. & R.L. Harwell, *An Analysis of a Silvopastoral System for the Marginal Land in the Southeast United States*, 10 AGROFORESTRY SYS. 187 (1990). A more recent study found that silvopastoral systems have a comparable net present value on Loblolly Pine plantations and yield improved values on Longleaf Pine plantations in the Southeast United States. Sonia R. Bruck et al., *Modeling the Financial Potential of Silvopasture Agroforestry in Eastern North Carolina and Northeastern Oregon*, 117 J. FORESTRY 13, 13–20 (2019).

96. One study examining yields of an alley cropping system in Illinois incorporating hazelnut and chestnut trees, hay, and blackcurrant shrubs found that the system produced more calories per hectare than a traditional corn and soybean rotation after only four years. *See* Wolz & DeLucia., *supra* note 16.

97. *See* H.E. Garrett et al., *Alley Cropping Practices, in* NORTH AMERICAN AGROFORESTRY: AN INTEGRATED SCIENCE AND PRACTICE, *supra* note 91, at 133; Udawatta & Jose, *supra* note 83, at 20.

98. *Id*. This estimate assumes a sequestration rate of 3.4 MMT carbon ha^{-1} yr^{-1}. Alley cropping in temperate ecosystems has demonstrated sequestration rates up to 204 MMT C ha^{-1} yr^{-1} and sequestration rates of 229 MMT C ha^{-1} yr^{-1} C have been documented in tropical ecosystems (which comprise less than 1 percent of the United States). *See* Maren Oelbermann et al., *Soil Carbon Dynamics and Residue Stabilization in a Costa Rican and Southern Canadian Alley Cropping System*, 68 AGROFORESTRY SYS. 27 (2006).

99. Trees uptake carbon and nitrogen from the environment. Excess carbon and nitrogen can be used for material growth (leaves and fruits), stored for use at another time, or sequestered, which precludes further use. Peter Millard & Gwen-Aelle Grelet, *Nitrogen Storage and Remobilization by Trees Ecophysiological Relevance in a Changing World*, 30 TREE PHYSIOLOGY 1083 (2010); Wolz et al., *supra* note, 11, at 883–84.

for farm laborers compared to other interventions.[100] Alley cropping can also increase farm income by diversifying revenue streams,[101] reducing irrigation, pesticide, and fertilizer needs,[102] and increasing yields.[103] A 2019 study found alley cropping to be more profitable than both timber monocultures and conventional annual rotations in the Midwest despite significant policy barriers to the practice.[104]

c. Windbreaks: Trees around Farms

Windbreaks are planted on farm perimeters, fields and livestock pastures, and around buildings. They function primarily as a living wall to protect soils and crops against damage from wind erosion.[105] Windbreaks were first planted at a large scale in the United States in the wake of the 1933 Dust Bowl to control erosion within and between farms.[106] During the Dust Bowl, federal action stimulating windbreak planting helped overcome the collective action problem of crop production losses faced by individual adopters.[107] Many kilometers of these original windbreaks have been replaced with annual crops.[108] Installing windbreaks on 5 percent of U.S. cropland would sequester up to 32.25 MMT CO_2 eq. per year, partly by reducing wind disturbance of soil organic matter.[109]

Windbreaks provide a wide range of environmental and economic services. Not only do they sequester carbon, but they also directly improve crop productivity by improving soil moisture retention on the farm.[110] Windbreaks increase crop yields by protecting them from the more variable temperatures, wind flows, and precipitation due to climate change.[111] Wheat and soybean fields in Kansas and Nebraska with windbreaks showed yield increases (between

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100. Other barriers faced by migrant farmworkers to avoiding heat related illness include lack of prevention training (77 percent); no access to regular breaks (34 percent); and no medical attention (26 percent). Nancy L. Fleischer et al., *Public Health Impact of Heat-Related Illness Among Migrant Farm Workers*, 44 AM. J. PREVENTATIVE MED. 199, 202 (2013).

101. Wolz & DeLucia, *supra* note 16, at 11.

102. Wolz et al., *supra* note 11, at 887 (discussing increased water-use efficiency and reduced pest populations and nutrient losses in alley cropping systems).

103. *Id.* at 886.

104. Wolz & DeLucia, *supra* note 16, at 7.

105. Commonly one row of shrubs, one row of deciduous trees, and one row of conifers provide sufficient protection against wind erosion. J.R. Brandle et al., *Windbreaks in North American Agricultural Systems*, 61 AGROFORESTRY SYS. 65, 66 (2004).

106. 16 U.S.C. §§ 568-70 (1924).

107. *See generally* Part I. Outside the United States, windbreaks were also adopted on farmland at large scale in Scotland in the mid-1400s. *See* Zeynep K. Hansen & Gary D. Libecap, *Small Farms, Externalities, and the Dust Bowl of the 1930s*, 112 J. POL. ECON. 665, 671–72 (2004); Brandle et al., *supra* note 105, at 65.

108. Carson Vaughan, *Uprooting FDR's "Great Wall of Trees"*, WEATHER CHANNEL: UNITED STATES OF CLIMATE CHANGE (Oct. 2017), https://features.weather.com/us-climate-change/nebraska/.

109. Udawatta & Jose, *supra* note 83, at 36.

110. T.P. Baker et al., *Impacts of Windbreak Shelter on Crop and Livestock Production.* 69 CROP & PASTURE SCI. 785, 786 (2018).

111. *Id.* at 789.

10 percent and 16 percent on average) compared with non-protected fields.[112] Windbreaks on grazing land can improve forage production, birthing success, and the overall well-being of grazing animals.[113] Moreover, insofar as windbreaks can be connected between farms, they are an essential tool to help preserve wildlife populations, including pest-predator birds and pollinator insects, by providing movement corridors connecting fragmented habitats.[114] Windbreaks also provide non-agricultural economic benefits by protecting roads, homes and other infrastructure from extreme temperatures and snow drifts, which can reduce costs related to heating, wind damage, and snow removal.[115]

d. Riparian Buffers: Trees around Waterways

Riparian buffers are trees, shrubs and perennial grasses planted along water systems such as coastal marine areas, streams, and lakes to prevent upslope runoff of unwanted sediments and chemicals from the soil into the water.[116] Riparian buffers have substantial adoption potential, given the 5.6 million kilometers of streams in the United States and 106 million square kilometers of fresh waterways.[117] Planting a thirty-meter wide riparian buffer on just 5 percent of all U.S. rivers would sequester an estimated 17.25 MMT CO_2 eq. per year.[118]

Just as windbreaks slow soil movement during heavy winds, riparian buffers slow unwanted surface and subsurface flows of soil, fertilizers, and pesticides between farmland and surrounding waterways during heavy rainfall.[119] For example, an Iowa study found that a riparian buffer composed of grasses, shrubs, and tree species on a corn and soybean farm along a creek prevented 97 percent of sediment and over 80 percent of nutrients from being

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112. Raúl J. Osorio et al., *GIS Approach to Estimate Windbreak Crop Yield Effects in Kansas–Nebraska*, 93 AGROFORESTRY SYS. 1567, 1573 (2019).

113. Brandle et al., *supra* note 105, at 74.

114. *See* Sarah Taylor Lovell & William C. Sullivan, *Environmental Benefits of Conservation Buffers in the United States Evidence, Promise, and Open Questions*, 112 AGRIC., ECOSYSTEMS & ENV'T 249, 252 (2006); Gary Bentrup et al., *Temperate Agroforestry Systems and Insect Pollinators A Review*, FORESTS, Nov. 5, 2019, at 11; Carola A. Haas, *Dispersal and Use of Corridors by Birds in Wooded Patches on an Agricultural Landscape*, 9 CONSERVATION BIOLOGY 845, 845 (1995) (finding that rare movement by migratory birds between windbreak sites occurred significantly more frequently between connected sites than unconnected sites).

115. Millard & Grelet, *supra* note 99; Lovell & Sullivan, *supra* note 114, at 251.

116. R. C. Schultz et al., *Riparian Forest Buffers in Agroecosystems–Lessons Learned from the Bear Creek Watershed, Central Iowa, USA*, 61 AGROFORESTRY SYS. 35, 48 (2004) (finding that a thirty-foot forested buffer reduced the sediment loss by 97 percent and retained 80 percent of the carbon and nitrogen. The buffers reach their maximum efficiency at a minimum of five years).

117. *National Summary of State Information*, EPA, https://iaspub.epa.gov/waters10/attains_nation_cy.control (last updated 2017).

118. Udawatta & Jose, *supra* note 11, at 239.

119. Nair & Graetz, *supra* note 90, at 276.

washed away.[120] Runoff prevention prevents toxic algal blooms downstream, maintains healthy aquatic food webs, and keeps water clearer for aesthetic enjoyment.[121] Like windbreaks, riparian buffers provide habitat and movement corridors for beneficial species like birds and insects. Riparian buffers, however, have the added benefit of regulating temperatures for stream ecosystems and supporting wildlife by creating nearshore habitats for diverse fish populations.[122] Additionally, riparian buffers can be designed such that they provide added revenue to the farm. Austin Unruh, founder of Crow and Berry Land Management in Lancaster Pennsylvania, works with farmers to design productive riparian buffers. The buffers designed by Unruh rely on woody perennial crops such as dogwood, winterberry and willow that both filter nutrients out of waterways while generating products sold as ornamentals.[123]

e. Forest Farming: Multistory Tree Gardens

"Forest farming" refers to the cultivation of shade-tolerant products like mushrooms, medicinal herbs, ornamental branches, and berries under an intentionally modified or maintained forest canopy.[124] Forest farming has a long and varied global history; farmers and foresters have, for instance, used carob tree pods as a sugar replacement in Cyprus, white mulberry as a flour substitute in Afghanistan, and have cultivated sugar maple trees to support wild ginseng and mushrooms in the understory of forests in the Northeastern United States.[125] The level of effort required for forest farming also varies greatly. Tree and non-timber products can be purely harvested from highly cultivated understories or foraged from wild ecosystems.[126] Few estimates of the carbon sequestration potential of forest farming in the United States exist.[127] However, as forests are

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120. K.H. Lee et al., *Sediment and Nutrient Removal in an Established Multi-Species Riparian Buffer*, 58 J. SOIL & WATER CONSERVATION 1, 1 (2003) (finding that adding trees and shrubs to grass buffer increased efficiency of the buffer by 20 percent).

121. Millard & Grelet, *supra* note 99; Lovell & Sullivan, *supra* note 114, at 251.

122. *See* Lovell & Sullivan, *supra* note 114, at 252; Schultz et al., *supra* note 116, at 36.

123. Interview with Austin Unruh, Owner, Crow & Berry Land Management (Sept. 13, 2019).

124. KEN MUDGE & STEVE GABRIEL, FARMING THE WOODS: AN INTEGRATED PERMACULTURE APPROACH TO GROWING FOOD AND MEDICINALS IN TEMPERATE FORESTS 1 (2014).

125. J.L. Chamberlain et al., *Forest Farming Practices, in* NORTH AMERICAN AGROFORESTRY: AN INTEGRATED SCIENCE AND PRACTICE 219, 220 (2009); *see also* Jonathan P. Sheppard et al., *Sustainable Forest Management Beyond the Timber-Oriented Status Quo Transitioning to Co-Production of Timber and Non-Wood Forest Products—A Global Perspective*, 6 CURRENT FORESTRY REPS. 26, 27 (2020) ("Long before the technology existed to cut timber, humans were foraging forests for food, medicine and other basic necessities.").

126. Chamberlain et al., *supra* note 125, at 221.

127. However, tropical home gardens are estimated to sequester up to 32.1 milligrams of carbon per hectare annually. Urban food forests are a close analog for temperate systems found in the United States, enhancing access to fruit, nuts, and medicinal crops while creating communal spaces for urban residents. These systems have the potential to mimic original forest structures and can therefore turn small plots of land into large carbon sinks. B.M. Kumar, *Carbon Sequestration Potential of Tropical Homegardens*, *in*

a significant global carbon sink,[128] expanding the economic potential of forests beyond timber—a $600 billion industry, or 1 percent of global GDP—will help preserve these ecosystems that are vital for climate change mitigation.[129]

Indeed, many U.S. rural landowners currently practice small-scale forest farming to increase the marginal income on their existing woodlots or to conserve their forested land. The market for non-timber forest products in the United States is valued at an estimated $1 billion, with maple products contributing $100 million and American ginseng $25 million.[130] A recent study of surveyed households in Europe found that the European market for non-timber forest products would be worth $27.5 billion.[131] Thus, the U.S. market for tree products have ample room to expand, given the wide variety of forest products, medicinal plants, and production systems that have yet to be explored.[132]

II. POLICY PATHWAYS[133]

Federal programs have played a major role in shaping farm production since the 1930s when a steady stream of new government regulations, programs, and subsidies transformed the sector.[134] Government payments rose from 3 percent of net farm income in 1929 to 31 percent by 1940 and remain a substantial

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TROPICAL HOMEGARDENS: A TIME-TESTED EXAMPLE OF SUSTAINABLE AGROFORESTRY 185, 186–93 (B.M. Kumar & P.K.R. Nair eds., 2006).

128. *See* Allie Goldstein et al., *Protecting Irrecoverable Carbon in Earth's Ecosystems*, 10 NATURE CLIMATE CHANGE 287 (2020) (finding that conversion of temperate forests to cropland could lead to the additional loss of 74 tons of C per hectare irrecoverable in thirty years, a timescale critical to avoid dangerous climate impacts).

129. *Forests Generate Jobs and Incomes*, WORLD BANK (Mar. 16, 2016), https://www.worldbank.org/en/topic/forests/ brief/forests-generate-jobs-and-incomes.

130. *See* Sheppard et al., *supra* note 127, at 28. This estimate does not include foraged goods that are never sold.

131. Marko Lovrić et al., *Non-Wood Forest Products in Europe—A Quantitative Overview*, FOREST POL'Y & ECON., Apr. 24, 2020, at 1, 4. These amounts were converted using an exchange rate found on Aug. 2, 2020: 1 Euro to 1.18 USD.

132. *See* SMITH, *supra* note 1; Chamberlain et al., *supra* note 125, at 228–29.

133. The following policy recommendations for agroforestry are preceded by two other major works. *A Permanent Agriculture* was the first book to articulate a comprehensive vision of agroforestry in the United States after the author visited different agricultural systems across the United States and in Asia, Europe, Africa, and South America. *See* SMITH, *supra* note 1. While Smith's *Tree Crops* remains compelling today, Eric Toensmeier's *The Carbon Farming Solution* provides a contemporary account of agroforestry's potential, focusing on its capacity to sequester carbon. *See* ERIC TOENSMEIER, THE CARBON FARMING SOLUTION: A GLOBAL TOOLKIT OF PERENNIAL CROPS AND REGENERATIVE AGRICULTURE PRACTICES FOR CLIMATE CHANGE MITIGATION AND FOOD SECURITY (2016). As both Smith and Toensmeier note, indigenous peoples practiced agroforestry in North America prior to European colonial settlement. *See generally* Marc D. Abrams & Gregory J. Nowacki, *Native Americans as Active and Passive Promoters of Mast and Fruit Trees in the Eastern USA*, 18 HOLOCENE 1123 (2008). Their practices, as well as the practices of other indigenous peoples around the world, continue to serve as an important source of knowledge and inspiration for modern agriculture.

134. *See* LEHNER & ROSENBERG, *supra* note 31 at 148.

portion of farm income today.[135] In addition to providing large-scale operations with substantial capital and income, federal farm policy has generously funded agricultural research, extension, and infrastructure programs since the New Deal.[136] This support, however, has focused on annual commodity crops, particularly corn, wheat, cotton, and soybean, as well as animal production systems that feed on those crops.[137] As a result, federal agricultural research, extension, credit, and safety net programs rarely address the needs of agroforesters, making adopting agroforestry systems a risky enterprise.

Despite a lack of federal support for agroforestry, farmers have demonstrated a strong interest in agroforestry practices in recent years. Regional agroforestry groups have appeared throughout the country,[138] while extension and private consultants report a growing number of inquiries from producers about agroforestry.[139] Approximately 1.5 percent of all farms in the United States have incorporated some agroforestry practice as of 2017, with adopters concentrated in the mid-Atlantic and Pacific Northwest regions.[140] Geographic variability in ecologically viable agroforestry practices and regional markets for agroforestry products cautions against one-size-fits-all policy prescriptions.

Long-lasting agricultural policy reform must be rooted in a clear understanding of the barriers farmers face in adopting and sustaining agroforestry practices. The last major federal initiative to expand agroforestry practices effectively expanded tree planting on private agricultural land, but many trees disappeared without legally binding agreements or sustained long-term support. That initiative, the Great Plains Forestry Project, sent an army of young men to plant 220 million trees in an area making up a quarter of the contiguous United States, in response to the severe soil erosion of the 1933 Dust Bowl.[141] In exchange, private landowners agreed to prepare the land for tree planting and erect protective fencing.[142] One forester declared the project to be "remarkably successful" five years after the it began.[143] However, less than a decade later, another forester observed that federally promoted conservation practices, including windbreaks, had been "widely forgotten" by farmers after

135. Nathan A. Rosenberg & Bryce Wilson Stucki, *The Butz Stops Here Why the Food Movement Needs to Rethink Agricultural History*, 13 J. FOOD L. & POL'Y 12, 14 (2017).

136. LEHNER & ROSENBERG, *supra* note 31 at 148.

137. *Id*. at 157.

138. *Id*.

139. *See id*.

140. *See* U.S. DEP'T OF AGRIC., 2017 CENSUS OF AGRICULTURE: UNITED STATES SUMMARY AND STATE DATA 660 (2019), *available at* https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_ US/usv1.pdf.

141. Rationale for the shelterbelt also cited co-benefits such as providing firewood, seasonal fruit, aesthetic relief, and climate moderation—similar to those described above. Joel Orth, *The Shelterbelt Project Cooperative Conservation in 1930s America*, 81 AGRIC. HIST. 333, 336 (2007).

142. WILMON H. DROZE, TREES, PRAIRIES, AND PEOPLE: A HISTORY OF TREE PLANTING IN THE PLAINS STATES 130–31 (1977).

143. U.S. Dept. Agriculture, *Work of the United States Forest Service* 25 (1939).

their five-year contract period was up.[144] By 2017, a reported 57 percent of the New Deal-era windbreaks in Nebraska had been removed by successive generations of farmers to make space for annual crops and irrigation infrastructure.[145] Other Great Plains states likely have similarly large rates of windbreak removals.[146] Agroforestry's footprint must be maintained or expanded over the long-term in order to reap its climate benefits. As a result, federal policy changes designed to expand agroforestry must ensure that farming with trees is a long-term commitment. This Part begins by discussing barriers to agroforestry and ends by recommending integrated policy reforms that work together to address those barriers and make agroforestry an attractive long-term practice for farmers.

A. Barriers to Adoption

"To have the land cared for, you have to have enough people to care for it, who know how to care for it, who want to care for it, and who can afford to care for it."[147]

This Subpart begins by discussing the three main barriers to production agroforestry in U.S. agriculture: (1) Social norms against planting trees on productive farmland and lack of information for practitioners about appropriate agroforestry practices; (2) insufficient financial incentives for planting and maintaining productive trees; and (3) inaccessibility of farmland for new farmers.[148] Federal policy plays an important role in marginalizing production agroforestry: billions of dollars of federal funds support annual monocultures every year, leaving almost nothing for diversified agroforestry systems. Without significant changes in farm policy, agroforestry will not be able to overcome these barriers to expansion. The section concludes with a series of legal and policy reforms designed to lower these barriers, with the ultimate aim of facilitating long-term incorporation of trees on farms.

1. Social Norms and Information

Studies conducted in the Midwest indicate that many farmers perceive trees as harmful to agriculture or merely as an optional addition to a productive farm.

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144. Aldo Leopold, *The Land Ethic, in* A SAND COUNTY ALMANAC AND SKETCHES HERE AND THERE (Oxford Univ. Press, 1949).

145. Vaughan, *supra* note 108.

146. A tree cover data inventory and recovery strategy is currently being developed at the National Agroforestry Center, a federally funded research and outreach center dedicated to agroforestry. *See Windbreaks of the Great Plains*, USDA NAT'L AGROFORESTRY CTR., https://usfs.maps.arcgis.com/apps/MapSeries/index.html?appid=ceb1a9f56acb480a944b9fada7ec258e (last visited Mar. 18, 2021); *infra* Subpart II.B.1.a.

147. Wendell Berry, 2013 Yale Chubb Fellowship Lecture.

148. Keefe O. Keeley et al., *Multi-Party Agroforestry Emergent Approaches to Trees and Tenure on Farms in the Midwest USA*, SUSTAINABILITY, Apr. 25, 2019, at 1.

According to many long-time agroforestry educators, negative perceptions of trees on agricultural land may present the biggest barrier to agroforestry adoption.[149] Indeed, trees were described by some Missouri farmers in a 2003 survey as "more of a hindrance than an asset" and incompatible with economically valuable row crops.[150] Missouri landowners were, in turn, less likely to express interest in agroforestry the more farming experience they had and the more row crops they farmed, according to a 1999 survey.[151] Aversion to trees on farmland may also make private landowners less likely to allow others to plant trees on their land; for example, Canadian landowners who expressed aversion to trees on farmland were much more likely to resist leasing their land for tree plantations.[152]

a. History of Clearing Trees

Negative perceptions of trees as incompatible with agriculture may stem from the collective memory of earlier generations clearing trees to establish farms.[153] Larry Godsey, associate professor of agricultural business at Missouri Valley College, explains:

> My father's generation and grandfather's generation spent many, many years and toil and sweat moving trees off the pasture and now you're going to tell them to plant trees on the pasture. That just doesn't click in their heads. It just doesn't meet their idea of what *good farming* is.[154]

Despite the prevalence of diversified agroforestry practices among pre-colonial Native American groups, tree-clearing and annual agriculture have dominated European-American agricultural history. For example, Native American groups in New England practiced forest farming in combination with seasonal hunting and fishing and shifting cultivation of maize and beans.[155]

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149. "I think number one barrier is social norms." Telephone interview with Larry Godsey, Associate Professor of Agribusiness, Missouri Valley College (Aug. 29, 2019) [hereinafter Godsey Interview]; *see also* James P. Lassoie et al., *The Development of Agroforestry as an Integrated Land Use Management Strategy, in* NORTH AMERICAN AGROFORESTRY: AN INTEGRATED SCIENCE AND PRACTICE, *supra* note 91, at 1, 12 (discussing how among rural landowners "trees are generally considered a detriment to the viability of a farming enterprise").

150. Andrew H. Raedeke et al., *Farmers, the Practice of Farming and the Future of Agroforestry An Application of Bourdieu's Concepts of Field and Habitus*, 68 RURAL SOCIO. 64, 76 (2003) (finding that valuation of family farming is the strongest determinant of resistance to trees on farmland).

151. J. Gordon Arbuckle Jr. et al., *Non-operator Landowner Interest in Agroforestry Practices in Two Missouri Watersheds*, 75 AGROFORESTRY SYS. 73, 79–80 (2009).

152. Pamela D. Neumann et al., '*My Grandfather Would Roll Over in His Grave' Family Farming and Tree Plantations on Farmland*, 72 RURAL SOCIO. 111 (2007).

153. *Id.* at 115. Neumann et al.'s study of Canadian farmers found that greater commitment to the notion of the family farm was the strongest determinant of increased resistance to trees on farmland. *Id.* at 129.

154. *See* Godsey Interview, *supra* note 149.

155. Careful forest management played a critical role in all four forms of food production. Regular, selective burning of forests in southern New England promoted soil nutrient recycling for crop cultivation

Early English colonial settlers cleared forested land for grain cultivation.[156] Later settlers in the 1700s girdled, axed, and burned forests down the Atlantic coast to plant commodity crops like wheat, rye, and tobacco.[157] Westward pioneers in the early 1800s continued to clear trees on fertile Midwestern land to raise grain and pigs.[158] Between 1850 and 1910, farmers cleared 190 million acres of forest—an amount of land slightly larger than the state of Texas—to make way for new cropland.[159] Increasing urbanization in the nineteenth century began to create a market for tree fruits.[160] Nonetheless, orchards and berries still remain a marginal production practice, representing only 7 percent of total agricultural sales and 0.6 percent of total farmland, most of which is concentrated in California.[161] In sum, productive agroforestry has played a marginal role in the history of Anglo-American agriculture.

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and biodiversity for hunting and gathering. *See* WILLIAM CRONON, CHANGES IN THE LAND: INDIANS, COLONISTS, AND THE ECOLOGY OF NEW ENGLAND 34-53 (1983).

156. However, the first English settlers actually mimicked agroforestry practices of Native American groups, like forest farming and silvopasture, due to a lack of farming experience and familiarity with temperate ecosystems. Later colonial farmers cultivated annual grains on fertile soil found in forests whose trees helped produced a rich black humus, but then they cleared those forests for permanent cropland. Unlike the shifting slash-and-burn agriculture practiced by Native groups in southern New England, permanent forest clearing reduced the capacity of those ecosystems to retain water and regulate temperatures, resulting in "sunnier, windier, hotter, colder, and drier" soils as well as more frequent and severe flooding due to runoff from frozen soil. *See* WILLARD W. COCHRANE, THE DEVELOPMENT OF AMERICAN AGRICULTURE: A HISTORICAL ANALYSIS 21, 51 (2d ed. 1993) ("What produced well in the Old World failed in the New World…"); PERCY W. BIDWELL & JOHN I. FALCONER, HISTORY OF AGRICULTURE IN THE NORTHERN UNITED STATES 5–9 (1925) ("[T]he colonists were often on the verge of starvation. . . [t]hey were too 'civilized' to get a living from the woods, the shore, and the streams with as little effort as the Indians."); CRONON, *supra* note 155, at 114 ("[T]he lumberer was not the chief agent in destroying New England's forests; the farmer was.").

157. *See* BIDWELL & FALCONER, *supra* note 156, at 77–78; CRONON, *supra* note 155.

158. *See* COCHRANE, *supra* note 156, at 51–54; BIDWELL & FALCONER, *supra* note 156, at 157–59 ("For almost two centuries Americans had been pioneering in the forests, and clearing woodland had become a national habit. The processes of girdling, grubbing, log-rolling, and burning, and the construction of log houses . . . [was] mostly handed down orally from one generation to another.").

159. BIDWELL & FALCONER, *supra* note 156, at 267 ("In the settlement of western Pennsylvania and New York, eastern Ohio, Kentucky, southern Indiana, and southern Illinois the first task of the immigrant in the production of crops was the clearing of the land of brush and trees."); *see also* DOUGLAS W. MACCLEERY, AMERICAN FORESTS: A HISTORY OF RESILIENCY AND RECOVERY 21, 29 (Forest History Society, 2011); Thomas R. Wessel, *Agriculture, Indians, and American History*, 50 AGRIC. HIST. 9, 15 (1976) ("Girdling trees and planting corn after grubbing out the underbrush dominated western agriculture until well into the nineteenth century.").

160. BIDWELL & FALCONER, *supra* note 156, at 380-82. Other marginal agroforestry practices include maple sugar production, collection of tree nuts, and the use of woodlands for livestock grazing. J.P. Lassoie et al., *Agroforestry Research and Extension Needs for Northeastern North America*, 67 FORESTRY CHRON. 219, 220 (1991).

161. 64 percent of orchard acreage is located in California. U.S. DEP'T OF AGRIC., *supra* note 140, at 7, 265, 286.

Negative perceptions of agroforestry among farmers may also be sustained by skepticism of unconventional farming recommendations.[162] Because agricultural practices are place-specific, conventions about agricultural practices provide valuable information for farmers. For example, proper application of nitrogen fertilizer on a particular plot of land depends on the crop type, crop history, tillage methods and tillage history, weather and rainfall, level of soil organic matter, local variation in soil structure, and underlying geology.[163] Understanding these nuances in agricultural practice come through years of place-based experience. Abandoning old agricultural practices not only renders hard-earned knowledge obsolete, but it also renders expensive infrastructure and equipment useless—an onerous cost for a farming operation of any size.[164] Moreover, competitor farmers growing annual commodities can continue to seek agronomic advice from local consultants, neighbors, and extension agents—an advantage largely unavailable to adopters of innovative practices. Volatile commodity markets and chronic uncertainty about production costs and yields, exacerbated by increasingly unstable weather patterns, may make farmers even more averse to new practices.[165] In these conditions, convincing farmers to plant trees on their farms can be especially challenging.

b. Institutional Information Channels Rarely Promote Agroforestry

Institutions exerting influence over agronomic management information channels reinforce the perception that agroforestry practices are highly unconventional and, at best, economically and ecologically optional. This perception is due in part to the growing share of agricultural research funded by agribusinesses after a decades-long decline in public funding (further discussed below).[166] Public funding for agricultural research was higher than private sector

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162. *See* Andrew H. Raedeke & J. Sanford Rikoon, *Temporal and Spatial Dimensions of Knowledge Implications for Sustainable Agriculture*, 14 AGRIC. & HUM. VALUES 145, 152–53 (1997) (observing that farmers who rely on "local, experiential, subjective" knowledge make management decisions based on historical management methods).

163. *Id*. at 149. The nuanced nature of farming is reflected "The Four R's"—a mantra repeated by extension agents and fertilizer companies that farmers should apply the right fertilizer, at the right rate, using the right method, at the right time. *See generally* Terry L. Roberts, *Right Product, Right Rate, Right Time, and Right Place . . . the Foundation of Best Management Practices for Fertilizer*, 91 BETTER CROPS 14 (2007).

164. Peter H. Lehner & Nathan A. Rosenberg, *Promoting Climate-Friendly Agriculture for the Benefit of Farmers, Rural Communities, and the Environment*, 33 NAT. RES. & ENV'T 7, 8–9 (2018).

165. Technological uncertainty, where new production techniques make fixed past investments obsolete, and policy uncertainty, which affects costs and prices, create further risk for farmers. *See, e.g.*, Giancarlo Moschini & David A. Hennessy, *Uncertainty, Risk Aversion, and Risk Management for Agricultural Producers, in* HANDBOOK OF AGRICULTURAL ECONOMICS 87 (Bruce L. Gardner & Gordon C. Rausser eds., 2001) (proposing a formal model for agricultural uncertainty and risk-management tools).

166. *Id*. In a 2014 survey, nearly 80 percent of extension agent respondents indicated that private industry funded some of their research programs, while 56 percent indicated that industry funded some of their extension programs. Rayda K. Krell et al., *A Proposal for Public and Private Partnership in Extension*, 7 J. INTEGRATED PEST MGMT. 1, 3 (2016).

funding as late as 2004.[167] By 2014, however, private sector funding was almost 50 percent higher than public funding.[168] While extant agribusinesses have incentives to fund the promotion of practices that require patentable technology and inputs, agribusinesses will not promote perennial systems, which generally require fewer and less expensive patentable products.[169]

Technical assistance is increasingly provided by the private sector as well.[170] Indeed, in a 2016 survey, Illinois landowners responded that they most often sought farming information from agricultural seed and chemical suppliers.[171] In a 2011 survey of U.S. extension service professionals, however, only about 50 percent of respondents said their state offered technical assistance programs in agroforestry.[172] Thus, public funding is needed to fill the knowledge gaps about agroforestry that the private sector may not have incentives to address.

However, even public funds dedicated to agroforestry may inadvertently communicate that agroforestry is a conservation practice rather than a system of agricultural production—in other words, that agroforestry is farming near trees, not farming *with* trees. For example, USDA's Natural Resources Conservation Service (NRCS) administers the Environmental Quality Incentives Program (EQIP), currently the largest public cost-share program for agroforestry practices.[173] By concentrating agroforestry resources in a conservation-focused program, NRCS inadvertently portrays these practices (windbreaks, alley cropping and silvopasture) as optional conservation practices rather than as essential *production* practices that increase crop yields and come with secondary conservation benefits.[174] It is crucial that public communication around agroforestry clearly reflects the value of production because, while many farmers are motivated by conservation concerns, financial concerns are often paramount.

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167. ECON. RSCH. CTR., U.S. DEP'T OF AGRIC., AGRICULTURAL RESEARCH FUNDING IN THE PUBLIC AND PRIVATE SECTORS, 1970-2015 (2019), *available at* https://www.ers.usda.gov/data-products/agricultural-research-funding-in-the-public-and-private-sectors/.

168. *Id*.

169. "We live in a society where agriculture's information is clearly controlled by big industry. Row crops are controlled by the seed companies. Pastures are controlled by the beef and feed companies. So, what the farmer hears about pasture management doesn't come from receptive industries [to silvopasture]." Godsey Interview, *supra* note 149; *see also* Lehner & Rosenberg, *supra* note 164, at 7–8.

170. Linda Stalker Prokopy et al., *Extension's Role in Disseminating Information About Climate Change to Agricultural Stakeholders in the United States*, 130 CLIMATIC CHANGE 261, 268 (2015).

171. Chloe M. Mattia et al., *Identifying Barriers and Motivators for Adoption of Multifunctional Perennial Cropping Systems by Landowners in the Upper Sangamon River Watershed, Illinois*, 92 AGROFORESTRY SYS. 1155, 1160 (2018).

172. Exclusion of agroforestry in extension outreach programs has been attributed to limited resources. Michael Jacobson & Shiba Kar, *Extent of Agroforestry Extension Programs in the United States*, J. EXTENSION, Aug. 2013, https://archives.joe.org/joe/2013august/pdf/JOE_v51_4rb4.pdf.

173. *See* Lehner & Rosenberg, *supra* note 18, at 802.

174. Interview with Anonymous USDA Official (Aug. 20, 2019) [hereinafter USDA Interview].

c. Underfunded Research

Federal funding for agricultural research has fallen significantly in recent years, declining between 2003 and 2013 from $6 billion to $4.5 billion after adjusting for inflation,[175] leaving North America as the only region in the world where private agricultural research exceeds public spending.[176] This disparity disadvantages sustainable system research, which relies on public funds. As the USDA Economic Research Service (ERS) notes, public research produces "much of the fundamental research that creates the building blocks for major agricultural innovations" because private research "gravitate[s] toward technologies that are easy to patent or otherwise protect with intellectual property rights."[177] As a result, almost no private sector funding is allocated to practices or technologies that conserve environmental resources since they are unlikely to be part of profitable, patentable products or services.[178] Despite the growing need for publicly funded research into sustainable systems, such research remains, as one assessment put it, "woefully under-resourced."[179] This is particularly true for research into agroforestry crops and practices. While the USDA does not track how much support agroforestry receives, the available data indicate that it receives an incredibly small share of federal research dollars. An analysis of the USDA's 2014 research budget, for example, found that less than 0.1 percent went to agroforestry research.[180] Funding for agroforestry will need to be substantially increased in order for tree crops to become commercially viable on a wide scale. Just as public funds drove rapid improvements in annual crops during the twentieth century, government investments in breeding and agronomic research will be critical to agroforestry's expansion.

d. Early Adopters Driven by Social Norms Favoring Agroforestry

Fortunately, positive perceptions of agroforestry based on ecological and other non-economic values can also drive new adoption of agroforestry. Early adopters may be motivated by these values to establish agroforestry systems despite financial opportunity costs. Steve Gabriel, a silvopasturalist and extension specialist in New York State, observed:

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175. Matthew Clancy et al., *U.S. Agricultural R&D in an Era of Falling Public Funding*, U.S. DEP'T OF AGRIC.: AMBER WAVES (Nov. 10, 2016), https://www.ers.usda.gov/amber-waves/2016/november/us-agricultural-r-d-in-an-era-of-falling-public-funding.

176. Paul W. Heisey & Keith O. Fuglie, U.S. DEP'T OF AGRIC., ECON. RSCH. REPORT NO. 249, AGRICULTURAL RESEARCH INVESTMENT AND POLICY REFORM IN HIGH-INCOME COUNTRIES 14 tbl.3.2 (2018).

177. Clancy et al., *supra* note 175.

178. *Id.*

179. Liz Carlisle & Albie Miles, *Closing the Knowledge Gap How the USDA Could Tap the Potential of Biologically Diversified Farming Systems*, 3 J. AGRIC., FOOD SYS., & CMTY. DEV. 219, 221 (2013).

180. Marcia S. DeLonge et al., *Investing in the Transition to Sustainable Agriculture*, 55 ENV'T SCI. & POL'Y 266, 266 (2016).

> The reason [that farmers] go into agroforestry is that it aligns with their values . . . that would be first and foremost. Ecologically minded folks want to improve [forest maintenance] or sequester carbon.[181]

Professor Larry Godsey in Missouri echoed the observation:

> [M]ore people [are] adopt[ing] agroforestry because they have concerns about climate change and their environment. [They think,] "I know I can get more money doing something else, but I'm worried about the future."[182]

New and beginning farmers may be especially well-suited to establish agroforestry for these reasons. A 2015 survey of Illinois landowners in an intensively cropped watershed area found that the youngest participant group expressed the greatest interest in perennial systems.[183] A 1999 survey found that Missouri landowners motivated by environmental or recreational considerations were more interested in adopting agroforestry than those motivated by financial considerations.[184] Indeed, even among the general population, newer generations who have experienced, and will experience more negative effects of climate change express more concern about, and willingness to act on climate change.[185] Research indicates that more established farmers may also be less willing to learn new skills and systems required to establish agroforestry operations.[186]

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181. Telephone interview with Steve Gabriel, Farmer at Wellspring Forest Farm and Agroforestry Extension Specialist, Cornell Small Farms Program (Aug. 9, 2019).

182. Godsey Interview, *supra* note 149. "In my work with silvopasture . . . I'm finding very willing adoption in the grass-fed, grass-finished livestock culture. They tend to have ecological goals in their management, and have already left the mainstream." E-mail from Austin Unruh, Crow & Berry Land Management, June 4, 2020 (on file with authors).

183. Mattia et al., *supra* note 171, at 1162.

184. Arbuckle et al., *supra* note 151, at 80 (survey of Missouri non-farming landowners finding that environmental or recreational motivations for land ownership were positively associated with interest in agroforestry whereas stronger financial motivations for landownership and higher proportion of land planted with row crops were negatively related).

185. A poll conducted from 2015-2018 found that 70 percent of participants aged 18-34 say they worry about global warming compared to 56 percent of participants aged fifty-five or older. R.J. Reinhart, *Global Warming Age Gap Younger Americans Most Worried*, GALLUP (May 11, 2018), https://news.gallup.com/poll/234314/global-warming-age-gap-younger-americans-worried.aspx. Newer generations are also more willing to take steps to slow climate change. Matthew Ballew et al., *Do Younger Generations Care More About Global Warming?*, YALE PROGRAM ON CLIMATE CHANGE COMMC'N (June 11, 2019), https://climatecommunication.yale.edu/publications/do-younger-generations-care-more-about-global-warming/.

186. USDA Interview, *supra* note 174; N. Strong & M.G. Jacobson, *A Case for Consumer-Driven Extension Programming Agroforestry Adoption Potential in Pennsylvania*, 68 AGROFORESTRY SYS. 43, 43–52 (2006) (survey of Pennsylvanian farmers and woodland owners finding that older landowners motivated by preserving the land's legacy were less interested in agroforestry adoption); *see also* Lassoie et al., *supra* note 162, at 12 (listening session for rural landowners identified agroforestry's management complexity, which requires "too new skills and too much attention," as a major limit to adoption).

2. Financial Incentives

Public support for agroforestry must provide long-term financial incentives because trees that generate a marketable product are a long-term investment; trees take longer to grow and often much longer to produce returns on investment than annual crops.[187] However, current financial incentives—public subsidies, private capital, publicly chartered crop insurance, and markets for commodities and services—favor annual crops over perennial crops and monocultures over polycultures. Prevailing patterns of land insecurity further prevent farmers from seriously considering long-term investments on the land.[188] Indeed, in a 2006 survey, Missouri landowners cited longer management timeframes for trees and the high costs of establishing agroforestry systems as the top two barriers to adoption.[189] Additional financial support may sway farmers, who are already motivated by ecological values or who are otherwise willing, to incorporate trees on their farms.[190]

a. Financial Returns on Agroforestry Take Longer Than Annual Crops

Agroforestry systems generally take longer to return a profit than annual cropping systems, and estimates for financial returns on agroforestry systems can vary widely. This variability poses a challenge, not only to farmers making decisions about agroforestry adoption, but also to financial institutions making decisions about giving loans to those farmers. Financial analyses of agroforestry systems depend on the economic model used and the agroforestry system studied. These systems can include different practices (windbreaks versus alley cropping), products sought (nuts versus timber), geoclimatic regions (temperate versus tropical) and regional markets for commodities and ecosystem services. For example, one study found that black walnut alley cropping would be more profitable than corn-soybean rotations on a specific portion of cropland in four Midwestern states.[191] Even across different sites within individual farms, the sustainable number, species, and variety of trees will depend on pre-existing crop systems and agronomic practices used.[192]

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187. The IPCC identifies the time lag between adoption and realization of benefits as a key barrier to expansion of agroforestry. IPCC, *supra* note 73, at 4-62.

188. *See infra* Subpart II.A.3.

189. Corinne Valdivia et al., *Between Forestry and Farming Policy and Environmental Implications of the Barriers to Agroforestry Adoption*, 60 CANADIAN J. OF AGRIC. ECON. 155–75 (2012).

190. "We've got to figure out how to provide the incentives [so] that people who are concerned about the environment finally go, 'Okay.' We're talking about the marginal people, the ones who are on the edge . . . We have to get to that point where the incentives are enough to get more people adopting." Godsey Interview, *supra* note 149.

191. Wolz & DeLucia, *supra* note 16, at 7.

192. *See generally* PA. CHAPTER OF THE AM. CHESTNUT FOUND., PLANTING AND GROWING CHESTNUT TREES (2006), *available at* https://www.acf.org/wp-content/uploads/2016/08/planting_manual.pdf (describing effectiveness of chestnut tree cultivation in Pennsylvania as influenced

Not only do returns on agroforestry systems take longer, but trees provide multiple economic products which complicate financial analyses of specific systems. Commodity tree crops typically include fruits or nuts. Saplings grow for multiple years before bearing fruit. Chinese chestnut trees, for instance, take six to nine years before commercial harvest,[193] while black walnut trees take ten years before they can harvested commercially.[194] While on-and-off farm experiments with tree hybridization can reduce tree growth times, the longer life cycle of trees means that hybridizing trees takes longer than breeding annuals, which can have multiple generations in a single year.[195] The longer it takes for tree crop harvest, the greater the need for long-term support for farmers in the form of land security and sustained financial assistance.[196]

b. Public Subsidies Limited by Short Funding Cycles

USDA's conservation programs provide little financial or technical support for agroforestry practices, despite the important role these programs play in the farm safety net for annual crop production. Conservation programs provide inadequate incentives for long-term maintenance of productive trees and rely primarily on voluntary participation, problems mirrored by many recently enacted state-level climate laws.

The bulk of USDA conservation funding goes toward three programs: EQIP, the Conservation Stewardship Program (CSP), and the Conservation Reserve Program (CRP).[197] The 2018 Farm Bill allocated roughly $5.8 billion on average annually to conservation, with 38 percent of that amount going to EQIP, 34 percent to CRP, 17 percent to CSP, and the remaining 11 percent to smaller programs.[198] Both EQIP and CSP are working lands programs, meaning that they are designed to make productive agricultural land more

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by many factors, including: soil type, numbers planted, tree spacing, seeding versus planting seedlings, weed control, fertilization, and watering methods).

193. E-mail from Keefe Keeley, Co-Director of the Savannah Institute, June 18, 2020 (on file with authors); KEN HUNT ET AL., GROWING CHINESE CHESTNUTS IN MISSOURI 3 (Agroforestry in Action, AF 1007-2012, 2012), *available at* http://www.centerforagroforestry.org/pubs/chestnut.pdf.

194. WILLIAM REID ET AL., GROWING BLACK WALNUT FOR NUT PRODUCTION 1 (Agroforestry in Action, AF 1011-2009, 2009), *available at* http://www.centerforagroforestry.org/pubs/walnutNuts.pdf.

195. The University of Missouri has reduced the maturation period for certain black walnut species to eight years and certain chestnut species to three years. Godsey Interview, *supra* note 149.

196. "Everything that is true for a beginning farmer in Western Massachusetts . . . is even more so true for agroforestry. For a crop like chestnuts . . . I am not generating revenue for five to seven years on a crop that requires significant investment per acre." Interview with Russell Wallack, Farmer at Breadtree Farms (Sept. 2, 2019).

197. Lehner & Rosenberg, *supra* note 18, at 802.

198. CONG. RSCH. SERV., R45525, THE 2018 FARM BILL (P.L. 115-334): SUMMARY AND SIDE-BY-SIDE COMPARISON 5 fig.1 (2019).

environmentally friendly. CRP, on the other hand, is primarily a land retirement program, which takes agricultural land out of production.[199]

EQIP pays farmers to plan and install conservation practices, including agroforestry practices, but each state determines which practices are prioritized.[200] Almost every state funds windbreaks and riparian forest buffers, but other agroforestry practices are generally not prioritized, and in many states alley cropping, forest farming (multi-story cropping), and silvopasture are either unfunded or unsupported by NRCS county agents.[201] EQIP provided almost $1.4 billion in financial assistance to farm operations in fiscal year 2018,[202] and less than .05 percent of that amount went to silvopasture and alley cropping, two of the most promising agroforestry production practices for carbon sequestration funded by the program.[203]

CSP funds conservation practices, but unlike EQIP, does so within the context of a comprehensive, whole-farm conservation plan.[204] As a result, it is much more effective at achieving conservation goals; according to a 2018 analysis, every dollar spent on CSP results in a return of $3.95 to taxpayers, farmers, and the environment combined, while EQIP and CRP are estimated to have returns of $1.01 and $2.11 respectively.[205] CSP is also the largest USDA conservation program on an acreage basis,[206] despite having the smallest budget of the three main programs.[207] CSP pays farmers each year for five years with

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199. Newer CRP provisions allow restricted use of livestock and hay harvest. 7 C.F.R. § 1410.13 (2020). Other programs under CRP incentivize transfer of expiring CRP land to beginning and socially disadvantaged farmers and ranchers. *Id.* § 1410.64.

200. 16 U.S.C. § 3839aa-2(d)(7)(A).

201. *NRCS Conservation Practice Standards for Agroforestry*, U.S. DEP'T OF AGRIC.: NAT'L AGROFORESTRY CTR., https://www.fs.usda.gov/nac/practices/conservation-practice-standards.shtml (last visited June 22, 2021); E-mail from Russell Wallack, Farmer at Breadtree Farms (July 4, 2020) (on file with authors).

202. *NRCS Conservation Programs Environmental Quality Incentives Program (EQIP)*, U.S. DEP'T OF AGRIC., https://www.nrcs.usda.gov/Internet/NRCS_RCA/reports/fb08_cp_eqip.html (last visited Mar. 20, 2021).

203. *Id*. (calculated by the authors). $666,636 went to support silvopasture and $18,673 went to alley cropping.

204. For more on the benefits of CSP, and distinctions between CSP and EQIP, *see Farm Bill Myth-Busting The Conservation Stewardship Program*, NAT'L SUSTAINABLE AGRIC. COAL.: BLOG (Oct. 10, 2018), https://sustainableagriculture.net/blog/farm-bill-csp-myth-vs-fact/; Page Stanley, *What Congress Does Next Could Cost Farmers and Taxpayers Billions*, UNION OF CONCERNED SCIENTISTS: BLOG (Aug. 22, 2018, 10:16 AM), https://blog.ucsusa.org/science-blogger/what-congress-does-next-could-cost-farmers-and-taxpayers-billions.

205. UNION OF CONCERNED SCIENTISTS, FARMERS AND TAXPAYERS STAND TO LOSE BILLIONS WITH ELIMINATION OF THE CONSERVATION STEWARDSHIP PROGRAM: CSP'S HIGH VALUE FARM CONSERVATION DELIVERS 4-TO-1 RETURN ON INVESTMENT app. at 2 (2018), *available at* https://www.ucsusa.org/sites/default/files/attach/2018/08/CSP-ROI-Appendix-FINAL.pdf?_ga=2.57279594.1785337028.1576084408-1777444204.1576084408.

206. *Conservation Stewardship Program*, U.S. DEP'T OF AGRIC.: NAT. RES. CONSERVATION SERV., https://www.nrcs. usda.gov/wps/portal/nrcs/main/oh/programs/financial/csp/ (last visited Mar. 20, 2021).

207. *See* MEGAN STUBBS, CONG. RSCH. SERV., R45698, AGRICULTURAL CONSERVATION IN THE 2018 FARM BILL 13 tbl.2 (2019).

an option to renew for an additional five-year term if they agree to adopt additional conservation objectives.[208] Despite its impressive record in supporting sustainable practices, CSP provides relatively few farmers with support for agroforestry practices, and what little it does provide overwhelmingly goes to conservation practices at the edges of fields, such as windbreaks or riparian buffers. In records obtained through a Freedom of Information Act request, we found that only one producer had received CSP funding for silvopasture between fiscal years 2017 and 2019, and no producers received funding for alley cropping over the same period.[209]

CRP pays farmers to take environmentally sensitive land out of agricultural production for ten to fifteen years to plant perennial trees and grasses that provide ecosystem benefits.[210] However, many farmers bring their CRP acres back into production after the end of their contract period.[211] Program regulations, like high density requirements for trees and prohibitions on harvesting from and grazing around CRP trees, are designed to encourage farmers to plant and conserve unproductive forests.[212] As a result, because farmers cannot integrate newly planted trees into long-term, economically sustainable operations, they often treat large CRP payments as a temporary source of income before plowing up the trees to plant annual crops.[213]

Many regional, state, and local climate mitigation legislation and regulations are not well-tailored for the unique timelines and scales of carbon sequestration for agroforestry.[214] California, for instance, allocates a portion of revenue from its statewide carbon cap-and-trade program to the Healthy Soils Program, a state-administered, cost-share payment program for farmers to

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208. 7 C.F.R. §1470.26 (2020).

209. Letter from FOIA Officer Patrick McLoughlin in response to FOIA request 2019-NRCS-06806-F (Dec. 12, 2019) and accompanying Microsoft Excel files (on file with authors).

210. 7 C.F.R. § 1410.2 (2020).

211. Lehner & Rosenberg, *supra* note 18, at 802. Producers are paid to plant tree species that provide ecosystem benefits like water quality improvement and soil erosion control.

212. High tree density requirements prevent farmers from establishing silvopasture operations. FARM SERV. AGENCY, U.S. DEP'T OF AGRIC., CONSERVATION RESERVE PROGRAM: TREE PLANTING, *available at* https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/2015/CRPProgramsand Initiatives/Practice_CP3_Tree_Planting.pdf (last visited Mar. 20, 2020). As Larry Godsey explains: "If [CRP] let farmers plant a fewer number of trees or be more selective on the tree species that they could plant, then, by the time it comes out of the first 10 years, [farmers] could have some trees to thin out and turn into a silvopasture system." Godsey Interview, *supra* note 149.

213. Godsey Interview, *supra* note 149.

214. *See, e.g.*, A.B. A8429, 2019-2020 Leg., Reg. Sess. (N.Y. 2019) (requiring the Department of Environmental Conservation to establish and implement a statewide goal for carbon neutrality to be met by 2050); A.B. 32, 2005-2006 Leg., Reg. Sess. (Cal. 2006) (requiring adoption of a Renewable Portfolio Standard, a Low Carbon Fuel Standard, and a variety of land use and energy efficiency standards and incentives in meeting state emissions reduction goals). Many statewide climate bills expressly exempt agricultural emissions from regulation. *See, e.g.*, S.B. S6599, 2019-2020 Leg., Reg. Sess. (N.Y. 2019) (exempting livestock emissions from regulation); H.B. 19-1261, 72d Gen. Assemb., Reg. Sess. (Colo. 2019).

establish conservation practices, which covers all agroforestry practices.[215] Although funded agroforestry projects are expected to last at least ten years, Healthy Soils Program grant duration is limited to three years in line with the state legislative budget cycle.[216] As a result, California program administrators for the Healthy Soils Program can only "make it pretty clear" to agroforestry recipients that they are expected to maintain trees for at least ten years.[217] On the other hand, under New York's CO_2 Budget Trading Program, non-exempt emitters may purchase allowance credits from agricultural producers on the condition that carbon sequestration benefits created are "real, additional, verifiable, enforceable, and permanent."[218] However, many agroforestry projects are likely ineligible due to the permanent conservation easement requirement, which is tailored for timber-based afforestation projects.219

c. Private Funding Limited by Lack of Market Information

Private loans help farmers secure resources essential for establishing agroforestry systems, including land, labor, and equipment. However, lack of information about the profitability and risk profile of agroforestry operations in the financial sector restricts the availability of private capital. One of the most detrimental practices is the "highest and best use" standard used to assess agricultural loan applications. Specifically, Farm Credit System lending institutions must assess whether the farmer has or will adopt the "highest and best use" of the farm in appraising farmland for collateral.[220] This standard is determined in practice by whether the operation conforms to regional production practices.[221] The standard is inadequately designed to minimize risk and

215. *See* A.B. 1532, 2011-2012 Leg., Reg. Sess. (Cal. 2012); CAL. DEP'T OF FOOD AND AGRIC., 2018 HEALTHY SOILS PROGRAM INCENTIVES PROGRAM (2018), *available at* https://www.cdfa.ca.gov/oefi/healthysoils/docs/2018-HSPIncentives_RGA.pdf.

216. Telephone interview with Geetika Joshi, Senior Environmental Scientist, California Department of Food and Agriculture (July 11, 2019).

217. *Id*.

218. N.Y. Comp. Codes R. & Regs. tit. 6 § 242.10 (2020). Similarly, the Regional Greenhouse Gas Initiative, a multi-state, mandatory cap-and-trade program for electricity generators in the northeast, allows regulated emitters to purchase carbon offsets from afforestation projects with permanent conservation easements.

219. *Id.*

220. For an overview of agricultural loans, *see* Lehner & Rosenberg, *supra* note 18, at 812.

221. 12 C.F.R. § 614.4240(j) (2020) (defining "highest and best use" as resulting in the "highest market value" of land); FARM SERV. AGENCY, U.S. DEP'T OF AGRIC., NOTICE NO. FLP-766, REAL ESTATE EVALUATION AND APPRAISAL REQUIREMENTS FOR GUARANTEED LOAN MAKING AND SERVICING 4 (2017), *available at* https://www.fsa.usda.gov/Internet/FSA_Notice/flp_766.pdf ("highest and best use" determination depends on whether production is "maximally productive"); *see also* N.J. STATE AGRIC. DEV. COMM., APPRAISER HANDBOOK SUPPLEMENT: PINELANDS AREA AND AGRICULTURAL USE APPLICATIONS 11 (requiring collateral appraisal reports "highest and best use" determinations to include "full discussion of agriculture in the region and community and the trends evident in agricultural production including . . . product prices; yields; soil resources . . . suppliers, markets"), *available at* https://www.nj.gov/agriculture/sadc/farmpreserve/appraisals/Pinelands%20Appraiser%20Handbook%20Supplement.pdf.

inherently disfavors agricultural innovations. As Professor Larry Godsey explains: "Most banks are very classical in their economic viewpoint. They think, 'If it was the 'highest and best use', everybody would be doing it. But since everybody's doing row crop and pasture, then orchard crops cannot be best use.'"[222]

Because regional markets for tree crops, silvopasture products, and ecosystem services are largely either under- or undeveloped, both banks and operators have limited information about the revenue and costs of agroforestry operations.[223] Banks may also have few incentives to acquire information about the risk profile of unconventional systems given the large number of conventional agricultural loan seekers.[224]

3. Land Access

Insecure land tenure for new and beginning farmers compounds the counterproductive social norms and inadequate financial incentives aspiring agroforesters must contend with. Willing adopters must have adequate land security in order for agroforestry adoption and maintenance to be affordable in the long run, particularly for growing long-lived tree species with high sequestration capacity like chestnut. As chestnut farmer Russell Wallack explains:

> Everything that is true for a beginning farmer finding land is even more so true for agroforestry, in terms of land access, because you are not generating revenue for 5-7 years on a crop that requires significant investment on a per acre scale. Just this year . . . with basically all of my labor being my own . . . is costing in the $20,000 range to establish 7 acres. The cheapest that you would be able to pull it off would be $1,000-$2,500 per acre . . . so to add $5,000-$10,000 per acre for the cost of land up front . . . makes land access even harder.[225]

Existing patterns of land tenure likely do not support adoption: 69 percent of farmland in the United States is owned by persons over sixty-five while the average age of U.S. farmers has risen steadily in the last thirty years, from 50.5 in 1982 to 59.4 in 2017.[226] Moreover, the average size of farmland—444 acres—may be too large and expensive for establishing complex agroforestry operations, particularly for new farmers.[227] High costs of land ownership drive new farmers toward leasing to cut costs,[228] in turn increasing risks associated with investing

222. Godsey Interview, *supra* note 149.
223. USDA Interview, *supra* note 174.
224. *Id.*
225. Interview with Russell Wallack, *supra* note 198.
226. *See* Bigelow et al., *supra* note 85; *see also supra* Subpart II.A.1.d.
227. The large size of farmland increases transaction costs for agroforesters seeking to rent or purchase land. USDA Interview, *supra* note 174.
228. Land leasers tend to be younger than landowners. *See* Bigelow et al., *supra* note 85.

in perennial crops. Almost 40 percent of farm acreage in the United States is leased,[229] and 70 percent of those leases are annual rather than multi-year.[230] This lack of land security poses a major barrier to agroforestry: operators without adequate land security are unlikely to invest in agroforestry practices, which can take years and even decades to pay off.

B. Policy Recommendations

To effectively encourage agroforestry adoption and long-term ecosystem maintenance, policies must address all three barriers holistically. Targets must include (1) allocating significantly more resources toward the demonstration and research of site-specific agroforestry operations; (2) crafting short-term incentives for establishing trees; and (3) establishing long-term financial support for agroforestry producers, including land access and market support for agroforestry products and services. Specific recommendations in each category are listed in turn. Our recommendations are focused on federal policy, but similar policies should also be pursued at the state level.

1. Fund Agroforestry Research, Information Dissemination, and Technical Assistance

Congress should establish new agroforestry centers in six representative ecological regions of the United States to conduct and coordinate research, technical assistance, and outreach efforts. The federal government should also provide additional funding for competitive research and demonstration projects and outreach and training for agroforestry practices.

a. Establish Regional Federal Agroforestry Centers

Congress should fund the establishment of at least six agroforestry centers serving the Midwest, Mountain, Northeast, Northwest, Southern, and Southwest regions, respectively, to conduct research and provide technical assistance for agroforestry practices.[231] Such centers would most likely be based at land-grant universities, which already have agricultural research, outreach, extension, and economic development programs.[232] They should also collaborate with and,

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229. U.S. DEP'T OF AGRIC., *supra* note 140.

230. *See* Bigelow et al., *supra* note 85, at 25.

231. However, six centers would only cover half of the ecoregions in the coterminous United States. Additional centers to cover the remaining six ecoregions would ideally be established in the long-term. James M. Omernik, *Ecoregions of the Conterminous United States*, 77 ANNALS ASS'N AM. GEOGRAPHERS 118, 120 (1987) (defining ecoregions as a useful framework for resource management, where ecoregions share soil, land use, land surface form, and potential natural vegetation); *Ecoregions*, EPA, https://www.epa.gov/eco-research/ecoregions (last visited Mar. 20, 2021).

232. Researchers from the University of Missouri, Cornell University, and Virginia Polytechnic Institute, and State University (Virginia Tech), among others, have received USDA funding for

when possible, be located within existing institutions that have a strong track record of supporting agroforestry research and outreach to ensure that they help strengthen existing programs. Annual budget requirements should be at least $2.5 million for each center, in order to provide multi-state regions with sufficient staff, facilities, and programming.[233]

New regional agroforestry centers should be modeled on the University of Missouri Center for Agroforestry (UMCA), which has stimulated the growth of agroforestry through a variety of research, outreach, education, and economic development programs.[234] Established in 1998, UMCA has quickly become an international hub for research on temperate agroforestry, while working to bring that research to producers and agricultural professionals through publications, trainings, and convenings.[235] UMCA has also proven remarkably effective at leveraging its annual $1 million allocation—between 1998 and 2019, the center received an additional $55 million in funding through grants and contracts.[236]

The National Agroforestry Center, which was established in the 1990 Farm Bill could serve as a liaison to network between the six regional centers.[237] The National Agroforestry Center, based in Lincoln, Nebraska, conducts research, develops tools and technology, coordinates technical assistance efforts, and provides information to practitioners assisting farmers with agroforestry practices.[238] For example, the National Agroforestry Center created a free, GIS-based digital tool to help farmers design tree buffers in locations most effective for capturing chemical and silt runoff.[239] Policy-relevant tools include a model to predict carbon storage amounts in windbreaks of different ages, and inventories of total tree cover in specific agricultural regions to coordinate efforts

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agroforestry research and extension efforts. *See Funded Grants in Your State*, SUSTAINABLE AGRIC. RSCH & EDUC., https://www.sare.org/Grants/ Funded-Grants-in-Your-State (last visited Mar. 20, 2021).

233. Interview with Michael Gold, Professor of Forestry, University of Missouri (Sept. 10, 2019). This amount is commensurate with funding levels at highly effective agricultural research, outreach, and technical assistance institutions, if somewhat conservative. The Leopold Center for Sustainable Agriculture at Iowa State had a budget of approximately $2 million until recent state budget cuts, while The Land Institute and the Rodale Institute had expenditures of approximately $4.2 and $5.2 million respectively in fiscal year 2018. *See* Lehner & Rosenberg, *supra* note 47, at 10,860–61; THE LAND INST., ANNUAL REPORT 2018, at 8 (2018); RODALE INST., 2019 ANNUAL REPORT: GROWING THE ORGANIC MOVEMENT SINCE 1947, at 8 (2019).

234. *See* UNIV. OF MO. CTR. FOR AGROFORESTRY, THE CENTER FOR AGROFORESTRY: PATHWAY TO 2030, at 4–11 (2020), *available at* https://centerforagroforestry.org/wp-content/uploads/2021/04/UMCA-Pathway-to-2030-STRATEGIC-PLAN_2020_FINAL.pdf.

235. *See* UNIV. OF MO. CTR. FOR AGROFORESTRY, CENTER FOR AGROFORESTRY ANNUAL REPORT 2019, at 25–30 (2020).

236. *Id.* at 4.

237. *See* Food Agriculture Conservation and Trade Act of 1990, Pub. L. No. 101-624, § 1243, 104 Stat. 3359 (1990); *USDA National Agroforestry Center*, U.S. FOREST SERV., https://www.fs.usda.gov/rmrs/usda-national-agroforestry-center (last visited Mar. 21, 2021).

238. *About the Center*, U.S. DEP'T OF AGRIC.: NAT'L AGROFORESTRY CTR., https://www.fs.usda.gov/nac/about/index.php (last visited Mar. 20, 2021).

239. AgBufferBuilder, U.S. DEP'T OF AGRIC.: NAT'L AGROFORESTRY CTR., https://www.fs.usda.gov/nac/resources/tools/AgBufferBuilder.shtml (last visited Mar. 20, 2021).

across multiple farms.[240] Resources tailored to specific regions are essential for agroforestry adoption, particularly in high-potential but currently underserved areas like the Midwest.[241]

b. Increase Competitive Funds for Research and Demonstration Projects

Congress should create at least two competitive grant research programs focused on agroforestry research. One program should be housed within the National Institute of Food and Agriculture's (NIFA) Agriculture and Food Research Initiative (AFRI), USDA's primary competitive research grant program. This program should receive a minimum of $10 million in mandatory funding in order to provide competitive grants to academic researchers for both basic and applied research. The second program should be modeled after the Sustainable Agriculture Research and Education (SARE) program, whose applied, farmer-driven research focus has a remarkable record of developing and propagating sustainable practices.[242]

Competitive grant programs would help overcome two substantial barriers to agroforestry expansion. First, substantial federal funding for agroforestry would stimulate more agroforestry-focused projects in the short run and encourage various institutions to incorporate agroforestry into their long-term research and outreach portfolios. Research for perennial agriculture and public agricultural research generally are both severely underfunded.[243] As a result, it is "incredibly challenging" for agroforestry proposals to overcome each application stage (pre-proposal to award) to secure SARE research and education funding. Meanwhile agroforestry grant proposals through AFRI have success rates in the single digits, according to Michael Gold, Professor of Forestry and Associate Director of the University of Missouri Center for Agroforestry.[244] Second, longer-term grants are more suitable for agroforestry research than the short-term grants currently available.[245]

240. Qingjiang Hou et al., *A Spatial Model Approach for Assessing Windbreak Growth and Carbon Stocks*, J. ENVTL. QUALITY, Feb. 6, 2011.

241. *See supra* Subpart I.B.2.b.

242. Lehner & Rosenberg, *supra* note 18, at 796. Significant SARE funding has gone to farmer-led agroforestry projects since 1989, before the statutory establishment of the National Agroforestry Center. *See Sustainable Agriculture Research and Education (SARE) Agroforestry Grants*, U.S. DEP'T OF AGRIC.: NAT'L AGROFORESTRY CTR., https://www.fs.usda.gov/nac/resources/usda-programs/sare-agroforestry-grants/ (last visited Mar. 20, 2021); Malala Misa & Agnes M. Vargo, *Indigenous Agroforestry in American Samoa*, *in* PROCEEDINGS OF THE WORKSHOP ON RESEARCH METHODOLOGIES AND APPLICATIONS FOR PACIFIC ISLAND AGROFORESTRY 83, 84 (U.S. Forest Serv. General Tech. Report No. PSW-GTR-140, 1993) (report on indigenous agroforestry in American Samoa based on the first agroforestry study funded by SARE).

243. Lehner & Rosenberg, *supra* note 18, at 795–96.

244. Interview with Michael Gold, *supra* note 233.

245. SARE's annual funding ranges from $19 to $27 million and grants are relatively short-term (typically up to three years). *See id.*; *Research and Education Grants*, S. SUSTAINABLE AGRIC. RSCH. &

Local and regional demonstration projects funded by competitive grants are particularly cost-effective at promoting farmer adoption as the national infrastructure for agroforestry research and training is being developed.[246] Katie Commender, an agroforestry program manager at a sustainable agricultural non-profit in the Appalachian region, explains how she promoted fruiting riparian buffers:

> We started with one of the farmers. That farmer told all of his buddies down the road. The next thing you know we had all these phone calls coming into the office, like, "Hey, how do I get pawpaw [trees]? Where is that pawpaw girl?" . . . It's critical to have that farmer-to-farmer conversation. This is a really tight-knit community.[247]

Keefe Keeley, co-director at a Midwestern non-profit dedicated to agroforestry, echoes the importance of in-person exposure to novel agroforestry practice for adoption:

> We started . . . putting in demonstration farms because farmers really needed to see it to believe it. Because a lot of these agroforestry systems don't exist on a commercial scale right now, there isn't training and educational infrastructure for people to learn how to grow tree crops and pasture livestock.[248]

EDUC., https://www.southernsare.org/Grants/Grant-Programs/Research-Education-Grants (last visited Mar. 20, 2021); *Grants*, W. SUSTAINABLE AGRIC. RSCH. & EDUC., https://western.sare.org/grants/ (last visited Mar. 20, 2021).

246. Identifying and promoting early peer adopters—especially highly respected peers—also proves to be effective in spreading unconventional consumption behavior, like installing rooftop solar panels, reducing air travel, and eating meatless meals. *See* Gordon T. Kraft-Todd et al., *Credibility-Enhancing Displays Promote the Provision of Non-Normative Public Goods*, 563 NATURE 245, 245–48 (2018) (finding that more residents installed solar panels when community recruiters who engaged in face-to-face outreach also installed solar panels); Steve Westlake, *A Counter-Narrative to Carbon Supremacy Do Leaders Who Give Up Flying Because of Climate Change Influence the Attitudes and Behaviour of Others?* 45–46 (Oct. 2, 2017) (MSc dissertation, Birkbeck University), *available at* http://dx.doi.org/10.2139/ssrn.3283157 (finding in a survey of 380 social media users that 50 percent of survey respondents who know someone who has given up flying because of climate change report flying less themselves); Gregg Sparkman & Gregory M. Walton, *Dynamic Norms Promote Sustainable Behavior, Even if It Is Counternormative*, 28 PSYCH. SCI. 1663, 1672–73 (2017). Authors identify two mechanisms for change: dynamic norms can (1) lead people to anticipate a changed future world and (2) increase the perceived importance of a behavior to other people. *See* Stephanie Stern, *Encouraging Conservation on Private Lands A Behavioral Analysis of Financial Incentives*, 48 ARIZ. L. REV. 541, 580–82 (2006). Digitizing in-person demonstration projects can help reach farmers in the modern era. Private farm educators sometimes attract comparable numbers of digital viewers relative to public university extension programs. Expanding grant availability for social marketing efforts conducted by private educators to showcase agroforestry practices and public cost-share programs can be especially useful. *See* Justin Rhodes, *How Mark Shepard's Farm THRIVES under Sheer. Total. Utter. Neglect.*, YOUTUBE (2017), https://youtu.be/RePJ3rJa1Wg; *see also* University of Wisconsin Extension, *Alley Cropping*, YOUTUBE (2013), https://youtu.be/oJSYT26pq6k.

247. Interview with Katie Commender, Agroforestry Program Director at Appalachian Sustainable Development, (Sept. 2, 2019).

248. Interview with Keefe Keeley, Co-Executive Director at the Savanna Institute, (Aug. 31, 2019).

c. Dedicate Funds for Outreach and Training in Conservation Payment Programs

Congress should devote a substantial portion of new conservation program funding to outreach and training for agroforestry practices. Dedicated funding for outreach and training lowers two barriers conservation payment programs pose for agroforestry adoption. First, conservation payments available for agroforestry practices are currently not well publicized compared to less burdensome projects. For example, CRP practices like planting perennial grasses tend to be promoted because they are "easy for the farmer" compared to agroforestry practices.[249] Natural resource professionals administering conservation programs may not have an incentive to promote agroforestry practices absent dedicated funding.[250]

Second, dedicated funding for assistance would help producers navigate and apply for multiple conservation programs to secure funding for a single agroforestry project. Accessing available federal funds for agroforestry can be complex and time-consuming, and therefore especially burdensome for small scale producers. For example, the University of Missouri published a funding guide that identified twelve federal programs and five state programs available for agroforestry practices in Missouri, but each program has different application requirements, funding conditions, and award amounts.[251] Even within one program, a producer must apply for separate grants for different practices necessary for establishing a single agroforestry system.[252] Additional administrative assistance would enhance the effectiveness of existing conservation dollars for agroforestry.

2. Expand Agroforestry Financing, Safety Net, and Risk Management Options

Congress should ensure that conservation payment programs, crop insurance, and tax exemptions are adapted to better support agroforestry practices. USDA should also collect financial information on agroforestry operations to increase their access to credit, improve federal farm programs, and help producers make informed management decisions.

249. Godsey Interview, *supra* note 149.

250. *See supra* Subpart II.A.1.b.

251. LARRY D. GODSEY, FUNDING INCENTIVES FOR AGROFORESTRY IN MISSOURI (Agroforestry in Action, AF 1005-2005, 2018), *available at* https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/69210/af1005-2018NovReviewed.pdf?sequence=1&isAllowed=y.

252. EQIP, for instance, funds alley cropping and riparian buffers separately. *See* U.S. DEP'T OF AGRIC.: NAT'L AGROFORESTRY CTR. *supra* note 201.

a. Set Aside EQIP Funds for Agroforestry Practices

Congress should create a funding pool within EQIP dedicated exclusively for agroforestry practices. Agroforestry funding pools should be considered for other USDA programs as well, but EQIP is particularly well-suited for a dedicated agroforestry fund due to its focus on individual conservation practices. Such a dedicated EQIP funding pool for agroforestry already exists in Missouri on a modest scale.[253] EQIP currently offers technical assistance and cost-share payments for producers to adopt conservation practices, but states ultimately choose which practices are prioritized from a federal menu.[254] Such a program should be modeled after the Organic Initiative, which Congress created under the 2008 Farm Bill to make conservation practices related to organic production eligible for EQIP payments.[255] Under the Organic Initiative, organic producers and producers transitioning to organic production compete in a separate funding pool from the general EQIP funding pool, which effectively ensures that the program benefits organic production.[256] A similar program for agroforestry would create an incentive for all participating states to make agroforestry practices eligible for EQIP funding. This would not only facilitate wider adoption of agroforestry, but help agroforestry producers become competitive with other production systems earmarked under EQIP, such as livestock producers, who are statutorily required to receive at least 60 percent of total EQIP payments.[257]

b. Reform CRP Requirements to Encourage Planting Productive Trees

Congress should require the USDA to (1) offer extra CRP funds for producers to plant productive trees, including improved cultivars, under their CRP contracts and (2) lower the tree density requirements under CRP regulations.[258] Although CRP is a widely used conservation program,[259] funding

253. *See generally* LAUREN CARTWRIGHT ET AL., USING NRCS TECHNICAL AND FINANCIAL ASSISTANCE FOR AGROFORESTRY AND WOODY CROP ESTABLISHMENT THROUGH THE ENVIRONMENTAL QUALITY INCENTIVES PROGRAM (EQIP) (Agroforestry in Action, AF 1016-2017, 2017), *available at* http://www.centerforagroforestry.org/ pubs/NRCS_AgroforestryandWoodyCrop.pdf.

254. *See* 16 U.S.C. § 3839aa-2(d)(7)(A); Lehner & Rosenberg, *supra* note 18, at 802–03.

255. Food, Conservation, and Energy Act of 2008, Pub. L. 110-246, § 2503(i), 122 Stat. 1651.

256. In 2018, the cap for Organic Initiative EQIP contract payments was raised from $80,000 per six-year period to $140,000 for the four-year life of the 2018 Farm Bill. This cap comes closer to the higher $450,000 cap for general EQIP payments. Agricultural Improvement Act of 2018, Pub. L. 115-334, § 2304(f)(3(B), 132 Stat. 4490.

257. 16 U.S.C. § 3839aa-2(f)(1) (2019).

258. Each state has their own CRP requirements. Michigan's CRP regulations, for instance, only allow conifer trees to be planted in highly dense stands. NAT. RES. CONSERVATION SERV., U.S. DEP'T OF AGRIC., GENERAL TREE PLANTING: MICHIGAN CONSERVATION RESERVE PROGRAM (2006), *available at* https://www.fsa.usda.gov/Internet/ FSA_File/crpcp3.pdf.

259. Congress allocated 37 percent of conservation spending to the CRP in 2014, making it the largest conservation program, followed by EQIP. Approximately 24 million acres were enrolled under

conditions are designed to encourage short-term afforestation for the length of the contract rather than long-term, economically sustainable agroforestry operations. Currently, high density planting requirements for CRP contracts and tree species restrictions encourage timber-based afforestation but not productive agroforestry.[260] Extra incentives to plant productive trees will prolong the economic sustainability of afforestation practices under CRP. These simple reforms to the CRP will encourage participants to transition CRP trees to productive agroforestry systems at the end of the contract period, avoiding expensive contract renewals and helping to spur the development of new tree products and markets.[261]

c. Incorporate Agroforestry into the Federal Crop Insurance Program

Congress should mandate that USDA create a federally administered crop insurance program tailored for agroforestry operations. Diversified agroforestry operations are currently eligible for federal crop insurance through the Whole Farm Revenue Protection (WFRP) insurance program; individual crops are eligible for the specialty crop insurance policies.[262] Whereas WFRP insures all commodities on a farm under one insurance policy, specialty crop insurance programs cover specific individual crops, such as fruits and nuts.[263] Private crop insurance providers often forego WFRP policies due to the additional expertise and time required to assess, for example, the complex risk profile of a small, diversified farming operation targeting a niche market.[264] WFRP also does not protect losses of assets that will provide future revenue. Since agroforesters must wait several years before they can commercially harvest new trees, this policy puts them at a distinct disadvantage. A federal program would create a national body to develop the requisite expertise to address issues such as these while reducing overhead costs.

Producers often take on significant financial risk to establish agroforestry systems.[265] Without a safety net with correct price guarantees, natural disasters

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CRP contracts in 2016. Press Release, USDA, USDA Announces Conservation Reserve Program Results (May 5, 2016).

260. As Larry Godsey explains, under Missouri's CRP regulations: "[Farmers] had to plant 300 trees per acre, which is just a massive number of trees[.] If they let the farmers plant a fewer number of trees . . . then, by the time it comes out of the [CRP contract], they could eventually turn that into a silvopasture system." Godsey Interview, *supra* note 149.

261. *See* Stern, *supra* note 246, at 576–77.

262. Specialty crop insurance policies either protected a farmer's normal crop yield or normal revenue. *See* ISABEL ROSA & RENÉE JOHNSON, CONG. RSCH. SERV., R45459, FEDERAL CROP INSURANCE: SPECIALTY CROPS 13 (2019).

263. *Id*. at 4.

264. *Id*. at 19–20.

265. As Larry Godsey explains: "In Missouri, we had some landowner groups promoting planting trees and then one day we had a huge windstorm that blew down 118,000 acres of timber and there was no insurance and no tax benefit to recover the loss[.] So that really turned people against timber and trees." Godsey Interview, *supra* note 149.

or market fluctuations can seriously hinder regional efforts to encourage agroforestry adoption.[266] A federal crop insurance program for agroforestry should address two insurance policy problems specific to tree systems. Under the current system, insurance payouts generally compensate up to the previous year's revenue or yield in case of yield losses. But unlike annual crops, damage to perennial crops might lead to multi-year production losses.[267] An improved federal agroforestry insurance policy should use aggregate financial risk information to determine actuarily sound, multi-year payouts after events causing multi-year yield losses, such as floods or droughts. Such a program should also integrate the USDA's Farm Service Assistance (FSA) Tree Assistance Program, which was created in the 2014 Farm Bill to provide financial assistance for replanting or rehabilitating eligible trees, bushes, and vines lost by natural disasters.[268]

Second, an agroforestry federal crop insurance program should expand the geographic range of agricultural experts eligible to determine whether a potential insured farm has used "good farming practices" required to receive coverage.[269] Under the Federal Crop Insurance Program, farmers practicing sustainable nonconventional methods often have difficulty meeting the "good farming practices" standard since determinations must be made by "agricultural experts" in their immediate geographic area.[270] A larger range will incorporate a more diverse selection of agricultural experts.

Moreover, current guidelines give insurance companies the power to deny coverage if a conservation practice "negatively impact[s] the insured crops ability to make normal progress toward maturity and produce at least the yield used to determine the production guarantee."[271] These rules discourage producers from adopting certain agroforestry practices that promise increased long-term productivity, such as alley cropping and windbreaks, since they may reduce production in the near term. Incorporating information from agroforestry-specific experts and aggregated financial risk information would improve the

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266. Currently, insurance policies available for agroforestry systems are probably priced too high, which encourages only high-risk producers to purchase insurance. *See* ROSA & JOHNSON, *supra* note 264, at 20.

267. Godsey Interview, *supra* note 149.

268. *See* 79 Fed. Reg. 21092-93; *Tree Assistance Program (TAP)*, U.S. DEP'T OF AGRIC.: FARM SERV. AGENCY, https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/tree-assistance-program/index (last visited Mar. 20, 2021).

269. A similar policy allowing organic producers to use opinions from organic agricultural experts outside their immediate area increased the amount of organic acreage enrolled in crop insurance by 34 percent during the first year. *See* Lehner & Rosenberg, *supra* note 18, at 800 (citing 7 C.F.R. § 457.8 (2015)).

270. *See* Chad G. Marzen & J. Grant Ballard, *Climate Change and Federal Crop Insurance*, 43 ENVTL. AFFS. 387, 398 (2016).

271. FED. CROP INS. CORP., U.S. DEP'T OF AGRIC., FCIC-14060, GOOD FARMING PRACTICE DETERMINATION STANDARDS HANDBOOK 34 (2020).

financial soundness of the insurance system, which would, in turn, encourage less risky agricultural practices.

d. Expand Federal Tax Deductions to Cover All Agroforestry Practices

Congress should expand federal tax deductions to cover expenses not only related to conservation practices and commercial timber production, but all agroforestry practices at different stages of commercial maturity.[272] Tax incentives can play a crucial role in growing small businesses by creating incentives for small businesses to make investments with longer-term returns.[273] Agroforestry producers often fall in this category; trees have longer growth periods than annual crops while many agroforestry systems require smaller acreages than commodity crop production. However, the tax code currently favors commercial timber production, windbreak planting, and maintaining agroforestry systems at a mature stage of commercial development. The tax code should extend benefits to cover expenses incurred in establishing silvopasture, alley cropping, forest farming, and riparian buffers.

First, Congress should amend the reforestation tax credit so that the costs of planting trees in any agroforestry production system, as defined by the NRCS, qualifies for a basis depreciation deduction.[274] Currently the credit only rewards planting trees primarily for timber production.[275] The reform would effectively allow producers planting trees primarily for fruit, nut, or livestock production to also deduct up to $10,000 of expenses for the first year and amortize the remaining expenditures over a seven-year period.

Second, Congress should amend the business expense tax credit to remove the cap on deductions for expenses on property used for productive agroforestry systems, a term to be defined by NRCS.[276] This tax credit currently provides a special deduction for certain property used in an active trade or business, but the eligible amount is capped by the total taxable income from the farm. This discourages producers of perennial crops from investing in necessary equipment in the early years of production.[277] For example, an agroforestry producer would not be able to deduct the cost of a walnut harvester purchased in the first year that their walnut orchard begins to produce nuts if the equipment cost might exceed the total crop revenue. This reform would encourage agroforestry

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272. *See* LARRY D. GODSEY, TAX CONSIDERATIONS FOR THE ESTABLISHMENT OF AGROFORESTRY PRACTICES (Agroforestry in Action, AF 1004-2010, 2010), *available at* https://mospace.umsystem.edu/xmlui/bitstream/handle/ 10355/10039/af1004-2010.pdf?sequence=4&isAllowed=y.

273. Additionally, unlike conservation payments, Congress does not need to affirmatively allocate indirect subsidies like tax deductions, thus they may be more resilient against changing political winds. *See* William Gale & Samuel Brown, *Small Business, Innovation and Tax Policy A Review*, 66 NAT'L TAX J. 871 (2013).

274. *See* 26 U.S.C. § 194 (2018).

275. *See id.* § 194(c)(1).

276. *See id.* § 179(b)(1).

277. *See id.* § 179(b)(3)(A).

producers to invest in equipment when needed, even if costs exceed gains for that year.

Lastly, Congress should amend the conservation tax credit to allow deduction of expenses associated with agroforestry practices, as defined by NRCS.[278] Currently, this tax credit allows landowners who are actively farming to only deduct expenses for planting windbreaks and establishing other primarily conservation-oriented practices.[279] Expenses must be consistent with a plan approved by the NRCS or comparable state agency and are capped at 25 percent of gross income derived from farming that year.[280] Other agroforestry practices that have substantial conservation benefits, including alley cropping, riparian buffers, and silvopasture, should be explicitly included within this tax credit.

e. Incentivize Provision of Financial Information with Additional Conservation Payments and More Favorable Loan Terms

Congress should incorporate incentives for agroforesters to provide cost, yield, revenue, and other relevant financial information within existing programs. More favorable federal loan terms, like longer deferment periods and lower interest rates, and additional conservation funds under EQIP and CRP can be made available to participants who voluntarily report their financial information. Individual information should be anonymized and aggregated in a database that provides financial risk profile information for different kinds of agroforestry operations in different regions.

A database of agroforestry-specific financial information would improve institutional and individual decision making that is essential for expanding agroforestry. First, researchers can use the database to develop more accurate financial decision tools for producers and natural resource professionals use to make production and management decisions.[281] Second, producers can use the information to access loans and other forms of private capital to establish agroforestry systems and to keep existing agroforestry systems. Agroforestry producers often need private capital for making atypical agricultural purchases, such as smaller parcels of land in states dominated by large acreages dedicated to commodity crop production.[282] But the private financial sector's unfamiliarity with the risk profiles of different agroforestry operations and the absence of any incentive to acquire such information often lead banks to reject these unconventional loans. One bank reportedly asked a loan applicant to tear down

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278. *See id.* § 175.

279. *See id.* § 175(c)(1).

280. *See id.* §§ 175(b), 175(c)(3).

281. University of Missouri's Center for Agroforestry has developed several tools for specialty tree crop operations, including elderberry and chestnut. *See generally* ZHEN CAI, FINANCIAL DECISION SUPPORT TOOLS FOR AGROFORESTRY (Agroforestry in Action, AF 1006-2018, 2018), *available at* http://www.centerforagroforestry.org/ pubs/training/app1_2018.pdf.

282. USDA Interview, *supra* note 174.

their existing windbreaks as a condition of receiving an unrelated loan.[283] A central database of agroforestry-specific financial information would help the financial sector make more accurate risk management decisions in disbursing funds to agroforestry producers. It would also make a significant source of financial capital available for agroforestry without substantially increasing public costs.

3. Improve Land Access for Agroforesters

To overcome the significant land access barrier to at-scale agroforestry adoption, Congress should provide public land leases and deferred low- or zero-interest loans for agroforesters. Without adequate long-term land access, willing adopters cannot make use of improved information resources, public subsidies, or tax exemptions dedicated for agroforestry.

a. Create a Zero-Interest Farm-Ownership Loan Program for Agroforestry Farmers

Congress should create a zero-interest FSA farm-ownership loan program for agroforestry producers with low payments during the initial years of the loan. Requiring agroforesters to begin making substantial payments on loans before their trees are mature puts them at a major disadvantage relative to operators with annual crops, who have lower upfront costs and better short-term returns. Policymakers could model the loan program on the Clean Water State Revolving Fund, which provides deferred low- and zero-interest loans for eligible water quality improvement projects under the Clean Water Act,[284] or the Economic Development Administration's Revolving Loan Fund, which provides low-interest loans for economically stressed businesses for property purchases and long-term leases.[285]

b. Create a Federal Agroforestry Land Bank

Congress should fund a federal agroforestry land bank that reserves suitable federally owned property to lease to agroforestry producers for up to ninety-nine years.[286] The federal government owned 28 percent of land in the United States as of 2017, with management concentrated in the Bureau of Land Management (BLM), Forest Service (USFS), Fish and Wildlife Service (FWS), and National

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283. *Id.*

284. 33 U.S.C. §§ 1381, 1383(d)(1)(A)–(B) (2018). Eligible projects have expanded to include conservation agricultural practices like cover cropping and reforestation but not farmland purchases. EPA, 2019 ANNUAL REPORT: BUILDING THE PROJECT PIPELINE: CLEAN WATER STATE REVOLVING FUND 3 (2019).

285. *See* 42 U.S.C. § 3149 (2018); 13 C.F.R. §§ 307.15(b), 314.7(c)(1)–(2) (2020).

286. The lease period should be of sufficient length to ensure that producers are able to recoup their investment but should not be so long as to constrain effective federal land use planning and management.

Park Service (NPS).[287] Much of this land can be reserved for an agroforestry land bank.

For instance, a portion of grazing land managed by BLM and USFS could be set aside for silvopasture producers. Federally owned grazing land concentrated in the Western United States is currently leased to ranchers on the condition that they use management practices that preserve the ecological function of the soil, vegetation, and connected waterways.[288] But scholars and public interest groups have long alleged that these agencies have done little to enforce lease provisions regarding environmental protection.[289] Prioritizing silvopasture lessees (as identified by the NRCS, for example) would enhance environmental protection without necessarily increasing monitoring or enforcement costs.

As another example, USDA Rural Development currently auctions rural properties obtained after a USDA loan foreclosure—including farms and residential homes—to the highest bidder.[290] Individual listings are publicly accessible, though no aggregate inventory of foreclosed acreages exists.[291] Foreclosed rural property that meets certain specifications prime for agroforestry establishment can be added to the land bank instead of auctioned.

4. Improve Input, Distribution, and Infrastructure for Agroforestry Products

Congress should provide states with annual block grants to enhance the production, distribution, and consumption of agroforestry crops. The grant program should be modeled after the Specialty Crop Block Grant Program (SCBGP), which provides block grants to state agricultural agencies to fund projects that expand production and consumption of fruits, nuts, and other specialty crops.[292]

SCBGP has invested over $500 million to all fifty states combined since 2006. A spectrum of projects have received SCBGP funding, from establishment of a farm-to-school supply chain in Stanislaus, California to market research on the cosmetic and pharmaceutical uses of the pawpaw tree fruit in Missouri.[293]

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287. CAROL HARDY VINCENT ET AL., CONG. RSCH. SERV., R42346, FEDERAL LAND OWNERSHIP: OVERVIEW AND DATA 3, 6 (2017).

288. 43 C.F.R. § 4180.2 (2019).

289. *See, e.g.*, Joseph M. Feller, *What Is Wrong With the BLM's Management of Livestock Grazing on the Public Lands?*, 30 IDAHO L. REV. 555 (1993); Lehner & Rosenberg, *supra* note 18, at 813.

290. 7 C.F.R. § 3555.306 (2020).

291. *Properties for Sale by the USDA-RD and USDA-FSA*, U.S. DEP'T OF AGRIC.: RURAL DEV., https://properties.sc. egov.usda.gov/resales/public/home (last visited Mar. 20, 2021).

292. *See* AGRIC. MKTG. SERV, U.S. DEP'T OF AGRIC., USDA DEFINITION OF SPECIALTY CROP, *available at* https://www.ams.usda.gov/sites/default/files/media/USDASpecialtyCropDefinition.pdf.

293. AGRIC. MKTG. SERV, U.S. DEP'T OF AGRIC., FISCAL YEAR 2019 DESCRIPTION OF FUNDED PROJECTS: SPECIALTY CROP BLOCK GRANT PROGRAM 42, 183 (2019), *available at*

SCBGP funds are well-tailored to local markets and region-specific crops because federal grant disbursement depend on projects proposed to states by regional producers, non-profit and community organizations, and other state-specific institutional stakeholders.[294] A separate pool of funding dedicated to agroforestry crops would stimulate region-specific production and consumption necessary to establish long-term market support for agroforestry systems.

CONCLUSION

Farming with trees is an established and widespread practice and one of the most promising methods for sequestering carbon. Agroforestry has the capacity to eliminate net agricultural emissions, both globally and in the United States, using current technology. However, its full potential will not be realized unless public policy adapts to meet its needs. Unlike annual crops, crops grown with trees require more upfront public support and longer lending, conservation, and federal farm program payment periods in order to be feasible for most farmers. Annual crops have also benefited from decades of sustained public investment in agricultural research, infrastructure development, and technical assistance. Similar investments in agroforestry would transform agriculture in the United States by giving farmers new marketing opportunities and sequestering substantial amounts of carbon. It would also bring enormous benefits to rural communities, including new economic opportunities, greater biodiversity, increased climate resilience, and lower rates of agricultural pollution. A federal farm policy that supports farming with trees will not only help create a more sustainable and equitable rural economy, but it will also play a critical role in meeting the challenge of climate change.

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https://www.ams.usda.gov/sites/default/files/media/2019SCBGPGrantstotheStates.pdf. Additionally, funded marketing projects utilize digital platforms, effective hashtag campaigns on Instagram and YouTube video series promoting state specialty crops. CAL. DEP'T OF FOOD & AGRIC., SPECIALTY CROP GRANT PROGRAM PROJECT ABSTRACTS 19 (2019), *available at* https://www.cdfa.ca.gov/Specialty_Crop_Competitiveness_Grants/pdfs/2019-SCBGP-ProjectAbstracts.pdf.

294. 7 C.F.R. § 1291 (2017).