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Policy pathways for perennial agriculture

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Perennial agriculture refers to agricultural systems in which perennial crops are a central strategy for producing farm products and ecosystem services. Perennial agriculture offers a range of ecosystem services, including improved soil health and biodiversity, high carbon sequestration rates, agroecosystems better adapted to climate change, improved water quality, and economically viable products. Shifting U.S. agriculture to be perennial-focused will require a range of support structures, including federal policy changes. Federal policymakers should support perennial agriculture by establishing safety nets like those available for annual crops, centering perennial practices in cost-sharing conservation programs, facilitating market opportunities, and investing in perennial agriculture research and development.

KEYWORDS

perennial agriculture, perennial crops, agroforestry, climate-friendly agriculture, agricultural conservation, multifunctional landscapes, regenerative agriculture, soil health

Introduction

Perennial agriculture (defined below) is considered a climate friendly and sustainable alternative to conventional annual agriculture, distinguishable through its emphasis on the use of plants with multiyear lifespans and unique conservation benefits (Crews et al., 2018). Growing concerns over the negative effects conventional agriculture has on key resources such as soil, water, and biodiversity have been met with interest in regenerative agriculture. The potential of perennial agriculture to catalyze a monumental shift in agricultural production has been thus far underappreciated in policy discussions. Instead, incremental changes to annual agriculture have been the focus. The transition to perennial agriculture, a more transformative approach, requires a paradigm shift in terms of food production and consumption. This article will define perennial agriculture and summarize its benefits, argue for broad perennialization of U.S. agriculture, and identify near-term gaps and opportunities in federal policy to support this shift.

What is perennial agriculture?

Perennial agricultural systems center around the use of crops that can be maintained and harvested over multiple growing seasons and years. When well-managed such systems are highly productive, forming the basis of sustainable food systems. Many notable examples of perennial agriculture arise from Indigenous traditions (Nair et al., 2017). Perennial plants include a range of tree, shrub, and herbaceous crops, producing an array of products: grains; forage; textile fibers; biofuel feedstock; and edible carbohydrate, protein, and oil. Perennial agriculture includes agroforestry (integration of trees into farming through practices such as alley cropping, silvopasture, riparian buffers, and forest farming), perennial forages for livestock grazing, and the cultivation of perennial grain and oilseed crops.

Regenerative agriculture seeks to promote land management practices that restore and enhance soil health and biodiversity and has great potential to support ecosystem services (i.e., a wide range of benefits to humans provided by ecosystems) (Basche et al., 2020; Newton et al., 2020). Perennial crops offer high levels of ecosystem service production compared to annual crops, including beneficial effects on soil, water, biodiversity, and climate (Toensmeier, 2017; Crews et al., 2018). Realizing their full potential for ecosystem-service production likely requires the use of regenerative practices. A useful definition set for perennial agriculture should thus reference management practices, with regenerative perennial agriculture (i.e., the integration of perennial agriculture and regenerative practices) likely having the greatest potential for provision of long-term, wide-ranging ecosystem services (Figure 1). We define and clarify these interrelated terms:

Perennial agriculture: agricultural systems in which perennial crops are a central strategy for producing farm products and ecosystem services (e.g., water quality, pollination, wildlife habitat, etc).

Regenerative perennial agriculture: perennial agriculture using crop management practices that harness the unique potential of perennial crops to deliver high levels of ecosystem services.

Perennialization: changes to a farming system or agricultural landscape that result in a greater percentage of land area in permanent or rotational perennial crops.

Ambiguities persist in defining perennial agriculture, with various concepts in discussion (Streit Krug and Tesdell, 2020; Reynolds et al., 2021). In particular, the percentage of a field devoted to perennial crops to be considered perennialized is debatable. In this article we rely on the above definitions, looking to future scholarship to refine these terms.

Why perennial agriculture?

Due to their unique capacity to produce both food and wide-ranging conservation benefits, perennial agriculture systems offer potential solutions to major challenges faced by U.S. agriculture (Jackson, 1980). Perennial crops have intrinsic advantages over annual crops (Toensmeier, 2017; Crews et al., 2018); accordingly, we posit (Figure 1) that conventional perennial systems offer superior ecosystem services to conventional annual systems. Regenerative perennial systems likely offer the greatest potential benefits, with further research needed to assess their full potential.

Soil health

Upon establishment, perennial agriculture reduces or eliminates the need for tillage. This reduces erosion, creates a year-round living root system, and provides organic matter inputs from leaf and root dieback that increase soil organic matter (Crews et al., 2018; Dupraz et al., 2018; Basche et al., 2020). Basche et al. (2020) analyzed federally-funded conservation practices and found that perennial practices including agroforestry had the greatest potential to improve soil health and address soil and water conservation concerns. Several forms of perennial agriculture receive the highest score for erosion control from NRCS (USDA-NRCS, 2021a).

Climate change mitigation and adaptation

Perennial systems achieve higher carbon sequestration rates than the most promising annual cropping practices (Toensmeier, 2017). Herbaceous perennial systems store carbon in soil organic matter (Crews and Rumsey, 2017), while woody systems store carbon as woody biomass (Toensmeier and Herren, 2016). According to a 2012 review, the widespread adoption of agroforestry practices in the United States alone could sequester 1961 MMT CO2eq. each year—enough to mitigate more than one-third of the national net greenhouse gas emissions (Udawatta and Jose, 2012; EPA, 2021). Additionally, perennial agriculture is a powerful climate change adaptation strategy (Janowiak et al., 2016; Wolz et al., 2018), transitioning the whole farm to a more diversified agroecosystem better suited to changes in climate and weather (Basche et al., 2020). The ecosystem-service strengths of perennial agriculture map well to key adaptation challenges for U.S. agriculture under climate change: increased heat, increased wind and rainfall intensity and associated erosion, longer and more intense droughts, increased disease and pest pressure, and a shift from snow to rain (US Global Change Research Program, 2018).

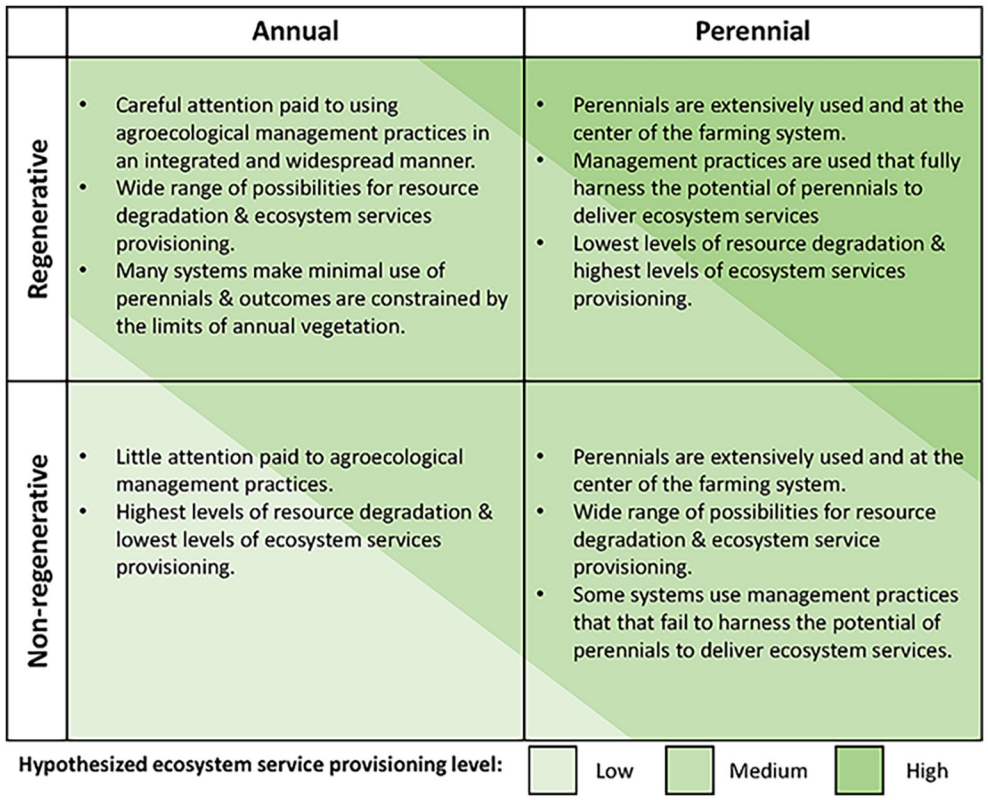

FIGURE 1
The figure identifies key facets of these agricultural systems and illustrates, through the color gradient, that even within these systems a range of outcomes is possible. See sections What is perennial agriculture? and Why perennial agriculture? for a definition and further discussion of ecosystem services.

Water resources and other ecosystem services

Perennial crops provide superior water quality benefits due to their deep and abundant root systems, reducing fertilizer runoff while more efficiently utilizing water and nutrients (Jungers et al., 2018). A 2019 review found that agroforestry systems reduce surface runoff, soil erosion, organic carbon losses, and related nutrient losses, while their associated practices reduce herbicide, pesticide, and other pollutant losses by an average of 49% (Zhu et al., 2020). Leaching of nutrients can be almost completely eliminated in crop fields with as little as 30% tree cover (Dupraz et al., 2018). Diversified perennial systems can also increase biodiversity, improve natural pest control, raise yields, and increase system resilience (Lin, 2011).

Economic value

Perennial crops offer producers economic benefits. Many perennial crops are currently specialty crops fetching relatively high prices and certain perennial systems can out-earn competing annual systems (Wolz and DeLucia, 2019). Producers can capitalize on increasing consumer demand for healthy food products, including tree nuts, fruits, and berries from shrubs (Conrad et al., 2018). Moreover, the ability of some perennial grain crops to offer multiple products reduces economic risk compared with some annual crops (Lazarus and Keller, 2018). Economically, perennial grain crops are currently less favorable, depending in the short term on cropping-system design and harvest of multiple production from these crops and longer term from yield increase through plant breeding (Law et al., 2022).

What is next for perennial agriculture in the United States?

In the United States there are presently 1.9 million acres in perennial crops, primarily in orchards (Food Agriculture Organization of the United Nations, 2021), and 769 million acres of pasture, grazed rangeland, and hay land (USDA-NRCS, 2003; Bureau of Land Management, 2021). While the U.S. area in agroforestry systems is modest today, 25–50% of national cropland and 10–28% of national grazing land

TABLE 1 Perennialization of U.S. agriculture: Practices (from Toensmeier and Herren, 2016).

	Phase one (shovel ready)	Phase two
Annual cropping systems	• Integrate perennials at borders and along contours • Ramp up existing perennial crops • Perennial crop development • Early adoption as industrial feedstocks	• Perennials as in-field conservation practices • Scaling up of perennial grains • Other perennial crops online • Widespread use of perennials as feedstocks, livestock feed, food
Livestock systems	• Silvopasture (trees in grazing land) early adoption	• Mass adoption of silvopasture • Use of LPC as feed

are considered suitable for this practice (Udawatta and Jose, 2012), setting the stage for broader uptake. With support, many "shovel-ready" practices (those which are mature and already implemented at scale) could be rapidly expanded, while research and development (R&D) could advance innovation and uptake of promising practices currently under development (Table 1). More perennial crops are under development and, with investment, will become available in the coming years (Table 2), from perennial rice and sorghum to industrial crops like milkweed (Toensmeier and Herren, 2016).

It is time to capitalize on the many benefits perennial agriculture offers and reorient U.S. agriculture to center on perennial systems, including those integrating annual crops. Achieving this vision will require fundamental pillars of support including technologies, land, and soil. Post-production infrastructure and end-use production require investment. Human "capital," including interest and know-how will need to be developed, including social and institutional capital (e.g., advocacy groups, extension). Financial, political, legal, and cultural support (e.g., consumer markets) are also necessary (Montenegro de Wit and Iles, 2016). Critically, R&D is needed to understand the landscape for deploying perennial crops and practices and to support the investment needed to refine innovations. Furthermore, the potential of perennial agriculture may only be appreciated once we reconceptualize agricultural productivity to be framed around ecosystem services, public goods, and other quality-based metrics over the volume or profit-based metrics typically reported for conventional annual systems (Rockefeller Foundation, 2021). This fundamental shift will stall as long as annual agriculture enjoys outsized support from government programs and laws and legal devices (e.g., land-leasing) reflect annual, but not perennial, systems.

This article addresses one aspect of this shift: near-term federal policy. Although the development and scaling of perennial agriculture will depend on regional socio-ecological factors and state policies, here we focus on the role of the federal government. Additionally, while we define perennial agriculture and the more-beneficial regenerative perennial agriculture, we do not distinguish between the two for policy-discussion purposes. While questions and research remain to solidify the vision and fuel the transition, policy change can play a pivotal role in accelerating the answers and reorienting the U.S. agricultural paradigm around perennial systems.

What role does federal policy play?

Federal farm programs are generally administered by the U.S. Department of Agriculture (USDA). Despite the aforementioned benefits, USDA has not used its leadership or financial heft to support perennial agriculture systems. Instead, USDA has largely buttressed annual crop dominated production systems. USDA activities promoting agricultural production, conservation, supply chains and markets, and research inadequately serve perennial agriculture systems today. If adapted, USDA policies could be leveraged to ignite the shift toward perennial systems.

Agricultural production policies

The agricultural sector relies on a number of programs (i.e., direct payment and insurance programs), the "farm safety net," to manage risk and support farm viability. Commodity crop producers can access the most robust support to secure against financial losses, including direct payment programs ($22.5 billion in 2019) (USDA-ERS, 2021), marketing assistance loans, and subsidized crop insurance. Options for specialty crop producers are fewer and vary by crop, with some enjoying access to crop insurance and others only eligible for disaster assistance programs (Johnson, 2019). Consequently, fewer options are available for many perennial crops, with perennial grains a notable exception.

While some perennial tree crops may be eligible for crop insurance in select regions, many caveats exist. For example, tree plantings are generally ineligible for insurance until maturation, with policies covering just one crop year (and/or replacement value) rather than the lifetime production potential (Federal Crop Insurance Corporation, 2008; Rosch, 2021). Meanwhile, disaster assistance programs have similar limitations despite covering more crops (Stubbs, 2020). Additionally, only certain commodity crops are eligible for direct payment programs (7 U.S.C. § 9011). Although the Whole Farm Revenue Protection (WRFP) program offers some promise for both perennial crops and diversified perennial systems, lack of awareness and

TABLE 2 Perennial portfolio.

	Perennial forages	Tree crops		Perennial grains	
		Current	Improved	Early prototypes	Fully developed
Current readiness	Ready now	Ready now	Major R&D investment needed	Ready now	Major R&D investment needed
Markets served	Meat and dairy	Specialty foods	Staple food	Specialty foods	Staple food
Market scale[a]	Large	Small	Very large	Small	Very large

[a]USDA-ERS (2022). Market scale, as used here, reflects ability to meet market demand.

support among insurance agents has limited the reach of the program (Miller and Miller, 2018). Further, the revenue insured is based on historic annual revenue of a given farm, thus excluding a producer whose farm is not yet producing annual yields. Additionally, crop insurance is unavailable to farmers who have not followed "good farming practices"—standards that generally reflect conventional agricultural practices and discourage innovative perennial practices (Marzen and Ballard, 2016).

To stimulate this perennial shift, federal policymakers should create an agricultural safety net that incentivizes transitions to perennial agriculture and supports producers taking risks to do so. Policy objectives could include: establishing a new direct payment program to support producers transitioning to perennial agriculture; piloting federally-administered crop insurance designed for perennial producers in target regions; expanding WFRP, incentivizing uptake by insurance agents, and developing new metrics for its support of perennial crop producers; and reforming the "good farming practices" to better support perennial agriculture.

Conservation policies

USDA provides cost-sharing payments to producers and landowners to incentivize sustainability. Through its working lands programs, namely the Conservation Stewardship Program (CSP) and Environmental Quality Incentives Program (EQIP), the Natural Resources Conservation Service (NRCS) contracts with producers to implement conservation practices on their working lands. USDA also pays producers to take environmentally sensitive land out of production for 10–15 years through the Conservation Reserve Program (CRP).

Unfortunately, these conservation programs place relatively little emphasis on perennial agriculture, despite its documented value in resource conservation. Although the working lands programs provide financial support for some perennial agriculture practices (e.g., alley cropping, silvopasture, and Kernza® perennial grain) (USDA-NRCS, 2022a,b), USDA generally does not highlight or incentivize such practices and support may not be available in a given state or region (USDA-NRCS, 2019). Due to these gaps, only a small fraction of the billions spent on working lands programs supports perennial agriculture practices (Chenyang et al., 2021; USDA-NRCS, 2021b). For example, EQIP funded almost $1.4 billion for conservation practices in Fiscal Year 2018, but <0.05% of that amount went to two of the most important perennial production practices, silvopasture and alley cropping (Lehner and Rosenberg, 2021).

Similarly, the current CRP represents another missed opportunity. Although CRP promotes tree-planting activities, it focuses on establishing wildlife habitats in the short term and timber revenue in the long term, rather than tree-crop production in agroforestry systems or intercropping (USDA-FSA, 2015). By prohibiting harvesting during the life of the CRP contract (7 C.F.R. § 1410.63), the program disincentivizes the planting of perennial crops that could offer both conservation benefits and the opportunity for producers to make an economically viable transition to a perennial system (Lovell et al., 2018). This could have wider implications, for example slowing the adoption of coppiced woody crops, in which plants are cut in rotation over multiple years.

USDA conservation programs must fully appreciate the ecological benefits perennial agriculture offers and prioritize affiliated practices. Policy objectives could include: encouraging each state to include perennial practices in their productive lands programs' practice list; offering a national funding pool for perennial practices in EQIP; revising the NRCS rankings of practices in order to offer a higher percent per acre for those perennial practices in CSP; increasing NRCS' technical assistance resources to support perennial agriculture; and reforming CRP to facilitate transitions to perennial agriculture systems.

Supply chains and market development

Agricultural products depend on extensive supply chains (production, storage, processing, distribution) and markets to reach consumers (Broad Leib, 2013). USDA supports these markets and supply chains through its Agricultural Marketing Service (AMS). AMS intervenes in markets by purchasing commodities from producers to stabilize prices, in addition to supporting its food assistance programs (Monke, 2016). AMS also administers grants to support the competitiveness of certain agricultural products and to support direct-to-consumer markets and regional market intermediaries (e.g., food hubs). Furthermore, USDA is one of the agencies responsible for developing and publishing the Dietary Guidelines for Americans, providing food-based recommendations to promote health, prevent diet-related chronic diseases, and meet nutrient needs. The Guidelines influence consumer behavior by informing perceptions around diet and by shaping USDA-administered nutrition programs, many of which use the Guidelines to establish procurement policies (Aussenberg et al., 2019). Finally, in a recent initiative, USDA has invested funds to expand "markets for America's climate-smart commodities" through its Partnerships for Climate-Smart Commodities program (USDA, 2022).

The dominance of annual crop systems in much of the country limits the supply-chain infrastructure and regional markets for perennial crops. Education specific to perennial crops' advantages is lacking. Though the Dietary Guidelines recommend consuming fruits, vegetables, nuts, and other perennial crops, USDA does not prioritize supply-side intervention around these concerns. Despite calls to do so, the Guidelines do not account for or seek to promote environmental sustainability (Willett et al., 2021). As one promising step, USDA awarded $60,000,000 to expand agroforestry products and markets as one of its Climate-Smart Commodities projects (USDA, 2022), but more is needed.

In the future, USDA could further catalyze the market demand perennial products need to achieve scale. Policy objectives could include: establishing an AMS Perennial Agriculture Market Development program to support perennial markets, supply chains, and value-added activities; updating procurement policies to support and preference perennial products; and promoting greater consumption of perennial agricultural products through the Dietary Guidelines and USDA nutrition programs and education.

Research policies

Federal support will be pivotal to moving new perennial crop varieties, species, and management practices past critical R&D hurdles and attract larger private sector investments. USDA supports a broad range of agricultural research through its "in-house" research agencies (intramural) and grant funding or partnerships with external entities (extramural) (Croft, 2020).

Despite some limited opportunities, perennial agriculture is not a primary focus area across USDA research programs. The intramural program action plans do not expressly include strategic research into perennial agriculture (USDA-ARS, 2021). Support from USDA external grants is also limited (DeLonge et al., 2016), and short grant durations can hinder research on perennials, which may take 10 years to become commercially viable. Several exciting recent funding awards—including grants to support the Grassland 2.0 project (grazed perennial grasslands) and research into Kernza® perennial grain—demonstrate the role federal R&D can play. Increased investment in plant genetics and breeding is particularly crucial because perennial grain crops require intensive crop breeding. Although a small handful of tree crops receive significant plant breeding and crop management research support from USDA and the private sector, most species are neglected as is the concept of integrated crop management *via* agroforestry. And while perennial forage crops have the largest public R&D investment of any perennial crop type, it remains disproportionately small relative to the value of perennial forage production. Finally, although the National Agroforestry Center (NAC) aims to provide leadership and coordination on agroforestry, it suffers from a relatively low budget and lacks its own external grant program (USDA-NAC, 2021).

To upscale perennial agriculture in the United States, substantial R&D activities remain. USDA could provide leadership by collecting data on the amount of land in perennial agriculture, studying relative production capacity of perennial crops and agricultural systems using quality-based metrics, and prioritizing perennial-centered research across its in-house programs (Lovell et al., 2018). Additional policy objectives could include: creating longer-term research grants appropriate for developing perennial crops; creating a dedicated perennial program within its Sustainable Agriculture Research and Education program or one similar for on-farm research; and expanding the activities of NAC. Regardless of approach, the overriding policy objective should be to increase federal R&D investment in perennial agriculture to a level proportionate to its potential benefits to U.S. agriculture, food system, and environment.

Conclusion

Reaping the benefits perennial agriculture offers will require a fundamental shift in the United States' approach to agriculture, from one dominated by annual crops to one centered on perennial agriculture systems with annual crops integrated. Federal policy can spur the investment, research, innovation, and paradigm shift needed to bring about that transition and

clarify the most economical and feasible pathways for realizing that vision. By retooling the USDA safety net, conservation, market enhancement, and research programs to work for perennial producers as they do for annuals, policymakers have multiple near-term options for implementing federal action to advance perennial agriculture. We call on USDA to launch this endeavor by developing a comprehensive, adaptive, and outcome-driven federal strategy to accelerate the transition.

Author contributions

ES led the drafting of Sections Introduction, What role does federal policy play? and Conclusion, as well as editing for the entire article. FI led the drafting of Section What is perennial agriculture? ET led the drafting of Sections Why perennial agriculture? and What is next for perennial agriculture in the United States? NJ drafted portions of Section What is next for perennial agriculture in the United States? EBL provided supervision, review, edits, and guidance on content and organization of the entire piece. All authors met several times to discuss and review substance and make major editorial decisions together. Each author reviewed multiple drafts and provided feedback, edits, and suggested citations.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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